25. Discussion

The EMAX exercise and process of model balancing were informative in many respects. Paramount was highlighting areas where our perceptions or understanding may merit revision or reexamination in light of this holistic view of the data, relative magnitudes of different nodes, or combined model outputs.

Answering the Original Question- Evaluating the Role of Small Pelagics

Specific question:

What is the role of small pelagic fish in the Northeast United States (NEUS) Continental Shelf Ecosystem, as determined by a recent network analysis?

Answer:

Small pelagics are an extremely important part of the NEUS Ecosystem, and it is likely that they will continue to be for the foreseeable future. A majority of energy in the system flows through these nodes (commercial, squid, anadromous and other). An increasingly important issue is how other species, especially commercially or ecologically important ones, respond to herring, mackerel, squid, and similar organisms. It appears that when the amount of small pelagics in the system changes, there are trickle-through effects to other network nodes. In terms of biomass, production, energy flows, and importance for upper trophic levels, small pelagics are a keystone group of species in this ecosystem.

Overall, the pelagic community is more prominent than the benthic community. More fluxes pass through pelagic nodes than benthic or demersal ones. In particular, consumptive demand (C:P) is quite high for small pelagics, which indicate that these are keystone species groups.

Summary of Other Results

Total system production is less than primary production when one accounts for respiration, trophic transfer efficiencies, etc. This leads to the question of whether we have optimized biomass for all groups simultaneously. This is a key question for global fisheries management and should be addressed in additional exercises.

The system appears to be driven more from bottom-up than top-down factors. The NEUS Ecosystem is one of the most productive marine ecosystems on the planet, and that assessment is reinforced by this study. As a proportion of primary production, most of the events at upper trophic levels (particularly fisheries catches) are an extremely small fraction. More telling is that total fisheries catch is a low proportion of overall energy flow. Even when we increase the biomass of small pelagics by two orders of magnitude, the effects on the next lower trophic level down (zooplankton) are minimal. Further, given the connectedness of all the species in this ecosystem, it appears that if one energy pathway is altered, another pathway compensates such that overall changes in standing stock biomass at a given trophic level are minimized. These are all symptomatic of a highly productive and highly resilient system.

Overall, we found that lower trophic levels can be important in balancing energy fluxes. Despite uncertainties in some biomasses and rates, it appeared that dissolved organic carbon was the largest biomass node in the ecosystem by several orders of magnitude.

In balancing the network models, we found that it was necessary to add nodes for bacteria and microzooplankton to “close the loop”, be more realistic, recognize current scientific developments, and resolve the model. In this case, the additional metabolic energy fluxes due to including these nodes allowed for a realistic accounting of energy flows to detritus which can otherwise present challenges for balancing models. This represents a major change in thinking and philosophy of how the oceans work compared with even 10 to 20 years ago. Our observations suggest that bacteria may be very important for the NEUS Ecosystem. Finally, although we added detrital respiration along with the bacteria, we recognize that this may need to be modified in future investigations

Overall, there are minimal differences between the 4 main ecoregions. Generally speaking, marine mammals are less prominent in the more southerly regions. Similarly, small pelagics are important (more prominent, higher standing B, etc.) in the Gulf of Maine. Conversely, benthos are more prominent (in terms of overall system functioning) in the southerly regions.

We recognized that biomasses of some groups are inherently uncertain and will likely remain so. We also acknowledged that there was a large degree of amalgamation within network nodes. Yet tradeoffs in taxonomic accuracy versus system-wide generality need to be made.

It would be highly desirable to verify and refine our conversion factors for biomass to carbon across species groups, as most other marine networks deal in units of carbon. Similarly, our approach to approximating population rates varied across groups, but represented an attempt to balance prior knowledge and reasonableness of model outputs. Overall, the network analyses could be improved by enhanced knowledge of P:B and C:B ratios, and of appropriate conversion factors.

It was apparent that there is an enormous amount of information available at the NEFSC. The EMAX analyses described in this report started where a lot of other investigations have ended. For example, we did not attempt to reestimate a large number of parameters when balancing the network models, since we had empirical estimates of many parameters, particularly biomasses. Instead, we used input parameter estimates for biomasses, consumption to biomass ratios, and other parameters as consistency checks. This approach differs from how many other energy budget investigations with fewer data have been conducted.

Data Gaps

One fundamental observation is that considerable data gaps exist for a variety of ecosystem components and processes necessary for EMAX modeling. Even in data rich systems there are still gaps (Table 24.1). This is not surprising given the complexity of the NEUS Ecosystem and the difficulties in sampling multiple spatial scales and marine habitats. Although data gaps were generally addressed by using the best available information from the literature, the limited empirical information on key vital rates, biomass estimates for some nodes, and most diet compositions was considered to be especially important for improving our understanding of the ecosystem.

Many of the key rate parameters necessary for understanding how marine ecosystems function are not well known. Even for the better-studied components of the food web (i.e., fish and marine mammals), population rates such as production, consumption and respiration are not commonly estimated. As a result, our EMAX analyses relied on literature values or simple approximations for many species groups. Imputting such rates created the danger of propagating potential errors from past studies, as well as not accounting for potential changes through time. We recommend a suite of process-oriented studies and complementary laboratory work to directly estimate production, consumption, and respiration rates for the individual species and species groups examined.

Another primary data gap was the lack of direct estimates of standing stock biomass for several groups of species. In particular, the biomasses of the following species groups were not well known: mesopelagic fishes*, macro- and mega-benthos*, micronekton, shrimp*, bacteria, microzooplankton, gelatinous zooplankton*, and larval fish*. For these species groups, we used historical estimates, expansion of density estimates taken from the literature, or expert opinion based on the relative abundances of other groups with biomass estimates. Several of these groups are very difficult to sample using existing technologies (e.g., micronekton, bacteria, and microzooplankton). Biomasses of the other groups, however, could probably be estimated if modified sampling gears or technologies were deployed in research surveys (* in list above). Regardless, the biomasses of these groups warrant further investigation, because they consistently emerge as pivotal species groups in modeling energy fluxes and balancing energy flows. For example, in one sensitivity analysis we found that a halving of the estimate of gelatinous zooplankton substantially altered the biomasses of other zooplankton, larval fish, and micronekton. These changes, in turn, transferred up the food web to affect commercially important and protected species groups.

Some species groups are always going to be problematic or inherently underdetermined. Until clear advances in sampling and monitoring technology are developed and become routine, we may have to simply recognize that many of our efforts for estimating parameters associated with these types of groups simply provide a bounding of possible magnitudes.

Diet composition of most species groups was limited, with the exception of mid-trophic level fishes which have been reasonably well sampled in this ecosystem. In particular, the feeding ecology of upper trophic level species warrants further investigation to characterize diet composition and consumption. Novel approaches to use sampling of isotopic signatures, fatty acids, protein structures, bioassays, etc., via tissue plugs can provide non-lethal means of assessing the diets of the larger, charismatic megafauna. Direct measurement of the feeding ecology of lower trophic level organisms (e.g., benthos, zooplankton) is also important and we recommend that research be conducted to improve the estimates of diet composition for these organisms. Even those species groups for which we have a relatively significant amount of information (e.g., demersal fishes), seasonal data collections of diet data would help to estimate energy fluxes among groups.

The effect of fisheries on the NEUS Ecosystem has been relatively well investigated through ongoing long-term fishery data collection programs. Nonetheless, an accurate accounting of fishery removals (both landings and discards) by location is needed to measure regional fisheries effects on ecosystem processes. Partitioning catches to area using current logbook and dealer data was complicated for some species. Creating a more spatially explicit reporting scheme for fisheries landings and discards in the NEUS Ecosystem would help to reduce uncertainty about estimates of regional fisheries effects.

Model Considerations

While estimating parameters of the network models, we found that diet composition and consumption rates were very important to achieving balanced energy budgets. In this context, getting the flows right is critical and it is important to iteratively refit the models to achieve balance. We also found that species groups with relatively small biomasses pose unique balancing problems.

Approximation or estmation approaches have varied, but literature ranges proved to be a helpful way to address and scale the magnitude of those estimates that were undetermined locally. There may be better ways to estimate many of our parameters, as the approaches we used often represent a compromise for the sake of simplicity.

We found that there was value in using multiple modeling approaches. While the differences among the software packages we examined were not trivial, the overall results were similar for the ones we used (Ecopath and EcoNetwrk). This concordance suggests that the underlying data, rather than the structural equations used in the particular models, had a dominant influence on the results.

Summary and Conclusions

Small pelagics clearly are and will likely remain a critical part of this ecosystem for the foreseeable future. Changes to the biomass and vital rates of these species could have major impacts on other components of the ecosystem. Currently, however, there does not appear to be a shortage of biomass of this group available for other groups. In addition, most small pelagic predators do have some capacity to switch prey. Thus, the strong trophic linkages seen in other ecosystems may not be of as much concern here.

Obviously there is a lot more we could elaborate on from this work. In particular, future efforts should initially consist of more detailed examinations of a broader set of cybernetic and systems metrics. Comparing the results of the contemporary study to some historical energy budgets from this region will also be valuable. Comparative studies exploring the differences and similarities across other marine ecosystems will better elucidate key marine and fisheries processes, patterns, and theories. We will also be able to even further elucidate the key dynamics of the ecosystem with further comparisons across the four ecoregions; more detailed analyses between the two (and perhaps other) model outputs; exploration of other statistics; and testing scenarios more rigorously and formally.

There is an ever-increasing need for holism in marine and fisheries science. One of the values of an exercise like this is gaining a better sense of the relativity of concurrent processes. That the dynamics of this and likely most marine ecosystems are dominated by the first two trophic levels is a sober reminder that the relative magnitude of important events and processes may often be beyond human control. Yet at the same time, our ability to even detect changes in network nodes that are often highly influenced by human events in marine systems (e.g., fishing) is critical. Being able to evaluate such events in the context of an entire system is going to be an increasingly important task as we move toward ecosystem-based fisheries management.