

VI. Integration

A. Similar Patterns, Key Observations

Substantial changes in the ecosystem occurred in the late 1970s to early 1980s. Change was apparent across several abiotic, biotic, and human metrics. Many metrics had a notable increase or decline during this period. Of the 123 metrics we examined with long enough time series, 44 exhibited an increase during this period. Additionally, 39 exhibited a decline during the same time. Thus, over 67.5% of the metrics we examined suggest that some event or series of events occurred in the late 1970s and early 1980s. The synchronicity of these changes also reflects the interaction among the various metrics. We explore what may have caused the changes and how the changes might be related in the next chapter. Here we want to document similar patterns among the various types of metrics.

B. Abiotic Metrics

Environmental conditions have varied through time.

Over a decadal time scale, there have been some moderate changes in water temperatures. The 1960s had cooler water conditions than the 1970s and 1980s, while the 1990s was somewhat warmer than preceding decades. It is uncertain if there is a relationship between these observed temperatures and the NAO. The offshore waters of Georges Bank and the open Gulf of Maine do not exhibit the same temperature trend as coastal waters. Within the Mid-Atlantic Bight, water masses shifted during the 1990s. There was less slope water in the Mid-Atlantic Bight in the 1990s with warmer and less saline water conditions. In the 1990s, there was

also more Scotian Shelf water in the Gulf of Maine, but the effects of this cooler water may have been offset by more coastal warming so that no trend in temperature was apparent. How these changes affected the biota remains a major question.

Some short-term cycling in temperature anomalies is apparent, on the time scale of 3-5 years. However, there is no appearance of a major regime shift in oceanographic conditions such as have been documented in the late 1970s in the northeastern Pacific Ocean. Overall, the observed oceanographic metrics suggest the system is undergoing natural variation about its long-term (40 year) average conditions, with some moderate serial correlation.

C. Biotic Metrics

The composition of the biotic community has changed across different levels of organization, from zooplankton to forage fish to top predators.

Phytoplankton abundance (as measured by standing biomass of chlorophyll *a* on the offshore shelf) has remained relatively constant through time. This suggests that primary productivity in this ecosystem is relatively stable. Two caveats are that the composition of species may have changed and that the productivity is not measured by chlorophyll *a*.

Predatory release on the zooplankton community was not apparent when planktivore abundance was severely reduced by fishing. The implication of this observation is that the zooplankton community is primarily regulated by bottom-up environmental forcing. In particular, given the substantial changes in the abundance of Atlantic herring and Atlantic mackerel, the primary pelagics, one would have expected the zooplankton community to increase substantially as these predators were less abundant.

It is unknown whether the benthic community has changed due to a lack of time series data. This gap in our knowledge may be important to fill and there is some ongoing research by the NEFSC directed at alleviating this gap.

The composition of the fish community has changed dramatically through time. Groundfish abundance declined dramatically under intensive harvest pressure. Squid, which are preyed upon by groundfish, increased in abundance during the 1970s as groundfish abundance declined. Similarly, American lobster catches increased following the decline in groundfish abundance. While groundfish declined, abundances of elasmobranchs, including spiny dogfish and skates, increased. Elasmobranch abundance began to decline in the 1990s, however, as fishery harvests increased from negligible to substantial levels, especially for large adult female spiny dogfish. The abundance of primary pelagics, Atlantic mackerel and Atlantic herring, declined substantially in the 1970s. In recent years, the abundance of primary pelagics has increased substantially as harvests and abundances of some predators have remained low.

D. Human Metrics

Revenues generated by the otter trawl fleet in New England, the primary component of the multispecies groundfish fishery, have declined through time. Otter trawl revenues peaked in the early 1980s and have declined since then. This long-term decline has occurred as the number of groundfish vessels has increased. Part of the increase in groundfish vessels was a federal government program to loan money to build more vessels following implementation of the Magnuson-Stevens Fisheries Conservation and Management Act (FCMA) of 1976. The impact of declining revenues and increasing vessel numbers is that this fishery is producing a smaller

benefit stream and that these benefits are being divided among a larger set of participants.

Overall, this would suggest that there may be less satisfaction within this fishery sector in recent years as profitability has been reduced, on average.

In a similar context, the composition of the landings of the otter trawl fleet in New England has changed dramatically through time. The increase in landings of non-groundfish species corresponds to the decrease in groundfish abundance. The behavior of the otter trawl fleet, as a top predator within the system, has changed in relation to the availability of various fishery resources. One potentially dangerous aspect of this type of behavior is that species groups may be serially depleted as the fishing fleet moves to target more abundant groups after others have been depleted. In the long term, this type of behavior is not likely to be sustainable and could result in substantial and possibly irreversible changes to the species composition of the ecosystem.

Information on the standardized fishery catch-per-unit effort (CPUE) data from the foreign and domestic fleets on Georges Bank during the 1960-1980s shows that capture decreased over threefold as aggregate fishery resource abundance declined. Such a decrease in efficiency would be expected based on bioeconomic theory for an open-access resource - this is another indication that the top-down impact of human predation on the system has been substantial. The decline in CPUE is similar to the declining trend in groundfish abundance. The declining trends in the two metrics are not identical because fishery CPUE is not likely directly proportional to abundance and is difficult to standardize when fishing practices and fishing gear have changed through time.

The harvest control rule for the Georges Bank haddock stock suggests that this

productive resource has been chronically overfished since the 1930s. The long term impact of overfishing on Georges Bank haddock has led to a severe decline in haddock abundance. Although some rebuilding of this stock has occurred in recent years under restrictive management, Georges Bank haddock abundance is still well below target abundance. It seems likely that other groundfish species, for example Atlantic cod, have experienced similar long-term exploitation patterns although long-term assessment data are not available to directly support this point.

Fishing regulations on the New England otter trawl fleet, the primary component of the groundfish fishery, have increased since the implementation of the Magnuson-Stevens FCMA of 1976. One apparent result of increased regulation has been a reduction in the landings and fishing mortality on groundfishes. These decreases may have helped to foster some rebuilding of the groundfish resources. However, despite recent increases in abundance, many groundfish are less abundant than during the early 1960s, immediately prior to the intensive harvests by the foreign distant water fleets.

The behavior of the groundfish fishing fleet in recent years shows that human predators exhibit spatial heterogeneity in their fishing behavior. Cultural and socioeconomic differences exist within the fleet at the port, county, and state level and there are some obvious spatial patterns in choice of fishing location and movements among fishing areas. Some of the reasons why certain choices are made can be related directly to regulatory and political-economic regimes, but others require further study.

One question raised by the decline in otter trawl revenues in recent years, is “Why are fishermen still choosing to fish when the economic returns are so poor?” For fisherman who

consider their livelihood not simply a job but a way of life, cultural aspects of the traditional fishing communities provide other important rationales to continue to participate in the fishing fleets. Changes in fishing practices and fishing communities, such as diversification to target non-groundfish resources, have probably contributed to sustaining the fishing fleet while target species abundances have declined and regulations have increased.

E. Summary

We have observed changes in the biotic, abiotic, and human components of the Northeast U.S. Continental Shelf ecosystem over the past forty years. Despite these changes, the relative constancy of aggregate biomasses across trophic levels (e.g., phytoplankton, zooplankton, fish groups, etc.) over the time series is surprising and suggests that aggregate system biomass is resilient to perturbations applied to date. This suggests that human activities thus far have not severely eroded the productive capacity of the system in terms of bottom-up forcing. Yet the species composition at any given trophic level has changed dramatically. The changes that have been observed may be attributable to both top-down forcing (e.g., through fishing) as well as inherent natural variation (bottom-up) in ecosystem processes.