Appendix 1

1.1 Description of the Ecosystem

1.1.1 Delineating the Ecosystem

Most of the fishery resources managed by the Council are found principally within the boundaries of the Northeast U.S. Continental Shelf Large Marine Ecosystem (NES LME) which encompasses an area of approximately 260,000 km^2 from Cape Hatteras in the south to the Gulf of Maine in the north. The shelf is wide off northern New England, extending over 200 km from shore, and relatively narrow off Cape Hatteras where the shelf break is approximately 30 km from shore. The Mid-Atlantic Bight spans the region from Cape Hatteras to southern Massachusetts. Other major subdivisions of the NES LME include Georges Bank and the Gulf of Maine (Figure 1). The Mid-Atlantic Bight is a well-recognized Zoogeographic Province. This Virginian Province supports a distinct faunal assemblage, including fish populations, relative to the adjacent Acadian Province to the north. The Acadian Province encompasses the Gulf of Maine and Georges Bank. The Nantucket Shoals region (Figure 1) is considered to be part of a transition zone.

These sub-divisions not surprisingly reflect major differences in physiography in the NES LME. In the Mid-Atlantic Bight, the topography is uniform, and the shelf gently slopes to the edge of the continental shelf. This system is strongly influenced by the effect of outflow from major estuaries in the region, most notably Pamlico Sound, Chesapeake Bay (the largest estuary in North America), Delaware Bay, and Narragansett Bay. Outflow from the Hudson River is also a major influence in the Mid-Atlantic Bight.

The Gulf of Maine, a semi-enclosed continental shelf sea, is characterized by an extremely complex physiographic structure. Three major deep basins occur in the Gulf. There are over 20 smaller basins located with the Gulf of Maine. Two relatively large ledge-bank systems (Stellwagen and Jeffries Ledges) occur within the Gulf of Maine proper. Four major river systems feed into the Gulf of Maine (the Androscoggin, Penobscot, Merrimack, and Kennebec Rivers), playing an important role in the oceanography of the coastal Gulf of Maine.

Georges Bank, a broad shallow submarine plateau forming the seaward boundary of the Gulf of Maine, is delineated to the north and east by the Northeast Channel and to the south and west by the Great South Channel. The bank encompasses approximately 42,000 km^2 within the 100 m isobath. The seaward margin of Georges Bank on the continental slope is incised with 11 major submarine canyons.

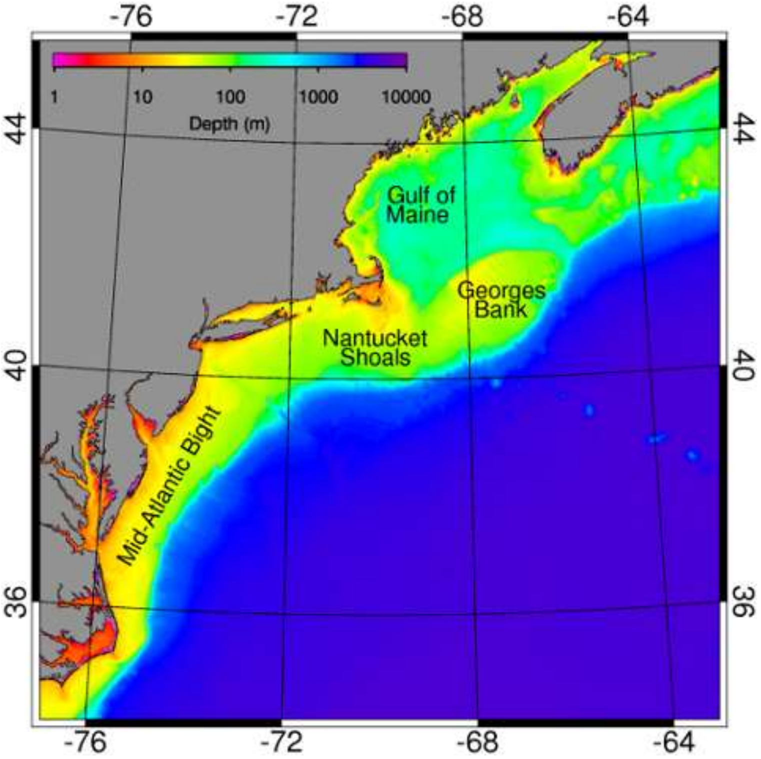

Figure 1: Bathymetric map of the Northeast Continental Shelf Large Marine Ecosystem.

1.1.2 Biological Components and Relationships

The Mid-Atlantic food web (Figure 2) has been characterized quantitatively using the information sources listed above and many others (Link et al. 2006, Link et al. 2008). Here, marine plants and animals are pictured as functional groups of similar organisms in boxes which are proportional to the total biomass of the group in the ecosystem. Lines between boxes represent important energy flows (predator-prey interactions). In the figure, we have highlighted relationships between the commercial small pelagics functional group in grey (containing Atlantic mackerel, butterfish, and Atlantic herring) and their predators (red) and prey (blue). Boxes colored purple are both predators and prey of commercial small pelagics. Any box with color is connected with commercial small pelagics, but the most important predator prey links are indicated with lines connecting the boxes. Therefore, in terms of energy flow, we see that the most important prey of commercial small pelagic are small and large copepods, micronecton (including euphausiids), macrobenthos, and larval/juvenile fish. The most important predators of commercial small pelagic include toothed whales and dolphins, medium pelagics and the fishery. More complex interactions in both directions happen between commercial small pelagics, demersal piscivoves (hakes, sharks, large flatfish, monkfish) and omnivores (skates and black sea bass), and gelatinous zooplankton functional groups. The most important direct energy flows for Mid-Atlantic fisheries include two small pelagic groups: commercial and other (which includes Atlantic menhaden), as well as demersal piscivores (groundfish and elasmobranchs), and filtering megabenthos (sea scallops, surf clams, and ocean quahogs).

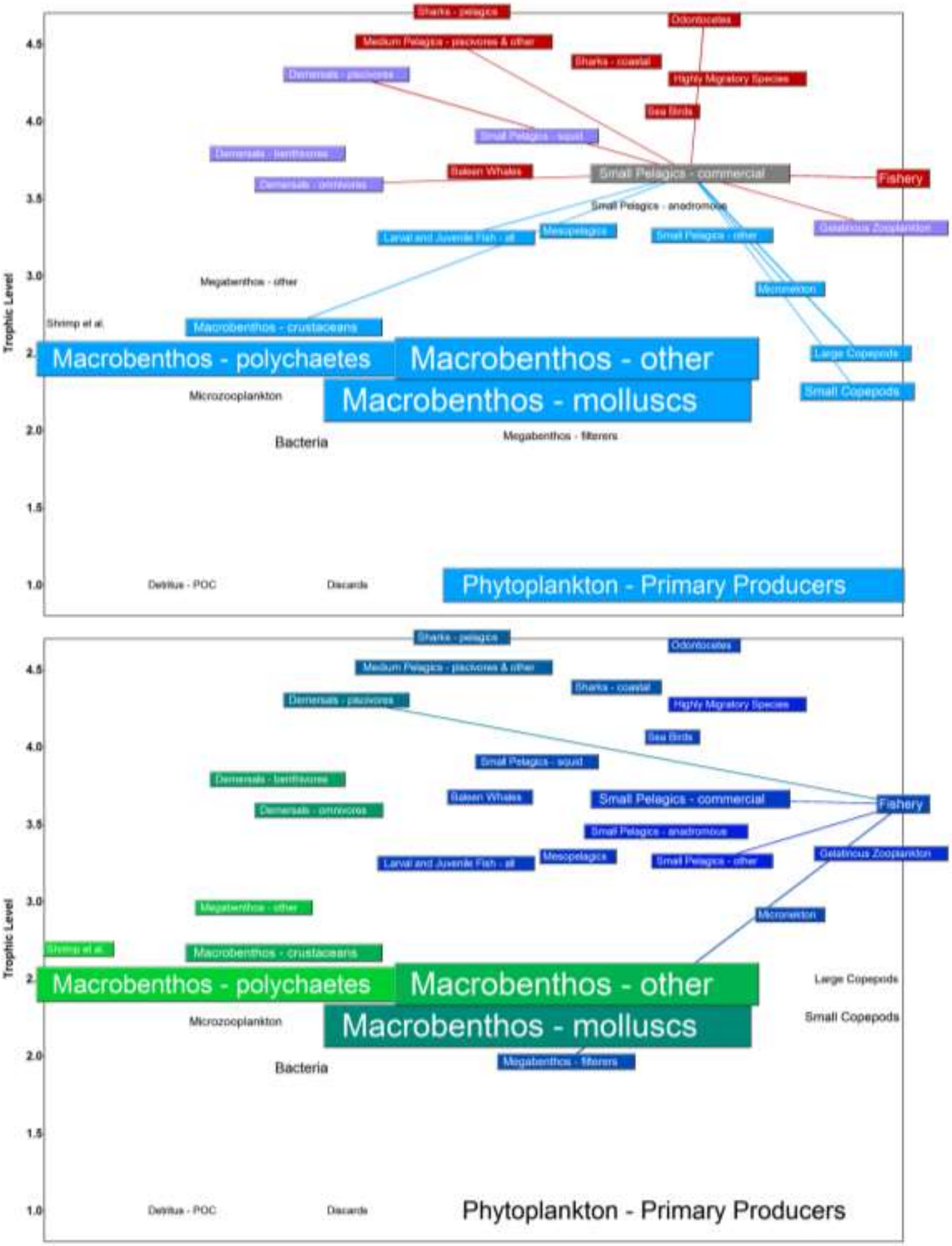

Figure 2: Food web model for the Mid-Atlantic region. Top panel: key links to commercial forage fish; bottom panel, key links to fisheries. See text for full description

A diverse assemblage of shelf and coastal fishes and squids can be categorized as forage species in the Mid-Atlantic region according to the MAFMC 2012 Forage Species definition.[1] Atlantic menhaden supports the single largest fishery on the U.S. east coast by weight and is managed by the Atlantic States Marine Fisheries Commission (ASMFC). Atlantic herring is managed jointly by the New England Fishery Management Council and ASMFC. Blueback herring and alewife fisheries, which have declined dramatically in the past 50 years and are under moratoria or greatly restricted landings in most coastal States, are managed jointly by the States and ASMFC. Atlantic mackerel, butterfish, and the longfin and Illex squids are managed by the MAFMC under a single FMP. Several taxa of small fishes that are not targeted in directed fisheries and are unmanaged, but are important as forage, occur in the coastal and shelf waters of the Mid-Atlantic region (see Appendix A of the Forage White Paper for a brief synopsis of each species). While not targeted currently in Mid-Atlantic fisheries, some (e.g., the Alosines) once supported substantial fisheries in the coastal zone. Some of the unmanaged forage species may be included in bycatches of targeted fisheries, for example Alosines (river herrings) in the Atlantic herring and Atlantic mackerel fisheries. At present, there are no declared proposals or plans to exploit the unfished forage species listed here.

A broader characterization of the forage base in the Mid-Atlantic used predator diets to determine which species or groups are consumed by many predators, as well as which species are important to different types of predators and in different habitats. Diet and consumption data of varying quality are described in detail in the MAFMC Forage White Paper, Appendix B. Predators are listed in the MAFMC Forage White Paper, Table 4, and the suite of forage species identified for each predator category are in the MAFMC Forage White Paper, Table 5.

Food habits information provides a picture of key forage for important Mid-Atlantic commercial fish as well. For example, estimated summer flounder diet composition on the Mid-Atlantic shelf (Figure 3a) reinforces the importance of cephalopods, mackerels, hakes, and herrings, as well as porgies/pinfish, if diet composition of 5% or more is considered important prey. Inshore, summer flounder eat more invertebrates according to the NEAMAP database. Bluefish, another important Mid-Atlantic managed predator, has a diet composition more based on fish on the shelf and in nearshore areas (Figure 3b). For bluefish, cannibalism represents an important part of their diet, estimated at 6%. Other Mid-Atlantic fish predator diets could be provided in more detail to determine which species represent important forage.

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[1] See the MAFMC Forage White Paper, Tables 1 and 2, at http://www.mafmc.org/s/MAFMC-Forage-White-Paper_Nov2014.pdf.

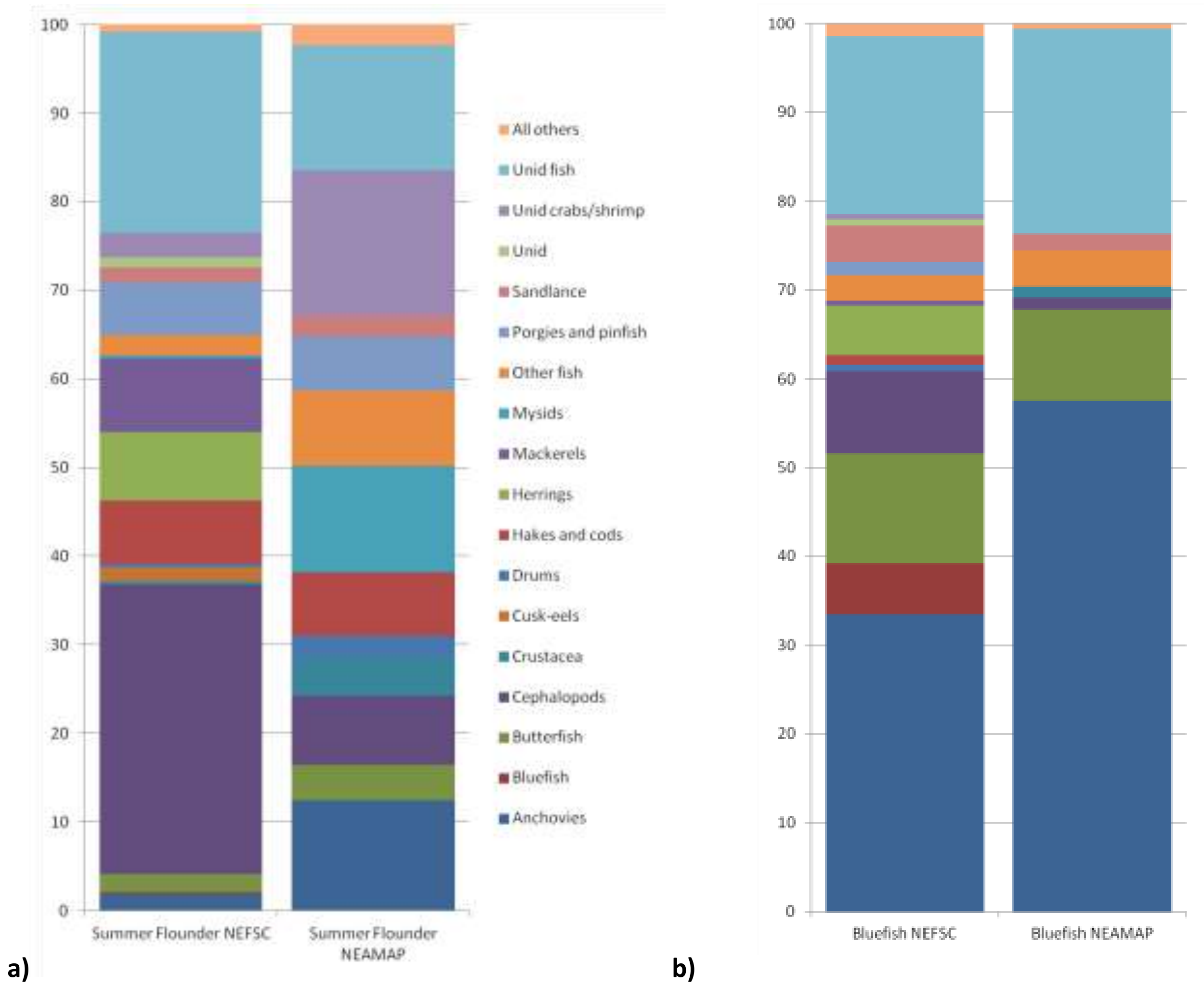

Figure 3: a) Summer flounder diet in the Mid-Atlantic, b) Bluefish diet in the Mid-Atlantic; NEFSC diet database 1963-2012 and NEAMAP database 2006-2012.

1.1.3 Oceanographic features (physical, chemical)

The oceanography of the NES LME is shaped by a number of factors including the flow of water from the north into our region, the influence of major river systems, winds, and tidal forces. The physical oceanography of the region is further strongly influenced by two major current systems, the equatorward flowing Labrador Current from the north and the poleward flowing Gulf Stream (Figure 4). Hydrographic characteristics such as temperature and salinity and oceanographic features such as circulation patterns and the position of frontal zones affect every aspect of the ecology of the system, including the distribution patterns of species at all levels of the food web, the basic biology of individual species, and dispersal and migration pathways.

Water entering the northern Mid-Atlantic Bight from the Gulf of Maine and Georges Bank flows equatorward (Figure 4). This generally southwesterly flow regime parallels the isobaths on the shelf. However, the flow highly variable and may reverse direction at times, notably during the summer months.

The surface circulation in the Gulf of Maine is cyclonic (counterclockwise), driven by buoyancy-driven flow resulting from the contrast between freshwater inputs from river systems and higher density water over the central gulf (Figure 4). The eastern Maine coastal current (EMCC), originating on the Scotian Shelf and flowing along the coast, is an important pathway for the transport of nutrients and planktonic organisms in the gulf.

Tidal forces also play an important role in the dynamics of the Gulf. Tides within the Gulf of Maine are among the strongest in the world ocean with the Bay of Fundy having the highest overall tidal amplitude. Smaller-scale circulation patterns may form over several of the features of the Gulf of Maine including some of its deep-water basins.

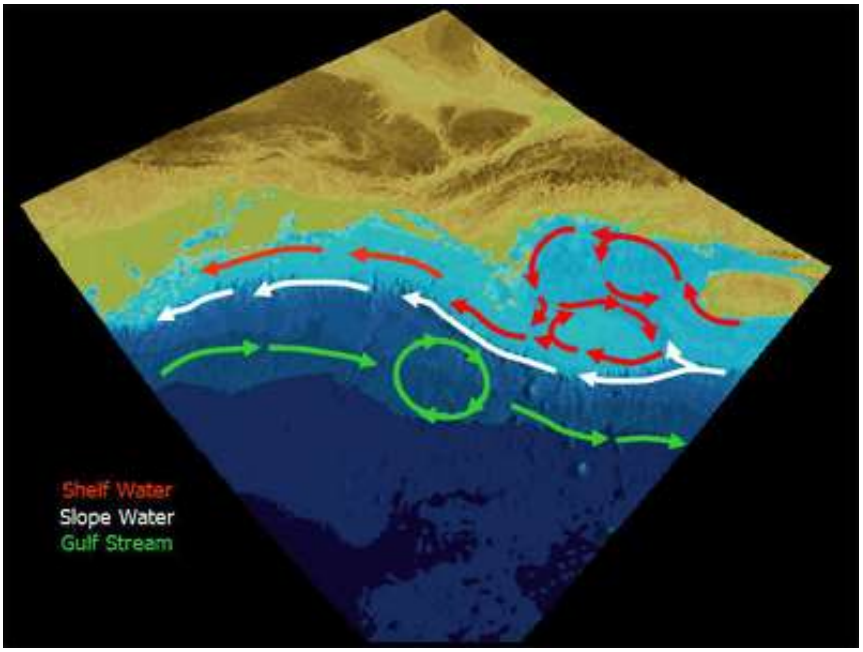

Figure 4: Principal circulation features on the NES LME and adjacent offshore regions showing equatorward flow of shelf and slope waters and poleward flow of the Gulf Stream with a warm core ring depicted.

Tides and topographic features of the Georges Bank region result in the establishment of an anticyclonic (clockwise) circulation pattern, particularly during the stratified period on the bank (see Figure 3). This semi-closed gyre holds important implications for the retention of planktonic organisms on the bank. A strong tidal circulation 'jet' forms on the steep northern edge of the bank and continues in more diffuse form around the northern edge and its southern flank. In the general flow, some water exits over the Great South Channel while the remainder recirculates on the bank. It has been estimated that the average retention time of a parcel of water (and associated organisms) is approximately 5 months during the stratified season and on the order of two months in the remainder of the year.

The Gulf Stream is a classic western boundary current system, driven by wind fields and serving as a major mechanism of heat redistribution in the North Atlantic. The Gulf Stream exerts important influences on the NES LME, particularly through the formation of meanders and eddies. Warm core rings - meanders that separate from the Gulf Stream and form a clockwise rotation pattern - can draw large volumes of water off the shelf, along with the phytoplankton and zooplankton in that water.

1.1.3.1 Water Masses

Seasonal warming of surface water of the Mid-Atlantic Bight results in the establishment of a strong thermocline and the isolation of a cooler subsurface water layer between the warmer surface waters and the foot of the shelf-slope front near the shelf-break. This 'Cold Pool' is a persistent and distinctive characteristic of the Mid-Atlantic region. The Mid-Atlantic Bight exhibits strong seasonal cycles in temperature and salinity. The annual temperature range in the Bight is the most extreme within the region with surface temperatures spanning 5-30°C. Freshwater inputs from the Hudson River and through Delaware and Chesapeake Bays strongly influence the salinity characteristics of the Bight. Warm, saline continental slope water extends seaward from the Mid-Atlantic Bight shelf water with a sharp discontinuity of these water masses at the shelf-slope front throughout the Bight and extending northward to Georges Bank.

Water mass characteristics of the Gulf of Maine are strongly influenced by input of Scotian Shelf water at the surface and continental slope water entering the Gulf through the deep Northeast Channel. Three distinctive water mass units have been identified in the Gulf. The influx of relatively warm, salty slope water through the channel forms the distinctive Maine Bottom Water layer below approximately 100m depth. This layer is relatively stable with respect to temperature (6-8°) and salinity (34-35 parts per thousand, ppt) characteristics. Overlying this layer is the colder Maine Intermediate Water (MIW) characterized by relative fresh waters (31-32 ppt). The temperature minimum generally occurs in the MIW layer except in the winter months when convective overturn results in mixing from the surface to the bottom water layer or below. The relatively fresh (31-33 ppt) Maine Surface Water in the upper 50m or so of the water column undergoes wide seasonal temperature excursions (from 1-15° C) as a result of atmospheric influences. The relative contribution of the Scotian Shelf Water to fresh water inputs to the Gulf is approximately equal to that of the major river systems.

On Georges Bank, strong tidal forces keep the water on the shallow crest of the bank (<60m) well mixed and isothermal throughout the year. Recent evidence suggests the importance of cross-over events from the Scotian Shelf onto Georges Bank, particularly in winter and short-circuiting the 'typical' pathway of water exchange from the shelf to the bank. The salinity on the bank is relatively stable and slightly higher than the Maine Surface Water, suggesting an influence from slope waters or deeper waters in the Gulf of Maine.

1.1.3.2 Climate and Physical interactions

Climate and weather patterns over the North Atlantic are strongly influenced by the relative strengths of two large-scale atmospheric pressure cells - the Icelandic Low and the Bermuda-Azores high pressure system. A deepening of the Icelandic Low is typically accompanied by a strengthening of the Azores High and vice versa. This characteristic pattern is called the North Atlantic Oscillation (NAO) and a simple index of its state is given by the difference in sea level pressure in the vicinity of the Azores and Iceland in winter (December-February). When the NAO index is positive, we see a northward shift and increase in westerly winds, and an increase in precipitation over southeastern Canada, the eastern seaboard of the United States, and northwestern Europe. We also see increased storm activity tracking toward Europe. Water temperatures are markedly lower off Labrador and northern Newfoundland, influencing the formation of Deep Labrador Slope water, and warmer off the United State. Conversely, when the NAO index is negative, we have a southward shift and decrease in westerly winds, decreased storminess, and drier conditions over southeastern, the eastern United States, and northwestern Europe. Water temperatures are warmer off Labrador and Newfoundland, but cooler off the eastern United States. These changes in the state of the North Atlantic Oscillation tend to persist over decadal time scales. Changes in winds, precipitation and temperature associated with the North Atlantic Oscillation can have far reaching effects on the oceanography of our region.

Over the last several decades, the NAO has primarily been in a positive state, however, we have experienced increased variability in the NAO over the last decade. We have generally experienced warm water temperatures during this period, particularly in nearshore areas. This temperature increase closely tracks the change in the NAO index.

Multidecadal patterns in sea surface temperature (SST) in the North Atlantic are represented by the Atlantic Multidecadal Oscillation (AMO) index. The AMO signal is based on spatial patterns in SST variability after removing the effects of anthropogenic forcing on temperature, revealing natural long-term patterns in SST. The AMO is characterized by warm and cool phases with periods of approximately 20-40 years. The AMO index is related to air temperatures and rainfall over North America and Europe and is associated with changes in the frequency of droughts in North America and the frequency of severe hurricane events. The AMO is thought to be related to the North Atlantic branch of the deep thermohaline circulation.

Temperature is one of the most important governing environmental factors for marine organisms. Marine organisms have minimum and maximum temperatures beyond which they cannot survive. Additionally, they have preferred temperature ranges and within these bounds, temperature influences many processes including metabolism, growth, consumption, and maturity. Thus, changes in temperature will have far-reaching impacts on species in the ecosystem and on the ecosystem itself. The NES LME experiences some of the highest amplitude changes in seasonal water temperatures on the planet. In addition, there are very large differences among the different regions of the shelf system (Figure 5).

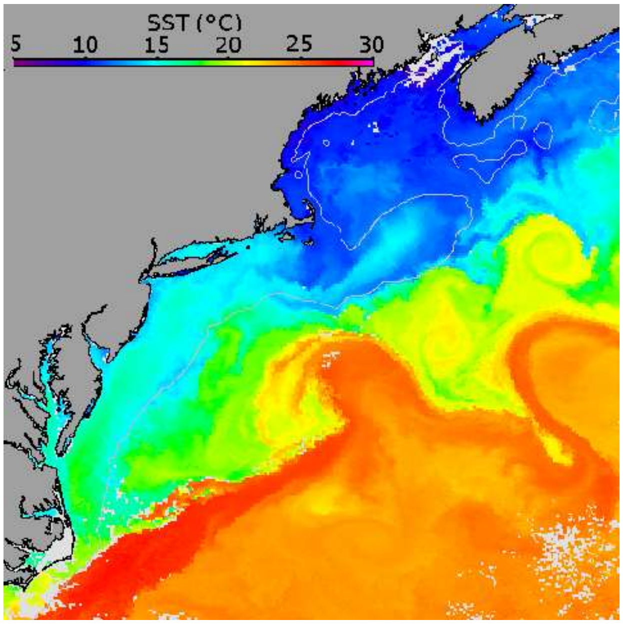

Figure 5: This satellite image depicts a daily snapshot of fall surface water temperature patterns on the Northeast U.S. continental shelf. Cooler temperatures are represented by darker colors shading to blue. Warmer temperatures, such as those associated with the Gulf Stream are represented by the warmer colors shading to red.

Temperature in the NES LME has varied substantially over the past 150 years (Figure 6). The late 1800s and early 1900s were the coolest in the 150-year record. This relatively cool period was followed by a period of warm temperatures from 1945-1955. There was a rapid drop in temperatures through the 1960s followed by a steady increase to the present. Summer temperatures over the past 5 years are comparable to the warm period in the late-1940s/early 1950s and the summer 2012 surface temperature was the highest in the 158-year record.

Winter temperatures in recent years, however, remain near the long-term mean indicating that the seasonal range in temperature has increased.

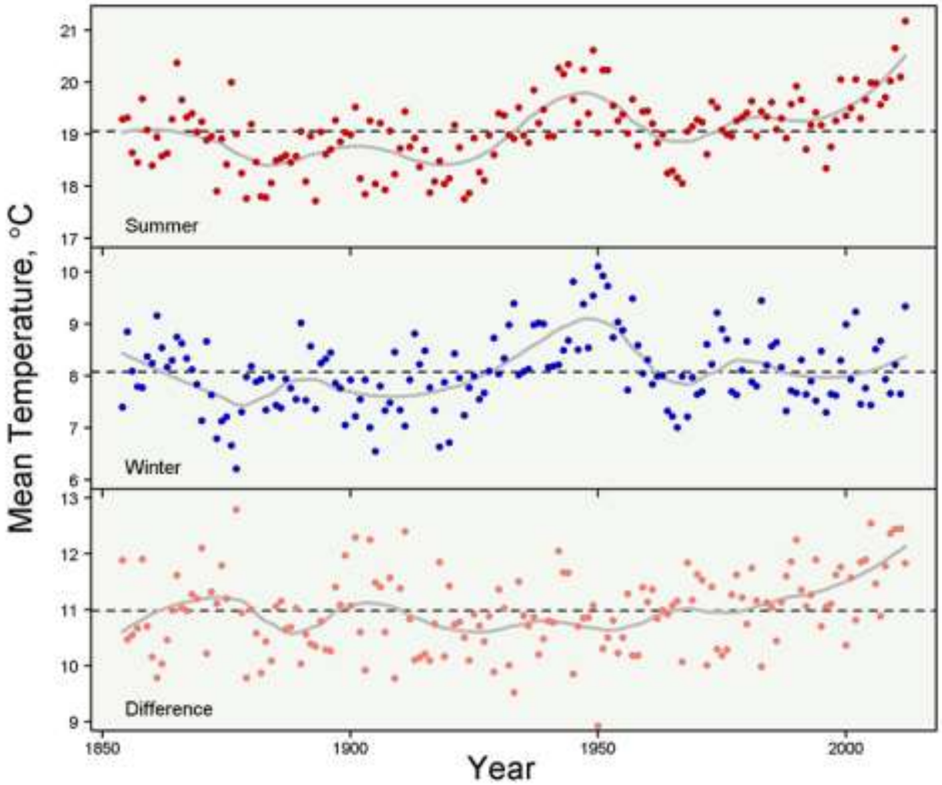

Figure 6: Long-term summer and winter sea surface temperatures averaged over the northeast U.S. continental shelf and adjacent waters from the ERSSTv3b dataset.

Regional water column temperatures measured by the Northeast Fisheries Science Center (NEFSC) give spatial context to the shelf-wide trends in sea-surface temperature (Figure 7). Surveys began in the late 1960s, so the time series are shorter than sea-surface temperature records shown in Figure 6. Time series constructed within each region reveal interannual temperature fluctuations larger than 2°C near the surface and bottom. Long-term warming trends are observed at the surface and bottom in the Mid-Atlantic Bight, Gulf of Maine, and Georges Bank regions and at the surface in the Scotian Shelf region, with waters warming by 1°-1.5°C over the length of the records. Even larger warming trends have been observed in recent years, with the surface and bottom waters warming by more than 2 degrees since 2004 within all regions except the Mid-Atlantic Bight. Perhaps most notable, 2012 temperatures were the warmest observed in the 35-year record at the surface and bottom over all regions of the NES, exceeding long-term annual mean values by up to 2 degrees at the surface and 1 degree at the bottom.

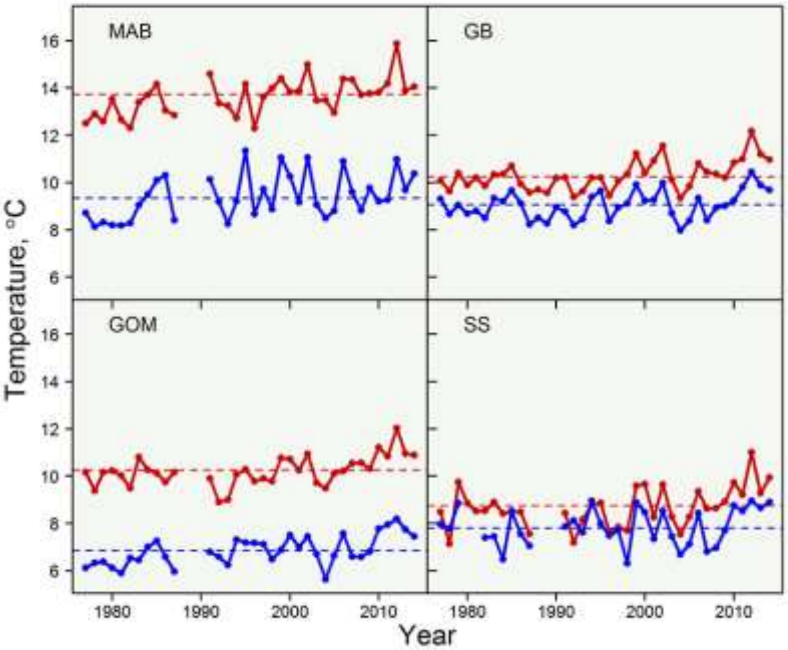

Figure 7: Annual mean surface (red) and bottom (blue) water temperatures from the NEFSC survey programs from the four Ecological Production Units.

Shifts in distribution of marine populations in our region have been documented as water temperatures have increased. Most marine species exhibit distinct thermal preferences with well-defined optimal temperatures. Populations of marine animals at the high end of their thermal range will be adversely affected under current climate change scenarios if redistribution to more favorable conditions is not possible. Temperature preferences of species and overall habitat requirements (for example, substrate type, prey and predator abundances, etc.) will determine the extent of potential distributional changes and adaptation by marine organisms. Overall, poleward shifts in distribution have been observed for species occupying the Mid-Atlantic Bight and Georges Bank, although compensatory changes in depth distribution also occur. However, other habitat requirements may prevent or limit movement for some species, requiring them to accommodate to higher temperatures. Because growth, survival, and reproduction function most efficiently within fairly narrow temperature ranges, energetic costs associated with living at unfavorable temperatures may result in loss or decline of regional populations. In the Gulf of Maine, the movement of many species is toward the southwest. Perhaps paradoxically, the bottom water temperature in the southwestern Gulf of Maine is colder than that of the northeastern Gulf.

Collectively these changes in distribution with respect to latitude or depth will affect the availability of fish and invertebrate species to regional fisheries, in some instances changing the character of these fisheries and the communities they support.

Temperature change may also affect the relative timing of the production cycles of the base of the food chain and consumers thus affecting their growth and survival. During the early life history stages of many fish and invertebrate species there are critical timing relationships between the seasonal primary production cycle and their spawning cycle. As the timing of the primary production cycle is changed by shifting thermal conditions, fish species may not be able to respond to these changes and suffer reduced growth and survival because food resources were not available at the right time of year.

Temperature plays a direct role in the physiology of fishes and marine invertebrates, controlling rates of growth and other processes with important implications for survival. Optimal temperatures for growth are critical for organisms to transition through vulnerable periods of their life history, thus temperature change will upset the growth strategies species use in a particular habitat.

Regional changes in salinity are also expected under climate change. Decreased salinity is expected in coastal areas affected by high precipitation and runoff. Increased runoff will intensify buoyancy-driven coastal currents and the effect these currents have on a range of ecosystem properties including organism transport and primary productivity. Increased salinity is anticipated in offshore areas where higher temperatures will lead to higher evaporation rates. Many marine organisms exhibit distinct salinity tolerance levels and it is anticipated that these changes will contribute to overall changes in distribution patterns of marine species. Changes in salinity will also affect the density of sea water and hence stratification.

Increases in water temperatures and in precipitation under global climate change will result in enhanced stratification of the water column with important implications for productivity. The overall effect will be to increase the energy required for mixing in the water column, resulting in less turnover and a reduction in the mixed layer depth. Replenishment of nutrients in marine ecosystems is dependent on enrichment of the water column from bottom waters, which will be directly affected by changes in stratification. The consequences of these changes can be expected to vary regionally

A reduction in wind-driven forcing in the major current systems such as the Gulf Stream will affect transport and can also be expected to reduce the formation of meanders and rings which can affect advective loss of continental shelf biota. For example, the frequency of warm core ring formation from the Gulf Stream has been related to recruitment success of a number of fish populations. In years in which larger numbers of ring events occur, recruitment is reduced, presumably due to advection as the rings entrain water from the continental shelf and slope regions.

1.1.3.3 Habitat (Including Human Effects)

Sediments

Sediments are the bottom materials deposited by water, wind or glaciers, as opposed to the more permanent bedrock. Sediments are by far the dominant type of surficial substrate in the NES LME and slope. They are important in an ecosystem context due to their abundance and for other reasons including: 1) some or all life stages of many plant and animal species are closely tied to certain sediment types, so their distribution and abundance are partly determined by sediments; 2) sediment-dwelling organisms from microbes through benthic macrofauna are important in food webs and other ecosystem functions; 3) sediments are a significant site for deposition and uptake of organic carbon and contaminants, and nutrient regeneration, and they sometimes contribute to bottom water hypoxia and release of toxic compounds such as hydrogen sulfide and ammonia; and 4) sediments are relatively amenable to monitoring to determine trends over space and time in contamination and other ecosystem indicators.

Geologists typically divide sediments into several size classes. The largest is gravels, which are 2 mm or more in diameter; with increasing size, these sediments are termed pebbles, cobbles, and then boulders. Sands are between 2 mm and 62.5 microns. Silts are from 62.5 down to 4 microns, and clays are 4 microns or less. Both silts and clays are also called “muds”. The finer sediments are more easily moved by bottom currents, which gives rise to the familiar pattern of sands and gravels being found in inshore and other high-energy (“erosional”) areas, and silts and clays in deeper and less energetic (“depositional”) areas.

In the Middle Atlantic Bight, the pattern of sediment distribution is relatively simple (6). Most of the surficial sediments on the continental shelf are sands and gravels. Silts and clays predominate at and beyond the shelf edge, with most of the slope being 60-100% mud. Fine sediments are also common in the shelf valleys leading to the submarine canyons, as well as in areas such as the “Mud Patch” south of Rhode Island. There are some larger materials, left by retreating glaciers, along the coast of Long Island and to the north and east. North and east of Cape Cod, sediment distributions are more complex (Figure 8). This is partly due to the area’s rugged bottom topography, which features many basins, swells, knolls, banks, and submarine canyons. Glacier-transported materials are much more common in this region. Bottom currents are also complex, and have a large influence on the area’s sediment types. The shallower parts of Georges Bank are predominantly sandy, and areas with relatively stable sands (which are moved only by storms) can be distinguished from areas where the sands are often in motion - this has important implications for faunal distributions. On the southern flank of the bank, sand waves over 15 m in height occur. The bank also has large areas of gravel pavement, especially at its northern edge, which are considered valuable habitat for species such as cod and scallop.

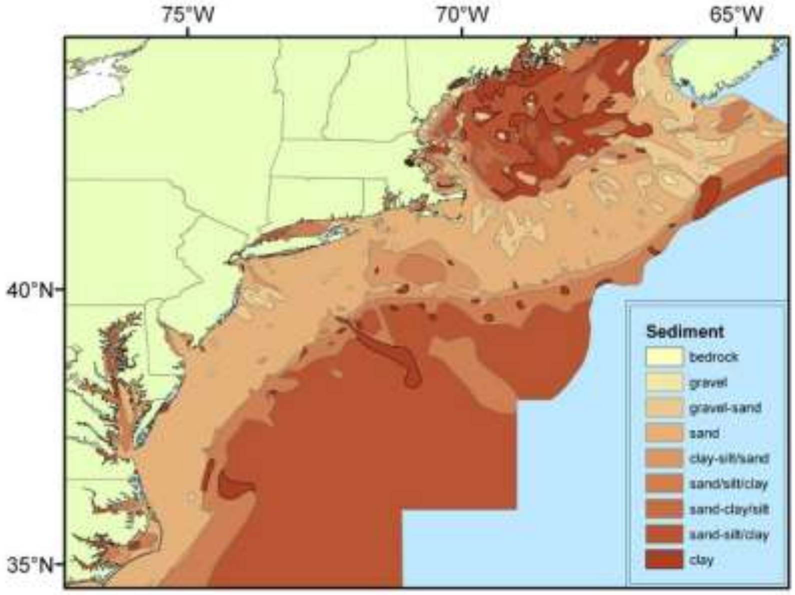

Figure 8: Sediment distribution in the NES LME.

North of Georges Bank, in the Gulf of Maine proper, the topographic highs have sands and larger materials including glacial erratics (boulders), while the basins are floored with muds interspersed with boulders and rocky outcrops. The sedimentary characteristics of the Gulf of Maine are the most complex in the region, with an intricate mosaic of bottom types in the nearshore Gulf of Maine, expanses of clay and silty sands in the deeper portions of the central and western gulf and a mix of sand/silt/clay in the deepest reaches. Areas of exposed bedrock are also found throughout the gulf (Figure 8).

Complex Physical Habitats

Hard, immobile substrates (including the larger of the sediment types discussed above) provide a distinct, important habitat for biota to attach to or live within or near. Besides providing stable attachment sites and shelter, the added surface area of complexly-structured hard substrates often increases food supply. Some or all life stages of many species are dependent on complex hard substrate, while other species use this structure although they are not as strictly tied to it. Man-made structures such as bulkheads, piers, bridges, shipwrecks and artificial reefs provide many of the same functions as do the natural hard substrates.

Rocky coastal areas are rare in the southern Middle Atlantic Bight, but become more common north and east of New Jersey and Long Island. Offshore (as noted in the Sediments section), bottom substrates in the Middle Atlantic include relatively little natural rock. However, the amount of complex hard substrate has been substantially augmented by man, especially via shipwrecks and construction of artificial reefs. It has been estimated that there is now more man-made than natural habitat of this type in the Middle Atlantic. The increase in amount of this habitat has probably affected distribution and abundance of harvested stocks including lobster, cod, red hake, ocean pout, scup, black sea bass and tautog, as well as the many other species associated with the habitat. There is a long-standing scientific debate over the extent to which artificial reefs increase overall production of fishery species, versus simply concentrating these resources, which in turn could increase the risk of overfishing them.

In northern New England, rocky substrates are the rule along exposed coastlines and in shallow waters. Bedrock and boulders left by glaciers are also very common at greater depths. There are several large submarine ledges (e. g., Jeffreys, Cashes) rising above the surrounding bottom.

Complex Biogenic Habitats

Seabed habitats comprise a complex blend of bottom features and associated animal communities. Often, habitats are “biogenic”; that is, formed by the animals themselves. These may also provide shelter for other species, including fish. Areas that are structurally complex as a result of geological features or biogenic structures often support highly diverse biological communities. Some of these habitats are also particularly vulnerable to disturbance by natural forces and human activities. It is for this latter reason that habitat protection has assumed an important role in current fishery management.

The types of habitat described above are centered on physiographic features associated with the sea bed. However, many marine animals spend their lives in the water column itself with some taking excursions to the sea floor for feeding and other purposes.

The physical geography of the sea is defined not only by bottom characteristics but by a complex array of oceanographic features including currents and frontal zones. Animals principally associated with the water column are considered to inhabit the pelagic ecosystem. Many types of schooling fish, marine mammals, sea turtles and top predators such as sharks, tunas, and billfish are important components of the pelagic ecosystem. Other important members of these pelagic communities include small (in some cases microscopic) animals that are important links in the food web. These zooplankton species drift in the ocean currents and are often concentrated in frontal zones and other oceanographic features. Frontal zones can be generated by tidal forces or by the confluence of water masses characterized by different temperature and other features. Fronts can often be recognized at the surface by concentrations of sea foam, debris, or other materials. In areas such as Georges Bank, fronts or convergence zones separate areas that are well mixed by tidal forces and winds from areas that are seasonally stratified (or layered, with warmer and/or fresher water on top) and these are important pelagic habitat areas for many species.

Many species forage in oceanographic structures such as fronts where their prey are concentrated. For example, large shoals of small pelagic fish such as herring and mackerel are often found at tidal mixing fronts where high densities of their planktonic prey are found. In turn, fishing activities directed at pelagic species are often concentrated in these areas to capitalize on these natural associations between predators and their prey.

Essential Fish Habitat

Essential Fish Habitat is defined as:

> *“...those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity. For the purposes of interpreting the definition of essential fish habitat, 'waters' include aquatic areas and the associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding or growth to maturity' covers a species' full life cycle”*

Habitat protection is a cornerstone in the development of ecosystem based fisheries management. Ecosystem based fisheries management is inherently geographically specific, and therefore naturally linked to considerations of habitat and local seascapes. The specification of “habitat areas of particular concern” under current management measures shows how fine-scale information on habitat and associated biological communities can be used to protect critical areas.

The interest in protecting vital habitat centers on the role it plays in the productivity of living marine resources. Habitats provide food and shelter for many species and therefore directly affect their productivity. If we lose critical habitat, the ability to support these organisms is diminished. The amount of sea life that an ecosystem can sustain – its carrying capacity – depends on the availability of appropriate habitat, among other factors. For species that live on or near the seabed, the types of physical habitat we have described is critical. For other species that spend their lives in the water column, oceanographic features such as frontal zones may be critical habitats.

1.1.3.4 Description of Managed Fisheries

Central to Ecosystem Based Management (EBM) is an understanding of coupled socio-ecological systems (human and natural environment) which reflects the interface and reciprocal interactions that link human (e.g., economic, social, cultural) and natural (e.g., oceanographic, atmospheric, geological, biological) sub-systems. Coastal communities of the NES LME (and around the U.S.) depend on the ocean for meeting economic, social, and cultural needs. Fishing (commercial, recreational, and subsistence), coastal tourism and recreation, shipping, and spiritual or cultural practices centered on marine locations or species are but a few examples. In turn, human activities shape the marine environment, generating a feedback mechanism between the coupled systems. The following overview highlights some indicators of these dependencies, and new avenues by which our scientific understanding of the underlying processes are being bolstered.

It also provides an initial understanding of the potential tradeoffs that must be made under both EBM and Marine Spatial Planning, as we analyze the nation’s use of the marine environment and understand: 1) how marine resources are utilized; and 2) potential user conflicts inherent in access to these resources. As technology allows new development in and uses of ocean waters, traditional uses of marine resources (e.g., boating, fishing, shipping, spiritual practices) must be considered in the planning process for evolving new activities such as renewable energy in the form of wind farms or tidal generators. MSP is utilized by ocean resource managers, in conjunction with EBM, to better determine how resources may be sustainably used and/or protected.

1.1.3.5 Social and Economic

Harvest And Processing Sector

The commercial fisheries of the NES LME have historically played a critical role in the economy of coastal communities throughout the region. Fishing has been called America's First Industry and the lure of unexploited resources was a major catalyst in the exploration and colonization of eastern North America by European fishing nations. In the Gulf of Maine (GOM), the total biomass extracted peaked between the late 1960s and 1990s (Figure 9). However, the maximum annual removal of crustaceans occurred in 2012, driven primarily by landings of American lobster (Homarus americanus), and landings of pelagics are near the time series' average. Crustacean landings in the Scotian Shelf are likewise at a series high, while mollusc landings are on par with the series average. Mollusc landings are also near long-run averages in Georges Bank. Although the landings composition has shifted dramatically, the total biomass removed from the Mid-Atlantic is very close to the series average [note that these estimates differ from previous Ecosystem Status Reports in using live weight rather than processed weight (e.g. scallop meat weight) to reflect more fully the biological dynamics of the systems]. The shift towards mollusc landings highlights the importance of Atlantic surf clams (Spisula solidissima), ocean quahogs (Arctica islandica), and Atlantic sea scallops (Placopecten magellanicus) to the Mid-Atlantic, while crustacean landings in this Ecosystem Production Unit are composed primarily of blue crab (Callinectes sapidus). Notwithstanding the above, recent landings are by and large substantially below historical levels.

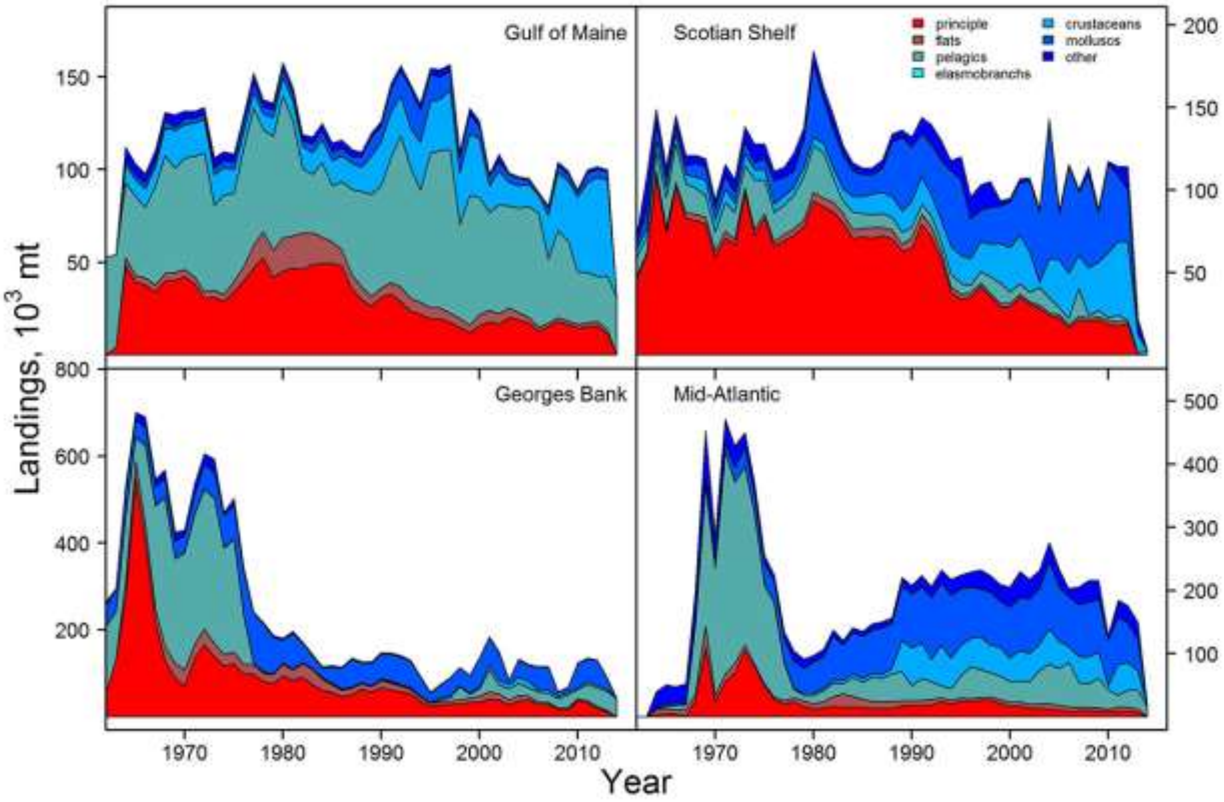

Figure 9: Landings (live weight) by subregion for the NES LME. The groups represented are: principal groundfish (Atlantic cod, haddock, pollock, silver hake, red hake, white hake, red fish, and monkfish), flatfish (i.e. summer flounder, winter flounder, yellowtail flounder), pelagics (i.e. Atlantic herring, Atlantic mackerel), elasmobranchs (i.e. spiny dogfish, winter skates), crustaceans (i.e. American lobsters, red crab), molluscs (i.e. Atlantic scallops, ocean quahogs, surfclams), and other. Note: landings of lobster are underrepresented in the time series.

Providing food is an important dimension of the recreational fishing experience, as reflected in the magnitude of the catch taken for consumption. It is however also an aesthetic pursuit and must also be considered as an important Cultural Service as well. Here we focus on recreational catch statistics. A downward trend in recreational fishing effort and landings has occurred over the last few years. Attributing the trend to a single cause is problematic, as recreational fisheries are a complex amalgam of for-profit party and charter vessels together with private boat and shore fishing more purely characterized as leisure and/or subsistence activities. The recent recession, lethargic economic recovery, and an increase in real fuel prices likely explain a portion of the recent trend, as individuals slow expenditures on recreational activities or substitute less expensive leisure activities for fishing. The recreational fishery also depends on many of the same depleted fish stocks as some of the most contracted commercial fisheries in the Northeast, and these depletions likely account for a portion of the longer trends in landings observed.

Fishery Dependent Communities

Coastal communities are currently experiencing impacts of multiple stressors: economic, social, and ecological. Factors affecting vulnerability include levels of access to resources and power (political, cultural, economic, and social) and of susceptibility to harm or loss. Existing levels of social vulnerability affect the level of impact that a community experiences from stressors. Therefore, identification and monitoring of socially vulnerable communities in the coastal zone is a critical aspect of EBM. 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 trends may be an indication of community vulnerability to development that can transform the coastal zone and increase coastal community vulnerability to the impacts of disruptive events (Jepson and Colburn 2013), such as extreme weather conditions.

The NMFS Community Social Vulnerability Indicators (CSVIs; Jepson and Colburn 2013) are statistical measures of the vulnerability of communities to events such as regulatory changes to fisheries, wind farms, and other ocean-based businesses, as well as to natural hazards, disasters, and climate change. The CSVIs currently serve as indicators of social vulnerability, gentrification pressure vulnerability, and commercial and recreational fishing dependence (with dependence being a function of both reliance and engagement; Figure 10).

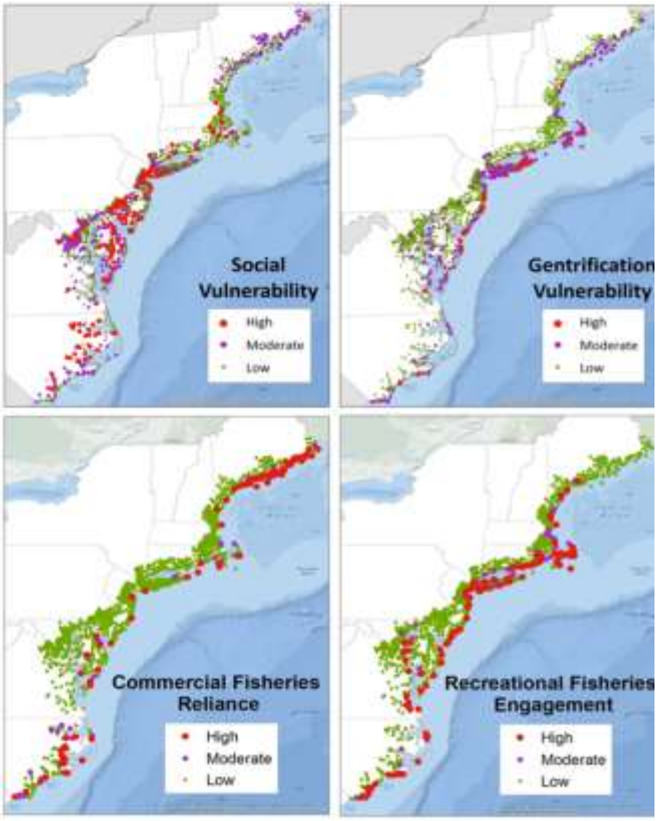

Figure 10: Rankings of social vulnerability, gentrification pressure vulnerability, and commercial fishing reliance and recreational fishing engagement.

Communities in the Northeastern U.S. are ranked as high, moderate, or low relative to the respective indicator. Figure 10 shows a high concentration of socially vulnerable communities in the Mid-Atlantic, while we see a high to moderate concentration of communities that may be vulnerable to gentrification pressure in Massachusetts, New York, and New Jersey. Community dependence on recreational and commercial fishing is mixed, with notably more communities in the Mid-Atlantic engaged in than reliant on recreational fishing (Figure 10).