XIX-61 Northeast U.S. Continental Shelf: LME #7

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The Northeast U.S. Continental Shelf LME extends from the Gulf of Maine to Cape Hatteras in the Atlantic Ocean. It is characterised by its temperate climate. Structurally, this LME is complex, with marked temperature and climatic changes, winds, river runoff, estuarine exchanges, tides and multiple circulation regimes. It is historically a very productive LME of the Northern Hemisphere. The LME has an area of 310,000 km^2, of which 1.96% is protected, and has 28 major estuaries and river systems (Sea Around Us 2007), including Casco Bay (Kennebec), Chesapeake (including the Potomac River), Delaware, and Long Island Sound (Connecticut River). Four major sub-areas are the Gulf of Maine, Georges Bank, Southern New England, and the Mid-Atlantic Bight. Book chapters and articles pertaining to this LME include Falkowski (1991), Sissenwine & Cohen (1991), Sherman *et al.* (1996a, 1996b, 2002, 2003) and Murawski (1996, 2000). A Northeast Shelf Ecosystem volume, edited by Sherman *et al.*, was published in 1996. A trophodynamic energy network model has recently been published (Link et al. 2008).

I. Productivity

This LME is bounded on the seaward side by the Gulf Stream, with its circulation and seasonal meanders and rings influencing the LME. The gyre systems of the Gulf of Maine and Georges Bank, and the nutrient enrichment of estuaries in the southern half of the LME contribute to the maintenance on the shelf of relatively high levels of phytoplankton and zooplankton prey fields for planktivores including menhaden, herring, mackerel, sand lance, butterfish, and marine birds and mammals. For a map of surface circulation, see Sherman *et al.* (2003). For an overview of the physical oceanography of the shelf, see Brooks (1996). The Northeast U.S. Continental Shelf LME is a Class I, highly productive ecosystem (>300 gCm^{-2}yr^{-1}), and is one of the world's most productive LMEs. Since 1977, the NOAA Northeast Fisheries Science Centre (NEFSC) has monitored this LME for primary productivity, chlorophyll-*a,* zooplankton biomass and species diversity, fish and fisheries, pollution and ecosystem health, socioeconomics and governance. Productivity varies in the 4 major sub-areas, and from season to season. Zooplankton is used as an indicator of major changes in stability of the lower levels of the food web and of biofeedback responses to oceanographic changes (Durbin & Durbin 1996). Over the past two decades, zooplankton has been stable with regard to biomass. Relatively high biodiversity and abundance of zooplankton within the ecosystem contributed to the recovery of herring and mackerel from their low levels in the mid-1970s and supported the recovery of several demersal fish stocks beginning in the mid-1990s (Sherman *et al.* 2003).

Oceanic fronts (Belkin *et al.* 2009)(Figure XIX-61.1): The Shelf-Slope Front (SSF) is associated with a southward flow of cold, fresh water from the Labrador Sea. The Mid-Shelf Front (MSF) follows the 50-m isobath (Ullman and Cornillon, 1999). The Nantucket Shoals Front (NSF) hugs the namesake bank/shoals along 20-30-m isobaths. The Wilkinson Basin Front (WBF) and Jordan Basin Front (JBF) separate deep basins from Georges Bank and Browns Bank and are best defined in winter. Georges Bank is surrounded by a tidal mixing front, GBF (Mavor and Bisagni, 2001). The Maine Coastal Front (MCF) and Cape Cod Front (CCF) are seasonal (Ullman and Cornillon, 1999).

Northeast U.S. Continental Shelf LME SST (Belkin 2009)(Figure XIX-61.2):
Linear SST trend since 1957: 1.08°C.
Linear SST trend since 1982: 0.23°C.

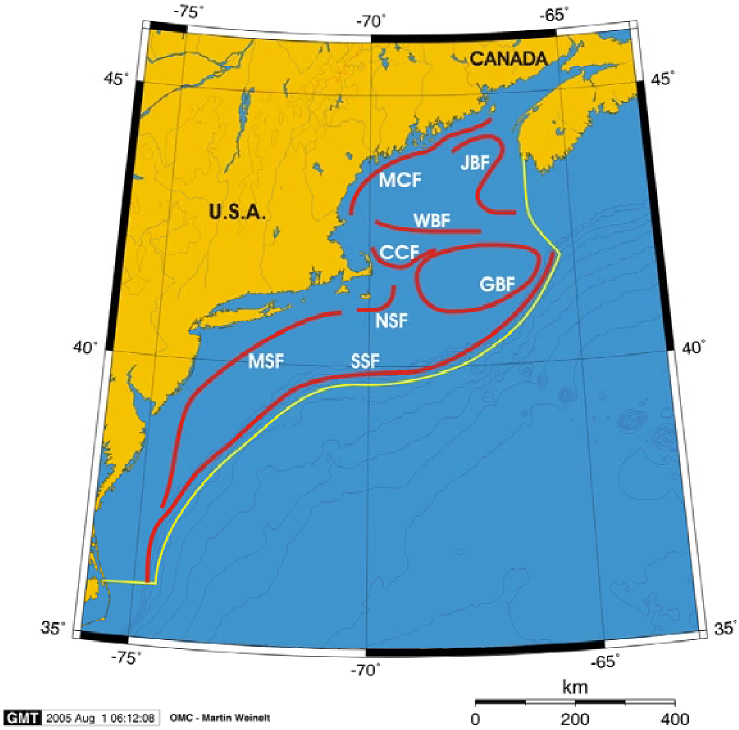


Figure XIX-61.1. Fronts of the Northeast U.S. Continental Shelf LME. CCF, Cape Cod Front; GBF, Georges Bank Front; MCF, Maine Coastal Front; MSF, Mid-Shelf Front; NSF, Nantucket Shoals Front; SSF, Shelf-Slope Front. Yellow line, LME boundary; after Belkin et al. (2009).

The Gulf Stream brings warm waters from the Gulf of Mexico into the Southeast U.S. Shelf, creating oceanographic conditions dramatically different from those of the Northeast U.S. Continental Shelf LME. The Southeast U.S. Shelf is protected from northern influences by the convergence of the Gulf Stream with the coast near Cape Hatteras, which leaves very little opening for the leakage of shelf/slope waters from the Mid-Atlantic Bight into the South Atlantic Bight. Subarctic influences can reach the Mid-Atlantic Bight of the NE Shelf LME but not the South Atlantic Bight of the SE Shelf LME (Greene and Pershing, 2007). Additionally the Gulf Stream, deflected offshore past Cape Hatteras, indirectly impacts the Northeast U.S. Shelf by warm-core rings, whereas the Southeast U.S. Continental Shelf is directly affected by the meanders of the Gulf Stream.

A cold spell in the 1960s resulted in a 2°C SST drop down to 10.5°C by 1965; the recovery took four years. From 1969 on, the Northeast U.S. Continental Shelf experienced a gradual warming with substantial interannual variability. The linear trend for 1957-2006 yields a warming of 1.08°C, whereas the linear trend for 1982-2006 yields a much smaller warming of 0.23°C.

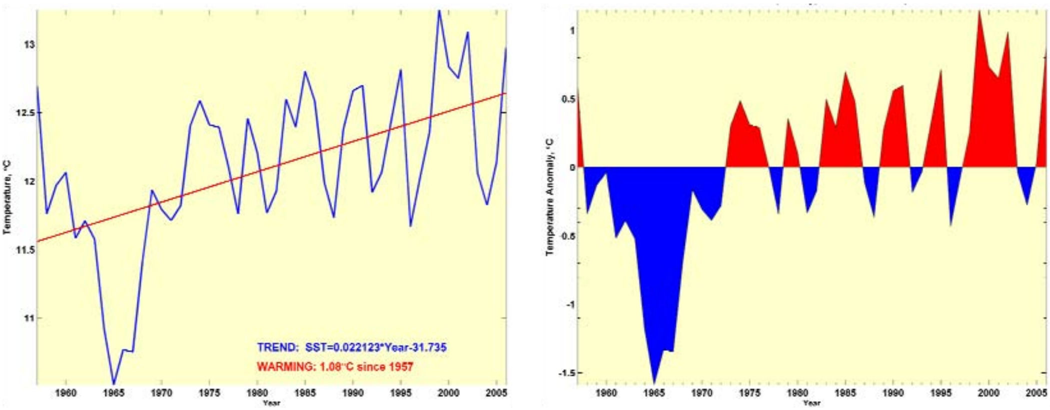


Figure XIX-61.2. Northeast U.S. Continental Shelf annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Northeast Shelf LME Chlorophyll and Primary Productivity

The Northeast U.S. Continental Shelf LME is a Class I, highly productive ecosystem (>300 $gCm^{-2}yr^{-1}$)(Figure XIX-61.3),

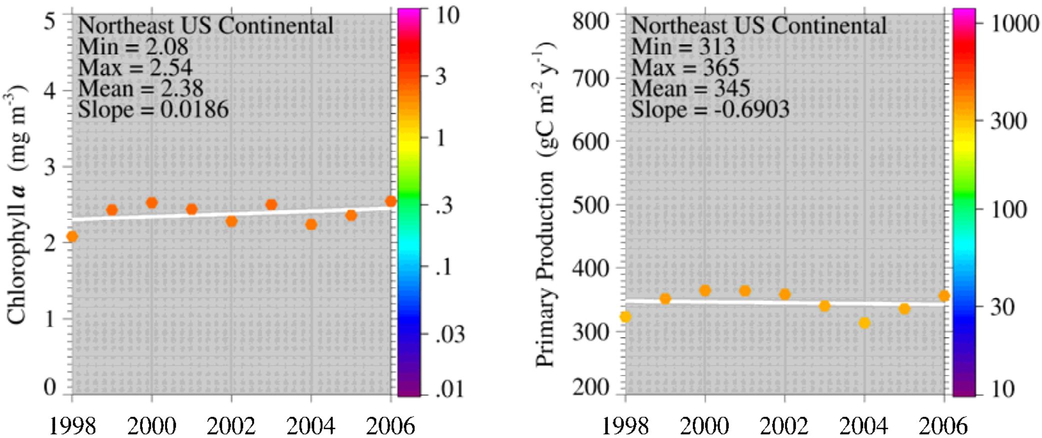


Figure XIX-61.3. Northeast U.S. Continental Shelf LME trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006, from satellite ocean colour imagery. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Much has been published on Northeast U.S. Shelf LME fisheries, including population assessments (Sherman *et al.* 1996c; Kenney *et al.* 1996; Mavor & Bisagni 2001) and the status of living marine resources in Our Living Oceans (NOAA 1999) and in the NEFSC Status of Stocks reports. The catch composition of this LME is diverse, and is comprised of demersal fish (groundfish) dominated by Atlantic cod, haddock, hakes, pollock, flounders, monkfish, dogfish, skates and black sea bass, pelagic fish (mackerel, herring, bluefish and butterfish), anadromous species (herrings, shad, striped bass and salmon), and invertebrates (lobster, sea scallops, surfclams, quahogs, northern shrimp, squid and red crab). In the late 1960s and early 1970s there was intense foreign fishing within the

LME. The precipitous decline in biomass of fish stocks during this period was the result of excessive fishing mortality (Murawski *et al.* 1999). Total reported landings declined from more than 1.6 million tonnes in 1973 to less than 500,000 tonnes in 1999, before increasing to just under 800,000 tonnes in 2004 (Figure XIX-61.4). The value of the reported landings reached US$1.8 billion (in 2000 US dollars) in 1973 and in 1979, and has maintained a level above US$1 billion except for the three-year period between1998 and 2000 (Figure XIX-61.5). Among the most valuable species are lobster, sea scallops, monkfish and summer flounder.

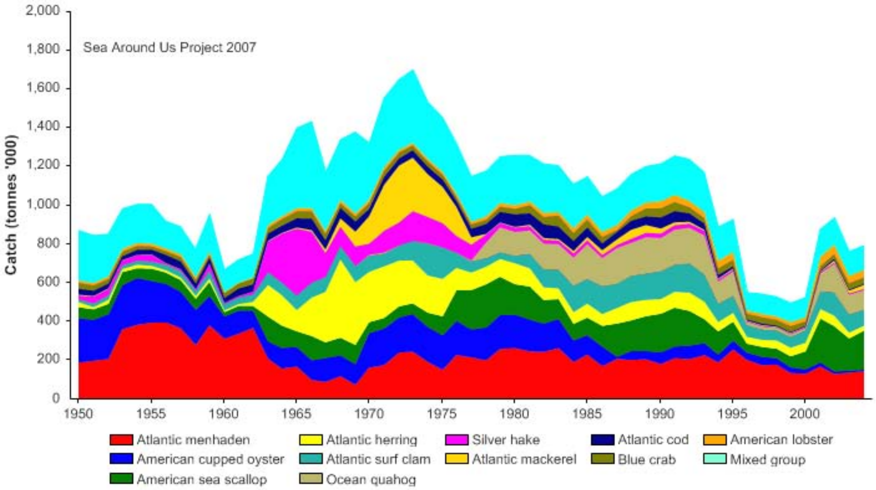


Figure XIX-61.4. Total reported landings in the Northeast U.S. Continental Shelf LME by species (Sea Around Us 2007).

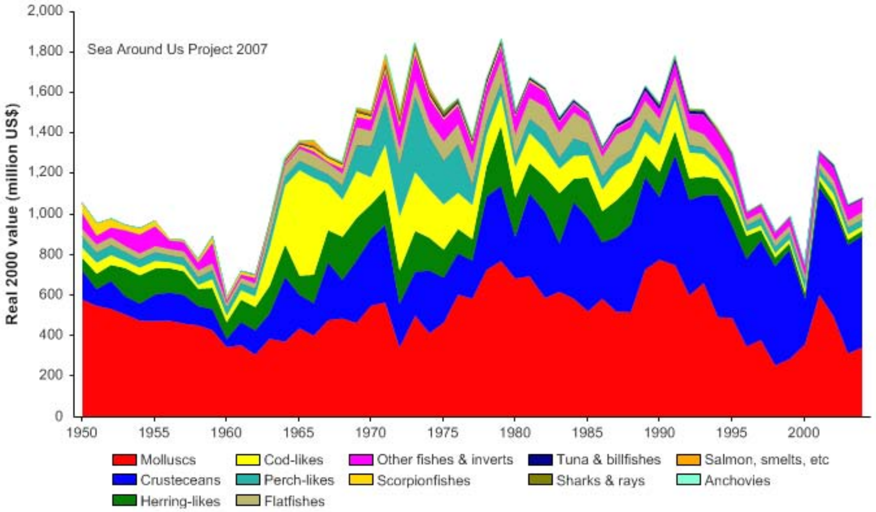


Figure XIX-61.5. Value of reported landings in the Northeast U.S. Continental Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR) (Pauly & Christensen 1995) to sustain the reported landings in the LME reached 90% of the observed primary production in the mid 1960s, but has declined to less than 20% in recent years (Figure XIX-61.6). The extremely high PPR recorded in the 1960s and 1970s was likely due to the exploitation of the accumulated biomass of cod stocks rather than from the exploitation of annual surplus production in the LME. The USA accounts for most of the ecological footprint in this LME, and Canada for some, although European countries also had a major share in the 1960s and 1970s.

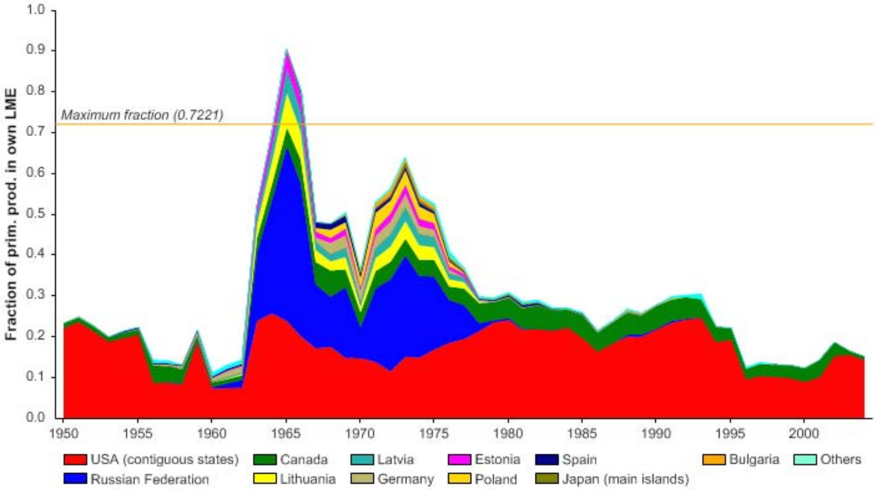


Figure XIX-61.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Northeast U.S. Continental Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (Pauly & Watson 2005) has declined since the early 1960s, when the rate of exploitation of demersal fish in the LME was high (Figure XIX-61.7, top), the consequence of a clear case of 'fishing down' of the food web (Pauly *et al.* 1998). The Fishing in Balance index showed a similar decline (Figure XIX-61.7, bottom), implying that the increase in reported landings in the 1970s did not compensate for the decline in the Marine Trophic Index over that period.

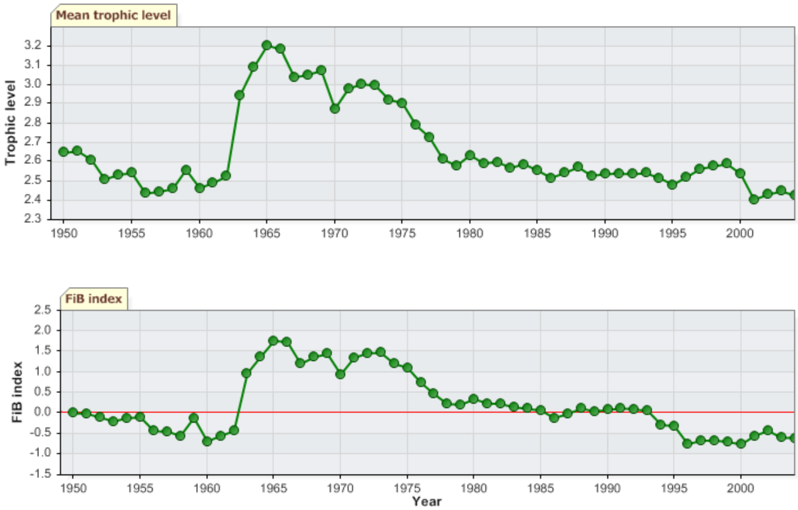
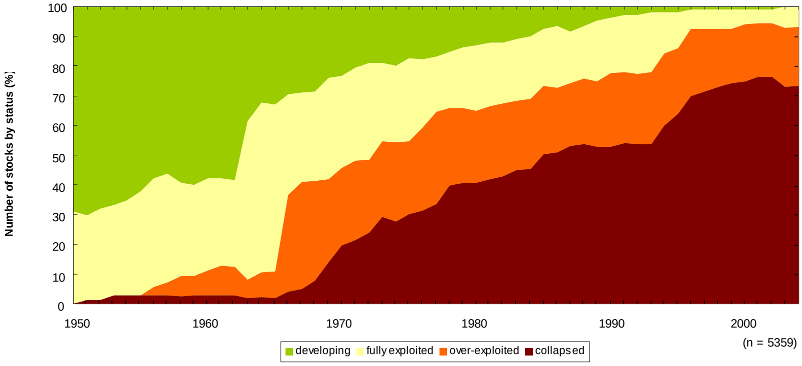


Figure XIX-61.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Northeast U.S. Continental Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots show that over 70% of commercially exploited stocks in the LME have collapsed, with another 20% being overexploited (Figure XIX-61.8, top). Slightly over 30% of the reported landings biomass is supplied by fully exploited stocks (Figure XIX-61.8, bottom). The US National Marine Fisheries Service (NMFS) includes “overfished” but not “collapsed” in its stock status categories. Currently overfished are several demersal stocks (NMFS 2009).



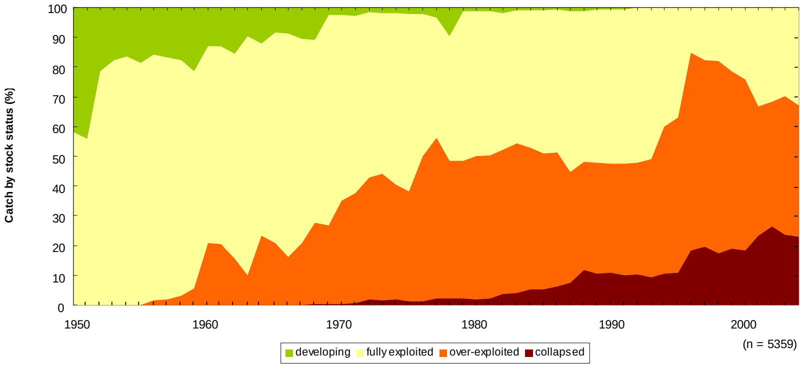


Figure XIX-61.8. Stock-Catch Status Plots for the Northeast U.S. Continental Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of ‘stocks’, i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

The status of demersal fisheries can be found in Our Living Oceans (NMFS 1999; 2009), Anderson et al. (1999a and 1999b), EPA 2004 and NMFS 2009. The Northeast Shelf groundfish complex supports important recreational fisheries as well (summer flounder, Atlantic cod, winter flounder, and pollock). Many demersal stocks are considered overfished and are currently rebuilding. Groundfish partially recovered because of reduced fishing effort and restrictive management in the late 1970s. The recovery trend of George’s Bank yellowtail and haddock observed in the late 1990s is linked to reductions in the exploitation rate when, in 1994, there was an emergency closure of portions of Georges Bank, and severe restrictions were placed on the fishing of demersal species by the New England Fishery Management Council Sherman et al 2003). The measures to reduce fishing effort included the reductions of days at sea and a moratorium on new vessel entrants (NMFS 1999). Landings of most groundfish species, however, were low in the mid 1990s as a result of poor recruitment and continued restrictions on effort. In a biomass flip, dogfish and skates increased in abundance in the 1970s, as groundfish and flounder declined. However, a decrease of dogfish and skates has been observed more recently, after a peak in the 1990s (NMFS 1999; Anthony 1996). Some of the Northeast Shelf LME's demersal stocks are among the best understood and assessed fishery resources in the US (EPA 2004, NMFS 2009). Abundance of pelagic mackerel, herring and bluefish has increased since the late 1970s and is presently above average. The virtual elimination of foreign fishing on Atlantic herring and mackerel stocks has resulted in the recovery of both species to former abundance levels, as neither species is a high priority table fish for the U.S. consumer. The herring stock is somewhat underutilized. Northeast pelagics are an important link in many marine food chains as they are utilized as prey by a variety of predatory fish, marine mammals and birds. Some anadromous species (shortnose sturgeon, Atlantic salmon) are listed as endangered and landings are generally low for Atlantic anadromous fisheries but for the recently observed increase in landings of striped bass following several years of management restrictions (NMFS 2009). The alteration of river migration routes blocking access to historic spawning grounds, pollution and coastal development have played a major role in the decline of Atlantic salmon, sturgeon, river herring, and shad. The only remaining Atlantic salmon populations occur in 8 small rivers in eastern Maine. In the face of declining natural populations, a small salmon aquaculture industry in Maine has grown to fill the production void and averages approximately 10,000 t annually. Invertebrate fisheries (American lobster, sea scallops) are the most valuable in the Northeast Shelf. The lobster fishery has become increasingly dependent on small and young lobsters that reach a legal size just prior to capture. There are efforts to reduce the currently high fishing mortality on lobsters. Both the closure of half of the U.S. portion of Georges Bank to scallop harvesting to protect groundfish stocks and the increase in the ring diameter of scallop dredges in 1994 contributed to an increase in sea scallop stock biomass (Anderson *et al.* 1999). A system of rotational closures for sea scallop management is in place to allow small scallops to grow to a larger size. Landings are presently at high levels.

The long-term potential yield for this LME was set at about 1.6 million tonnes (NMFS 1999). The long-term sustainability of high economic yield species depends on the rebuilding of fish stocks through the application of adaptive management strategies (Murawski 1996). Agencies involved in the complex management of Northeast fisheries include the New England Fishery Management Council, the Mid-Atlantic Fishery Management Council, the Atlantic States Marine Fisheries Commission, individual states, and Canada. Information on fishery management plans is available in Our Living Oceans (NMFS 1999; NMFS 2009). The NEFSC compiles information on the distribution, abundance and habitat requirements for the 38 commercially valuable species managed by the New England and Mid-Atlantic Fishery Management Councils (NMFS 1999).

III. Pollution and Ecosystem Health

The Northeast Coast is the most densely populated coastal region in the United States. The ratio of watershed drainage areas to estuary water areas is relatively small (EPA 2004). Hypotheses concerned with the growing impacts of pollution, overexploitation and environmental changes on sustained biomass yields in the Northeast Shelf LME are under investigation. Efforts to examine changing ecosystem states and the relative health of this LME are underway in the four sub-areas of the Northeast Shelf ecosystem. Major rivers systems (Hudson, Delaware, Chesapeake) contribute nitrates to estuaries and coastal systems from agriculture fertilisation, atmospheric deposition and sewage. The estuaries and near-coastal waters of the LME are under considerable stress from increasing coastal eutrophication resulting from high levels of phosphate and nitrate discharges into drainage basins (Jaworski & Howarth 1996). Whether the increases in the frequency and extent of nearshore plankton blooms are responsible for the rise in incidence of biotoxin-related shellfish closures (White & Robertson 1996) and marine mammal mortalities remains a question of considerable concern to state and federal management agencies. For this LME as a whole, water clarity is good, dissolved oxygen and coastal wetlands are fair, while the increasing extent of eutrophication is cause for concern). The water quality index is fair to poor (EPA 2004). About 60% of estuarine areas have a high potential of increasing eutrophication or existing high concentrations of chlorophyll-*a*. High levels of sediment contamination are found near urban centres, reflecting current discharges and the legacy of past industrial practices (EPA 2004). Over 25% of sediments exceed the EPA guidelines for contaminants. Nearly 40% of wetlands along the coast were eliminated between 1780 and 1980. About 10% of fish sampled by EPA have elevated levels of contaminants in their edible tissues (EPA 2001). Benthic community degradation, fish tissue contamination and eutrophication are increasing. Coastal contamination is especially high along the urbanised and densely populated areas along the northern part of the coast and in poorly flushed waters. Flux levels of zinc, cadmium, copper, lead and nickel are highest in the southern New England region, reflecting the level of urbanisation and industrialisation (O'Connor 1996). Heavy metal concentrations in demersal fish, crustaceans and bivalve molluscs are monitored as biological indicators (Schwartz *et al.* 1996). The Virginia Oyster Heritage Program highlights the critical role oysters play in keeping coastal waters clean and providing habitat for other marine life (EPA 2004). Of the 826 beaches in the Northeast Coast that reported information to the EPA, 18% were closed or under advisory for a period of time in 2002 due to elevated bacteria levels, rainfall events or sewage related problems (EPA 2004).

IV. Socioeconomic Conditions

The population of the coastal counties of the northeast coast, from northern Maine to the tidewaters of Virginia, is estimated at 54.3 million people for 2008, representing 78% of the total population of all the Northeast coastal states (NOAA 2005). Four of the nation's largest metropolitan areas, New York, Washington DC/Baltimore, Philadelphia and Boston, are located along the coast of this region. On average, 13 to 23 percent increases in coastal population were expected in Maryland and Virginia between 2003 and 2006. The economic centres in the region include New York City, the largest financial market in the world. Northeast economic activities include agriculture, resource extraction (forestry, fisheries, and mining), major service industries highly dependent on communication and travel, recreation and tourism, manufacturing and transportation of industrial goods and materials (USGCRP 2004).

In 2006, the Northeast Shelf ecosystem supported over 1,100 active fishing vessels in both federal (3-200 miles) and state waters. These vessels produced fish and shellfish (and other invertebrates) landings worth over US$1.2 billion. In the late 1960s and early 1970s, the intense involvement of foreign fishing fleets and overfishing led to marked declines in fish abundance (Sherman & Busch 1995). Analyses of catch per unit effort and fishery independent bottom trawling survey data were critical sources of information used to implicate overfishing as the cause of the shifts in abundance. Northeast fishermen were adversely affected by the collapse of the groundfish fishery in the late 1980s. A groundfish vessel buyout program (1995-1998) was designed to provide economic assistance to fishermen who voluntarily chose to remove their vessels permanently from the fishery. This resulted in a 20% reduction in fishing effort (NOAA 1999). The fishing culture is traditional in the region and fishermen have struggled to remain solvent and engaged in the fishing industry in the face of mandated declines in fishing effort as part of a groundfish stock rebuilding program. Fishing effort reductions led to curtailed revenues for fishermen (NMFS 1999, Hennessey & Sutinen 2005; Heinz 2000)). The reduction in fishing effort since 1994 has resulted in an initial recovery of several demersal fisheries, including stocks of sea scallops, haddock and Georges Bank yellowtail flounder. The Northeast has a low rate of projected future warming compared to other regions of the U.S. The U.S. Global Change Research Program report on the potential consequences of climate variability and change in the Northeast (USGCRP 2004) has projected increasing trends in precipitation of as much as 25% by 2100 with increased flooding from storms, rising sea levels, and coastal land loss. At risk are transportation, communication, energy, water sources and waste disposal systems, particularly in major Northeast cities presently characterized by insufficient capacity and deferred maintenance. Sea level rise in the Northeast coastal zone will also exacerbate stresses to estuaries, bays and wetlands from increasing pollutants, temperature and salinity and the inundation by sea water of wetlands and marshes.

V. Governance

The Northeast Shelf includes the coastal waters of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland and Virginia. Governance in this LME is shared among several stewardship agencies and there is a complex layering of management agencies. The 1976 Magnuson Fishing Management Act established the U.S. 200-mile EEZ, which led to reduction of fishing effort on herring and mackerel stocks and the recovery of their biomass. But the Act's single species focus neglected predator-prey relationships and other interactions. This focus has often resulted in conflicting goals and bycatch mortality (Murawski 1996). A Council system for fisheries management in the region was introduced in 1976 where co-managing stakeholders are responsible for developing regulations which are enforced by the National Marine Fisheries Service. Civil societies participating in this process include fishing groups and environmental organizations. The New England and mid-Atlantic Fishery Management Councils (Federal Fisheries) and the Atlantic States Marine Fisheries Commission (State water fisheries) regulate the region's fisheries through over 35 fishery management plans (FMPs). Regulatory measures since 1994 have been aimed at a managed recovery of depleted fish stocks through reductions in days at sea, increased minimum mesh sizes, expanded closed areas, trip limits, and now limited access privileges including individual transferable quotas (ITQs). Together with decentralized co-management, these measures have led to good recruitment and recovery of the spawning biomass of sea scallops and haddock stocks. One issue is the management of transboundary stocks of Atlantic cod, haddock, yellowtail flounder and pollock in Canadian waters on Georges Bank and in the Gulf of Maine. Another is the management of transboundary stocks and jurisdiction over Atlantic anadromous fisheries, along with Canada and West Greenland (NMFS 2009). Conservation tools are implemented through the North Atlantic Salmon Conservation Organization (NASCO). In terms of pollution and ecosystem health, the Chesapeake Bay Programme's partnership with the bordering states has set specific targets for improving the water quality of the Bay (EPA 2001). Wetlands protection regulations have reduced the loss of wetlands. Coordinated programmes with participation from states, academic institutions, the private sector and federal government are underway to improve monitoring strategies aimed at mitigating habitat loss, coastal pollution, eutrophication and fisheries overexploitation.

References

Anderson, E.D., Cadrin, S.X., Hendrickson, L.C., Idoine, J.S., Lai, H-L. and Weinberg, J.R. (1999). Northeast invertebrate fisheries, p 109-115 in: Our Living Oceans: Report on the Status of U.S. Living Marine Resource. U.S. Department of Commerce, Washington D.C., U.S.

Anderson, E.D., K.D. Friedland, and W.J. Overholtz. (1999a). Northeast pelagic fisheries, p 99-102 in: Our Living Oceans: Report on the Status of U.S. Living Marine Resources. U.S. Department of Commerce, Washington D.C., U.S.

Anderson, E.D., Mayo, R.K., Sosebee, K., Terceiro, M., and Wigley, S.E. (1999b). Northeast demersal fisheries, p 89-97 in: Our Living Oceans: Report on the Status of U.S. Living Marine Resources. U.S. Department of Commerce, Washington D.C., U.S.

Anthony, V.C. (1996). The state of groundfish resources off the northeastern U.S, pp. 153-167 in: Sherman, K., Jaworski, N.A. and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems. Progress in Oceanography, in press.

Belkin, I., Cornillon, P.C., and Sherman, K. (2009). Fronts in Large Marine Ecosystems. Progress in Oceanography, in press.

Brooks, D.A. (1996). Physical oceanography of the shelf and slope seas from Cape Hatteras to Georges Bank: A brief overview, p 47-74 in: Sherman, K., Jaworski, N.A. and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

Durbin, E.G. and Durbin, A.G. (1996). Zooplankton dynamics in the Northeast Shelf Ecosystem, p 129-152 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

EPA (2001). National Coastal Condition Report. www.epa.gov/owow/oceans/nccr/chapters/

EPA (2004). National Coastal Condition Report II. www.epa.gov/owow/oceans/nccr2/

Falkowski, P.G. (1991). A carbon budget for the Northeast Continental Shelf Ecosystem: Results of the shelf edge exchange process studies, pp 35-48 in: Sherman, K., Alexander, L.M. and Gold, B.D. (eds), Food Chains, Yields, Models, and Management of Large Marine Ecosystems, Westview Press, Boulder, CO, U.S.

Greene, CH and Pershing A. (2007). Climate drives sea change. Science 315:1084-1085.

Heinz, H. John III Center for Science, Economics and the Environment (2000). Fishing Grounds: Defining a New Era for American Fisheries Management. Island Press. Washington D.C., U.S.

Hennessey, T.M. and Sutinen, J.G., eds. (2005). Sustaining Large Marine Ecosystems: The Human Dimension. Elsevier Science, Amsterdam, The Netherlands.

Jaworski, N.A. and Howarth, R. (1996). Preliminary estimates of the pollutant loads and fluxes into the Northeast Shelf Ecosystem, p 351-357 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

Kenney, R.D., Payne, P.M., Heinemann, D.W. and Winn, H.E. (1996). Shifts in Northeast Shelf cetacean distributions relative to trends in Gulf of Maine/Georges Bank Finfish Abundance, p 169-196 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

Link, J., Overholtz, W., O'Reilly, John, 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

Mavor, T.P. and Bisagni, J.J. (2001). Seasonal variability of sea-surface temperature fronts on Georges Bank. Deep-Sea Research II 48(1-3):215-243.

Murawski, S.A. (1996). Can we manage our multispecies fisheries? p 491-510 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.

Murawski, S.A. (2000). Definitions of overfishing from an ecosystem perspective. ICES Journal of Marine Science 57(3):649-658

Murawski, S.A. et al (1999). New England Groundfish. Our Living Oceans: Report on the Status of U.S. Living Marine Resources, 1999. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-41. Washington, DC.

NMFS. (2009). Our Living Oceans. Draft report on the status of U.S. living marine resources, 6th edition. U.S. Dep. Commer. Washington DC, NOAA Tech. Memo. NMFS-F/SPO-80. 353 p.

NMFS (1999). Our Living Oceans - Report on the Status of U.S. Living Marine Resources. U.S. Department of Commerce, Washington D.C., U.S. NOAA Tech. Memo. NMFS-F/SPO-41. 301p.

NOAA (2005) Population Trends Along the Coastal United States: 1980-2008. Report issued March 1 2005. Appendix C, Northeast. Online at http://oceanservice.noaa.gov/programs/mb/supp_cstl_population.html.

O'Connor, T.P. (1996). Coastal sediment contamination in the Northeast Shelf Large Marine Ecosystem, p 239-257 in: Sherman, K., Jaworski, N.A. and Smayda, T.J. (eds), The Northeast

Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.
Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. Nature 374: 255-257.
Pauly, D. and Watson, R. (2005). Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.
Pauly, D., Christensen, V., Dalsgaard, J., Froese R. and Torres, F.C. Jr. (1998). Fishing down marine food webs. Science 279: 860-863.
Schmitz, W.S. and McCartney, M.S. (1993). On the North Atlantic circulation. Reviews of Geophysics 31:29-49.
Schwartz, J.P., Duston, N.M. and Batdorf, C.A. (1996). Metal concentrations in winter flounder, American lobster, and bivalve molluscs from Boston Harbour, Salem Harbour and Coastal Massachusetts: A summary of data on tissues collected from 1986 to 1991, p 285-312 in: Sherman, K., Jaworski, N.A. and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.
Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=6
Sherman, K., Grosslein, M, Mountain, D., O'Reilly, J. and Theroux, R. (1988). The continental shelf ecosystem off the northeast coast of the U.S., p 279-337 in: Postma, H. and Zijlstra, J.J. (eds), Ecosystems of the World 27: Continental Shelves. Elsevier, Amsterdam, The Netherlands.
Sherman, K. and Busch, D.A. (1995). Assessment and monitoring of large marine ecosystems, p 385-440 in: Rapport, D.J, Guadet, C.L. and Calow, P. (eds), Evaluating and Monitoring the Health of Large-scale Ecosystems. Springer-Verlag, Berlin. (Published in cooperation with NATO Scientific Affairs Division). NATO Advanced Science Institutes Series. Series 1: Global Environmental Change, Vol. 28.
Sherman, K., Green, J., Solow, A., Murawski, S.A., Kane, J., Jossi, J. and Smith, W. (1996b). Zooplankton prey field variability during collapse and recovery of pelagic fish in the Northeast Shelf Ecosystem, p 217-236 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability, and Management. Blackwell Science, Cambridge, U.S.
Sherman, K., Jaworski, N.A., Smayda, T.J., eds. (1996c). The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S. 564 pages.
Sherman, K., Kane, J., Murawski, S., Overholtz, W. and Solow, A. (2002). The U.S. Northeast Shelf Large Marine Ecosystem: Zooplankton trends in fish biomass recovery, p 195-215 in: Sherman, K. and Skjoldal, H.R. (eds), Large Marine Ecosystems of the North Atlantic: Changing States and Sustainability. Elsevier Science, New York, U.S.
Sherman, K., O'Reilly, J. and Kane, J. (2003). Assessment and sustainability of the U.S. Northeast Shelf Ecosystem, p 93-120 in: Sherman, K. and Hempel, G. (eds), Large Marine Ecosystems of the World – Trends in Exploitation, Protection and Research. Elsevier, Amsterdam, The Netherlands.
Sherman, K., O'Reilly, J., and Kane, J. (2003). Assessment and sustainability of the U.S. Northeast Shelf Ecosystem. In: Hempel, G. and Sherman K., eds. Large Marine Ecosystems of the World: Trends in exploitation, protection, and research. Elsevier, Amsterdam, The Netherlands.
Sissenwine, M. and Cohen, E. (1991). Resource productivity and fisheries management of the Northeast Shelf Ecosystem, p 105-121 in: Sherman, K., Alexander, L.M. and Gold, B.D. (eds), Food Chains, Yields, Models and Management of Large Marine Ecosystems. Westview Press, Boulder, U.S.
Ullman, D.S. and Cornillon, P.C. (1999). Surface temperature fronts off the East Coast of North America from AVHRR imagery. Journal of Geophysical Research 104(C10):23,459-23,478.
USGCRP (US Global Change Research Program) (2004). Climate change Impacts on the United States: The Potential Consequences of Climate Variability and change, Overview: Northeast. US National Assessment of Climate Change. Online at www.usgcrp.gov/usgcrp /Library/national assessment/overview
White, H.H. and Robertson, A. (1996). Biological responses to toxic contaminants in the Northeast Shelf . Large Marine Ecosystem, p 259-283 in: Sherman, K., Jaworski, N.A.and Smayda, T.J. (eds), The Northeast Shelf Ecosystem: Assessment, Sustainability and Management. Blackwell Science, Cambridge, U.S.