DRAFT

Coastal Pollution and New England Fisheries

Prepared for the NEFMC by

Christopher R. Meaney
and Chad Demarest

January 5, 2006

Acronyms

CCMA	Center for Coastal Monitoring and Assessment (National Oceanic and Atmospheric Administration)
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
CERLA	Comprehensive Environmental Response, Compensation and Liability Act
CRC	Coastal Resource Coordination program (National Oceanic and Atmospheric Administration)
CSO	combined sewer overflow
CSS	combined sewer system
CWSR	coastal waste site reports
DAC	Damage Assessment Center (National Oceanic and Atmospheric Administration)
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DEP	Department of Environmental Protection
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorus
DO	dissolved oxygen
DPW	Department of Public Works
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
ER	effects range level
ERL	effects range-low value
ERM	effects range-medium value
GIS	geographic information system
GOMCME	Gulf of Maine Council on the Marine Environment
GoMOOS	Gulf of Maine Ocean Observing System
LIS	Long Island Sound
LISS	Long Island Sound Study
MDC	metropolitan district
MWRA	Massachusetts Water Regional Authority
NCA	National Coastal Assessment (U.S. Environmental Protection Agency)
NCBC	National Construction Battalion Center
NCCRII	National Coastal Condition Report II (U.S. Environmental Protection Agency)
NEERS	National Estuarine Research Reserve System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System Permitting Program
NPL	National Priority List
NS&T	National Status and Trends Program (National Oceanic and Atmospheric Administration)
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
SAV	submerged aquatic vegetation
SSO	sewer system overflow
TMDL	total maximum daily load

TOC	total organic carbon
USCOP	United State Commission on Oceans Policy
USGS	U.S. Geological Survey
UV	ultraviolet
VOC	volatile organic compounds
WPCF	water pollution control facilities
WSS	winter stress syndrome
WWTF	waste water treatment facilities
WWTP	waste water treatment plant

1.0 Introduction

Recent efforts in the marine policy arena have increasingly encouraged the incorporation of ecosystem approaches into marine natural resource management efforts (USCOP 2004, Pew Oceans Commission 2003). The United States Commission on Ocean Policy indicated that "U.S. ocean and coastal resources should be managed to reflect the relationships among all ecosystem components, including humans and nonhuman species and the environments in which they live." (USCOP 2004) In order to incorporate such approaches, it may be necessary to further our understanding of ecosystem services, taking into account both ecological processes and anthropogenic influences.

Garcia and Cochrane (2005) indicate that anthropogenic impacts on fisheries other than those directly impacting fish stocks (i.e., wild capture) originate mostly from terrestrial activities in the coastal area. The introduction of materials such as fertilizers, pesticides, heavy metals and persistent organic pollutants are cited as having the greatest influence (2005). Enhancing our knowledge and understanding of coastal pollution will complement fisheries science and assist fisheries mangers in their attempts to incorporate an ecosystem-wide view of fisheries management.

The definition of pollution adhered to throughout this report is the one provide by the Oxford English Dictionary, Second Edition: The presence in the environment, or the introduction into it, of products of human activity which have harmful or objectionable effects (1989). The scope of this report addresses toxic pollution as well as nutrient pollution, however is should be noted that other types of pollution such as biological pollution may be of concern.

This report furnishes information on the relationship between coastal pollution and New England fisheries in two interrelated sections. The first provides an overview of coastal pollution in New England, detailing specific pollution sites along our coast. Because it is important to identify the effects of pollutants on fish at both the individual and community levels, as well as their surrounding habitats, it may be informative to examine the areas potentially acting as sources of contaminant importation. Site specific areas are identified in this section, and lists of state databases are included in order to facilitate future efforts constructing a comprehensive coastal pollution site inventory. Such an inventory may be important as managers and scientists attempt to move towards ecosystem approaches to marine resource management.

The second section presents impacts of pollution on marine fish and fish populations. It is an attempt to shed light on the documented relationships, or in many cases the lack thereof, between coastal pollution and marine fishery productivity. These links are frequently weak, and it is this lack of established causal relationship that necessitates occasionally broadening our search for relevant information in order to enhance our understanding of the issue. That is to say, we will attempt only to lay out the facts as they are found in the literature, in the hopes that further efforts in this field may fill in the many gaps between coastal pollution and the effect on marine fishery productivity.

The information presented in this report is not comprehensive. Due to the enormous scale of the issues involved, the information available is vast and deeply layered. This report simply attempts to provide a survey of pertinent information, presenting disparate data in a format intended to clarify the linkages and highlight data gaps. We hope this serves as a resource for all interested stakeholders who wish to understand more clearly the complexity of the relationship between coastal pollution and fisheries productivity in New England.

2.0 Coastal Pollution in New England

The purpose of this section is to highlight the specific areas that may be introducing pollutants into the marine environment. There are various levels of detail associated with identifying polluted coastal sites in New England of interest to fisheries managers. The scale of the issue is immense. Information is presented first at a broad regional level and then on a smaller, more localized scale.

At a regional level, this report will focus on sediment contamination and poor water quality. Bodies of water with high sediment contamination are listed in Table 2-A, and estuaries that suffer from poor water quality are contained in Table 2-B. Note that poor water quality is frequently associated with high eutrophic conditions, and it is these conditions we will discuss most often in this report.[1]

At the more local level, National Priority List (NPL) sites and New England cities with permits for Combined Sewer Systems (CSS) are presented as areas that contribute to coastal pollution. Finally, with the highest level of available resolution, we will highlight and discuss intra-state pollution sites.

Website links to databases are provided in this section in the hope of facilitating more comprehensive efforts in listing coastal pollution sites in the future.

2.1. Regional Perspective

The EPA has concluded that Massachusetts Bay, Long Island Sound, and the Atlantic Ocean have the highest level of contaminated sediments (EPA 2004b). Estuaries demonstrating poor water quality (a high eutrophic condition) caused by natural environmental processes as well as anthropogenic nutrient pollution are suspected of altering marine communities and adversely affecting fish reproduction. New England Estuaries with high eutrophic conditions are Boston Harbor, Long Island Sound, and the St. Croix River/Cobscook Bay, Me. (Bricker et al. 1999).

State environmental agencies and associated water pollution and toxic contaminant departments have created databases listing properties violating state or federal pollution regulations. The corresponding section provides websites where this information is available along with sources that provide geographic information system (GIS) data. Thorough investigation and analysis of this information will undoubtedly add to our understanding of the impacts on marine fishery productivity by coastal pollution sites.

---

[1] Eutrophication is the increase in the supply of organic matter to an ecosystem, a process that may occur naturally but often occurs as a result of nutrient overenrichment (Pew Oceans Commission 2003 and NAS 2000). Eutrophication will be discussed further in section 3.

Contaminated Waterbodies

The Environmental Protection Agency's 2004 National Sediment Quality Survey provides a broad view of New England coastal pollution sites. Sediment is frequently the focus of monitoring and is used in as an indicator of debilitated marine habitats.

The Survey depicts and characterizes the incidence and severity of sediment contamination and the probable affects to human and environmental health. Sampling followed a number of different measurement parameters and techniques to assess the probability of adverse effects. Two examples of the techniques used by the EPA were the measurement of toxicity based on acute or chronic solid phase sediment toxicity data, and estimation of the predicted proportion toxic from sediment chemistry using a logistic regression model. Site sampling stations are associated with their "probability of adverse effects" and are separated into different categories. For example, a Tier One sampling station is one where associated adverse effects on aquatic life or human health are probable, and Tier 2 sampling site's adverse effects are possible (USEPA 2004b).

The following nine watershed units were identified as containing areas of probable concern for sediment contamination: Lower Connecticut, Charles, Narragansett, Quinnipiac, Housatonic, Saugatouk, Long Island Sound, Hudson-Hoosic, and Southern Long Island. (EPA 2004b). The Sediment Quality Survey indicates that Massachusetts Bay and Long Island Sound appear to have the greatest amount of sediment contamination based on the number of Tier 1 sampling stations. Table 2-A depicts six waterbodies with the highest number of Tier One stations, and according to the EPA appear to have the greatest amount of sediment contamination (USEPA 2004b).

Body of Water	Number of Tier 1 Stations
Massachusetts Bay	24
Long Island Sound	15
Atlantic Ocean	13
Connecticut River	11
Housatonic River	11
Quinnipiac River	5

Table 2-A Waterbodies with the greatest amount of sediment contamination (from: EPA National Sediment Quality Survey 2004)

Eutrophication and New England Estuaries

In 1999, NOAA published the "National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nations Estuaries." The report presents the results of the National Assessment Workshop addressing the severity and extent of estuarine eutrophication for the first time on a national scale (Bricker et al. 1999).

The report provides a region-wide list of the status of estuaries. Locations north of Cape Cod are in the North Atlantic region and estuaries located from Cape Cod south to Virginia are considered part of the Middle Atlantic. More than half of the North Atlantic estuaries have moderate to high eutrophic conditions (Bricker et al. 1999).

Seven estuaries exhibit high eutrophic conditions (Table 2-B). Of those seven, Boston Harbor and Long Island Sound are the most heavily impacted by human activities. Narragansett Bay, given a moderate eutrophication ranking by NOAA, is believed to also be highly influenced by human factors (Bricker et al. 1999).

Area
St. Croix River/Cobscook Bay, Me
Englishman Bay, ME
Narraguagus Bay, ME
Sheepscot Bay, ME
Casco Bay, ME
Boston Harbor, MA
Long Island Sound, CT

Table 2-B New England Estuaries with poor water quality due to high eutrophic conditions (Bricker et al. 1999)

Many of the estuaries are expected to worsen, and future nutrient inputs are likely to negatively affect the naturally occurring conditions in the North Atlantic. Boston Harbor is the exception, though, and is expected to improve marginally over time (Bricker et al. 1999). It will be important for fisheries managers and scientists to pay careful attention to these areas, noting how these conditions affect marine species.

2.2. State Perspective

Identifying specific coastal pollution sites within each state provides a focal point that will be beneficial to fishery managers wishing to link fish presence/absence with these areas. Utilizing the EPA National Priorities List/Superfund designations, pollution sites within the five coastal states are listed. Descriptions of past polluting activities and the associated contaminants, as well as any potentially affected marine species, are provided. New Bedford Harbor and the Acushnet River in Massachusetts, as well as the Portsmouth Naval Shipyard in Maine, are examples of sites that are contaminated with substances such as PCBs and heavy metals, and pose threats to species such as Atlantic herring, Atlantic cod, and flounder (http://response.restoration.noaa.gov).

Combined Sewer Systems (CSS), common within Northeast states, are responsible for untreated effluent containing human and industrial waste, toxic contaminants, heavy metals and nutrients reaching the coastal zone. Providing visual representation of this information, and making it readily available to interested parties, may enhance our understanding of where sources of coastal pollution originate.

Following the description of CCS, Total Maximum Daily Loads (TMDLs) are discussed. TMDLs are the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Many waterbodies exceed these levels and are listed as impaired by state and federal regulators. This information may be useful to managers wishing to identifying sources of pollution and contaminants and associated concentrations that enter coastal marine systems. TMDLs and lists of impaired waters are not included in the report due to their length and level of detail, however websites containing these lists and corresponding GIS data layers are provided. This information is valuable to future efforts quantifying inputs into coastal marine ecosystems.

Coastal National Priority List Sites

A handful of federally listed hazardous waste sites line New England's coast. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) 1980 (commonly known as Superfund) authorizes the EPA to identify, remove and remediate hazardous waste sites. At its core are strict liability provisions and a process that includes site assessment, hazard ranking, and among other steps the addition of a site to the National Priorities List (NPL) signifying an area a hazardous waste site (Percival et al. 2004).

Coastal Waste Site Reports (CWSR), prepared by NOAA Coastal Protection and Restoration scientists, identify threats to NOAA trust resources (aquatic organisms and their habitat) (http://response.restoration.noaa.gov). Scientists, often working with EPA scientists, identify sites believed to affect natural resources, determine the potential for injury to the resources, evaluate cleanup alternatives, and carry out restoration activities. (http://response.restoration.noaa.gov).

Using information provided CWSR and from an EPA CERCLA database known as CERCLIS, a list of federally designated coastal hazardous waste sites is provided to assist in understanding past and present sources of hazardous coastal pollution that may affect marine fish.

NPL sites are located throughout New England; however given the scope of this report, only coastal sites with documented impacts on marine systems are included. In order to demonstrate the extent of past pollution and the potential impacts to local fish species, sites that have completed cleanup and remediation are included. A comprehensive listing of this material can also be found at http://response.restoration.noaa.gov and www.epa.gov/superfund/sites/cursites/.. When fully considering pollution inputs into the marine environment, it may be necessary to address sources not adjacent to the coast.

Connecticut

New London Naval Submarine Base, Groton CT

The New London Submarine Base is located on the eastern bank of the Thames River in Connecticut. The 576 acre site includes approximately 3 km of shoreline less than 4 km from Long Island Sound. The site was added to the final NPL in 1990. Soils sediments, groundwater, and surface water are contaminated with pesticides and heavy metals including cadmium, copper, DDT, and lead. The soil also contains VOCs, PCBs, and polycyclic aromatic hydrocarbons (PAHs). The lower Thames River is an important estuary habitat used by anadromous and marine species for spawning, as nursery grounds, and for adult forage. Species documented to utilize the area are sea run brown trout, American shad, hickory shad, alewife, and American shad. The section of river near the subase is used as spawning ground for winter flounder and as a seasonal nursery ground for bluefish and stripped bass.

Raymark Industries, Inc., Stratford CT

This site is located adjacent to the estuarine waters of the Housatonic River which flow into Long Island Sound. The primary contaminants of concern as identified by NOAA are trace elements, PCBs, dioxins, and PAHs such as anthracene, fluoranthene, dibenz(a,h)anthracene, as well as DDE. The Housatonic River and associated wetlands serve as habitat for numerous migratory and estuarine dependent fish and invertebrate species such as four species of flounder, butterfish, alewife, blueback herring and others. The 34 acre site has been capped and redevelopments have since taken place.

Rhode Island

Davisville Naval Construction Battalion Center (NCBC), North Kingston RI

Added to the NPL in 1989, materials such as battery acid, paint thinners, solvents, degreasers, transformer oils, jet fuels and sewage sludge were disposed on the NCBC property. Heavy metals including lead, cadmium, silver, mercury, and chromium were found in the sediments and along the shoreline of Allen Harbor. Other contaminants include polycyclic aromatic hydrocarbons (PAHs), solvents, and PCBs, sewage sludge, contaminated fuel oil, and halogens. Site conditions facilitate the movement of contaminants into groundwater and toward Narragansett Bay. Narragansett Bay and the area surrounding the site provides habitat for numerous species of fish and invertebrates such as alewife, stripped bass, Atlantic menhaden, Atlantic herring, winter and windowpane flounder and forage for American lobster among others. Cleanup at the site is ongoing.

Newport Naval Education Training Center, Middletown RI

The site is located on the western shore of Aquidneck Island in Narragansett Bay. An 11-acre portion of the site along the shore of Narragansett Bay, known as McAllister Point Landfill, accepted wastes consisting primarily of domestic refuse, acids, solvents, paint, waste oil, and oil contaminated with polychlorinated biphenyls (PCBs) from 1955 to the mid-1970s. Monitoring of wells detected petroleum products and heavy metals, including lead, and groundwater is also contaminated with volatile organic compounds (VOCs), PCBs, and petroleum hydrocarbons. Landfill soil and leachate contain heavy metals, petroleum hydrocarbons, and PCBs. The tidal action of the Narragansett Bay may spread contamination to the marine environment and nearby wetlands. Habitat and species of concern identified by NOAA are herring, bay anchovy, bluefish, menhaden silver hake, scup, winter flounder, various invertebrates and other species.

Rose Hill Regional Landfill, South Kingston

As indicated by a NOAA CWSR, areas of concern include the Suagatucket River, Point Judith Pond, and the Atlantic Ocean near the mouth of Point Judith Pond. Approximately 28 hectares in size, contaminants associated with the site are cadmium, lead, mercury, and silver, as well as benzene, and 1, 2-dichlorothene. The NOAA Coastal Resource Coordination Program indicates that the area at the mouth of Point Judith pond supports numerous marine species. The landfill is currently on the NPL.

Massachusetts

Atlas Tack Corporation, Fairhaven MA

The site discharged wastes into the surrounding environment including Buzzards Bay and New Bedford Harbor environment for 119 years. Contaminants of concern to the EPA and NOAA are cyanide, cadmium, copper, and volatile organic compounds such as toluene. The surrounding wetland, estuarine, and marine environment have been documented to include, American eel, flounder, and is documented as spawning areas for Atlantic cod, Atlantic mackerel, blueback herring, pollock, summer, winter and yellowtail flounder. Clean up efforts are currently underway.

New Bedford Site, New Bedford MA

An 18,000 acre site, characterized by a harbor and associated tidal estuaries, directly received industrial waste and PCBs in varying degrees for 6 miles. Within New Bedford Harbor there currently is an extensive cleanup effort. Fishing and lobstering is restricted to minimize human exposure to PCBs. Marine species that historically and presently use this area are at risk, and there is great concern that contaminants in New Bedford Harbor will circulate into Buzzards Bay and have deleterious impacts on marine species. Herring and flounder are just a few of the many species that may be potentially affected (NOAA Waste site report www.epa.gov/region1/nbh/).

Plymouth Harbor/Cannon Engineering, Plymouth MA

This site was deleted from the final NPL in 1993. Sediment and surface water containing chloroform, benzene, dichloroethylene, and PCBs washed into Cape Cod Bay near Plymouth Harbor. Marine species associated with concern were blue back herring, flounder, Atlantic cod, pollack, haddock and others.

Blackburn and Union Privileges, Walpole MA

Located in Walpole MA, this site has been used for commercial purposes since the 1600's, and is part of the Neponset River drainage basin that discharges into Dorchester Bay and the Atlantic Ocean. Groundwater samples indicated high concentrations of trace elements such as cadmium, lead, copper, and the chemicals ethylbenzene, xylene, pyrene and anthracene. The lower areas of the Neponset River and Dorchester Bay provide forage habitat for Atlantic cod, winter flounder, skate, and are believed to be potential nursery grounds for Atlantic herring. The EPA is currently conducting cleanup activities.

New Hampshire

Pease Air Force Base, Portsmouth/Newington NH

The Pease Air Force Base is located in the Piscatataqua River Drainage basin, on a peninsula bordered by Great Bay and Little Bay, near the city of Portsmouth. These waters drain into the Piscataqua River and ultimately flush into the Atlantic Ocean. Trace elements, cyanide, PAHs, DDT and its metabolites, total petroleum hydrocarbons and volatile organic compounds were detected in surface water, groundwater, soil, and sediment analysis. Fifty-two species of marine finfish were identified in the Great Bay estuary by the New Hampshire Fish and Game (New Hampshire Fish and Game 1981 in CRC report). Among those identified are Atlantic tomcod, smooth flounder, and river herring. It was also indicated that a limited sea scallop fishery exits as well as a lobster fishery. Physical clean up is completed however the site remains on the NPL.

Maine

Portsmouth Naval Shipyard, Kittery ME

The shipyard is located at the confluence of Portsmouth Harbor and the lower Piscataqua River, approximately 4 kilometers from the Atlantic Ocean. The site has a history of industrial activities associated with the repair, overhaul, modernization, and refueling of nuclear submarines. Before 1970 all facility sewage was discharged directly to the river and prior to 1976 all industrial wastes were discharged into the river. According to NOAA, numerous marine species migrate close to the site and reside for extended periods of time during sensitive life stages, and the area supports significant numbers of year-round resident species. Major species that utilize the associated habitats are shortnose and Atlantic sturgeon, Atlantic salmon, Atlantic herring, Atlantic cod, pollack, and various species of flounder, skate, hake as well as deep sea scallops. Trace elements, PCBs and PAHs have been detected in soil, sediment, and surface water. Physical cleanup at the base has begun.

Callahan Mining Group, Brooksville ME

This site is located adjacent to Harborside Village on Cape Rosier Peninsula on Penobscot Bay. Contaminants of primary concern with potential threats to marine organisms are cadmium, copper, zinc, and lead. Several NOAA trust resources are associated with Goose Pond estuary and Penobscot Bay. Species such as Atlantic herring, American plaice, pollock, red, white and silver hake, window, smooth, and winter flounder use the area as nursery grounds. Physical cleanup of this area has not begun.

Brunswick Naval Air Station, Brunswick ME

The site is located in Brunswick Maine south of the Androscogin River. Areas within this site were for the disposal of toxic waste. The soil and groundwater was believed to be contaminated with volatile organic compounds and was believed to threaten a commercial fishery located in Harpswell Cove. Cleanup has finished and the area is currently being monitored.

Combined Sewer Systems (CSSs) and Sewer System Overflows (SSOs)

Combined Sewer Systems (CSSs) were among the earliest sewer systems constructed in the Untied States. The 1994 EPA Combined Sewer System Overflow Control Policy defines a CSS as a wastewater collection system that conveys domestic, commercial and industrial wastewaters and storm water runoff through a single pipe system to a publicly owned treatment facility (U.S. EPA 1994a).

The systems are designed to overflow when the collection system capacity is exceeded, resulting in combined sewer overflow (CSO). The overflow ends up in rivers, streams, estuaries, and coastal waters, delivering with it microbial pathogens, oxygen depleting substances, total suspended solids, toxins, nutrients, floatables, trash, and human and industrial toxic wastes (EPA 1994a). In a 2004 report to Congress, the EPA estimates that between 23,000 to 75,000 SSOs occur each year in the United States, resulting in releases between 3 billion and 10 billion gallons of untreated wastewater (USEPA 2004a).

Sewer System Overflows (SSO) directly influence the coastal environment, as demonstrated by resulting shellfish and beach closures (USEPA 2004a). Table 2-C is an adaptation of a table provided by the EPA Report to Congress. This table provides data on coastal/riverine cities or towns with permits for CSS and the associated number of systems. Large cities on major river systems that flow directly to the Atlantic Ocean have been included.

State	Permittee Name	# of CSSs
CT	Hartford MDC WPCF	44
CT	Bridgeport East Side WPCF	12
CT	Bridgeport West WPCF	32
CT	New Haven East Shore WPCF	19
RI	Narragansett Bay -Bucklin	28
RI	Narragansett Bay Fields Point	45
RI	Newport City Hall	3
MA	Haverhill WWTF	21
MA	Boston Water and Sewer Comm.	37
MA	Chelsea	4
MA	City of Cambridge	11
MA	Somerville DPW	2
MA	New Bedford WWTF	35
MA	MWRA, Deer Island WWTP	14
MA	Montague WPCF	2
MA	Fall River WWTP	19
MA	Gloucester WPCF	5
MA	Lynn WWTF	4
MA	Taunton WWTPs	1
NH	City of Portsmouth	2
NH	Exeter	1
ME	Bangor WWTP	12
ME	Saco WWTP	5
ME	Machias WWTP	2
ME	Rockland WWTF	4
ME	Biddeford Wastewater Department	11
ME	Bar Harbor Hulls Cove	1
ME	Portland Water District	23
ME	Town of Kittery	3
ME	City of Portland	12
ME	Richmond Utilities District	2
ME	Bucksport	2
ME	Bar Harbor WWTF	3

Table 2-C Number of CSS by state and permit holder (adapted from Appendix D of the 2004 EPA Congressional Report)

Impaired Water bodies

Total Maximum Daily Loads (TMDLs) are the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. Many waterbodies exceed levels for certain contaminants and are listed as impaired. This information is useful for pollution regulation and may be useful to fisheries managers wishing to identify sources of pollution as well as concentrations of contaminants reaching coastal marine systems. The lists of impaired waters are quite long and include data on lakes, ponds, creeks, rivers, and estuaries. Provided below are links to website that list the rivers that have most recently been determined to be over their limits and thus impaired.

- New England
  http://www.epa.gov/waters/data/downloads.html Water quality assessments and listed impaired waters as well as a list of polluted watersheds and GIS shape files.

  http://www.epa.gov/owow/tmdl/states.html Regional Reports are located at this site, along with maps and spatial data.

  http://www.epa.gov/owow/tmdl/status.html The EPA Atlas of Americas Polluted Waters, useful quick reference.

- Massachusetts
  http://www.mass.gov/dep/smerp/

  http://www.mass.gov/dep/brp/wm/tmdls.htm list of statewide waters, not just coastal

- Connecticut
  http://www.dep.state.ct.us/wtr/wq/1998_303d.htm

- Rhode Island
  http://www.dem.ri.gov/programs/benviron/water/quality/rest/

- New Hampshire
  http://www.des.state.nh.us/wmb/tmdl/index_old.html

- Maine
  http://www.maine.gov/dep/blwq/docmonitoring/impairedwaters/

Within State Pollution Sources

Many State Environmental Agencies, for example the Connecticut Department of Environmental Protection (DEP), have data catalogs of properties in violation of state or federal pollution regulations (Duva pers. comm. 7/15/05). In order to more precisely identify coastal pollution sites, these types of data sources are valuable. Provided below is a list of websites and databases documenting a preliminary search of what is available to accessing data that will be useful in documenting coastal pollution sites. The level of detail varies among sites due to ambiguities in data presentation; it is possible that some sites have been overlooked.

- Connecticut
  http://www.dep.state.ct.us/wst/remediation/sites/sites.htm Department of Environmental Protection, lists of contaminated or potentially contaminated sites

  http://dep.state.ct.us/cgnhs/prgactiv.htm#GIS GIS feature class data such as a leachate and wastewater discharge inventory http://magic.lib.uconn.edu/ The University of Connecticut, Map and Geographic Information Center

- Rhode Island
  http://www.edc.uri.edu/rigis/ The link provides access to statewide and town data files on topics such as point locations of hazardous material sites, Rhode Island point discharge elimination system point locations for all sanitary waste sites, as well as feature class data for leaky storage tanks and associated piping used for petroleum and certain hazardous substances.

- Massachusetts
  http://www.mass.gov/mgis/gis_toc.htm The site contents page leads to data layers on groundwater discharge and locations of oil and hazardous waste disposal sites

- New Hampshire
  http://www.granit.sr.unh.edu/cgi-bin/load_file?PATH=/data/datacat/index.html
  Point data depicting National Pollution Discharge Elimination System (NPDES) outfall sources, point and non point pollution sources, and Toxic Release Inventory (TRI) data, consisting of a single coverage describing the facility releasing the chemical and the nature of the release.

- Maine
  http://apollo.ogis.state.me.us This site provides access to GIS data layers

2.3. Conclusion

Near shore coastal systems are subjected to a variety of pollution from runoff, industrial effluents, water pollution control facilities, as well as atmospheric deposition.
Focusing broadly at a regional scale, Massachusetts Bay and Long Island Sound have the highest level of contaminated sediments and appear to be the most contaminated. Anthropogenic influences clearly affect eutrophication in Boston Harbor and Long Island Sound.

Past and present coastal hazardous waste sites input harmful chemicals and metals into areas that are utilized by marine species for forage, reproduction, and nursing. Combined sewer systems are sources of toxic wastes, metals, and nutrients, which negatively affect the coastal environment.

Due to the scale at which pollution occurs, identifying and inventorying coastally polluted sites is a challenging task. Ideally, using coastal pollution and coastal pollution sites as a lens to focus efforts would entail compiling myriad sources of aquatic pollution data, including contaminant loads from river and steams, municipal inputs, and materials from properties suspected of leaching harmful chemicals and atmospheric deposition. While the scope of this task is immense, one of the aims of this paper is to provide insight and focus to such an endeavor.

While synthesizing the material for this section, different layers of detail pertaining to coastal pollution sites became evident. The EPA and NOAA provided detailed information on NPL sites, thoroughly discussing past polluting activities and the marine species of concern. Such specificity was not provided by other sources. In order to better our understanding of coastal pollution, future undertakings may be necessary to provide managers and scientists with commensurate levels of detail regarding nutrient overenrichment and other pollution sources.

To better assist those concerned with examining links between coastal pollution sites and fishery productivity, accurate and comprehensive databases and GIS layers are imperative. Visual representation of site specific coastal toxic waste sites, in addition to WWTFs, CSSs, and polluted water bodies are necessary for associating pollution sources with marine ecosystem health and areas of importance to commercially valuable fish species. Nearly universally, pollution maps for the coastal region and coastal-specific geographic data were not readily available or easily accessible. This type of information is clearly needed. It is the logical next step in further developing the link between coastal pollution and marine resource productivity.

3.0 An overview of the impacts of toxic pollution and nutrient overenrichment on New England fisheries

This section presents information from both existing literature and ongoing research efforts highlighting the biological and physiological affects of coastal pollution on marine resources. Specifically, the review focuses on the potential for population-level affects on managed species (e.g. adverse impacts on spawning, recruitment, size and/or age structure), and indirect effects such as impacts on forage species and marine primary productivity. The greatest effort was taken to provide information pertaining to New England marine species, however, in order to provide a well rounded understanding of the effects of pollution on fish, results and observations from other regions have been included.

A summary of available information on the effects of coastal pollution on fish and marine species is presented in Table 3-A. We will focus on the effects of two particular classes of marine pollution: toxic contamination and nutrient overenrichment. Toxic contamination refers to inputs of substances such as heavy metals, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs), and volatile compounds (Appendix 3 provides a list of specific hazardous contaminants). Nutrient overenrichment is the addition of high concentrations of nutrients such as nitrogen and phosphorus to the marine coastal environment.

Toxic Contaminant Effects	Nutrient Overenrichment Effects
Larval mortality	Mortality
Reproduction and Development Impairments	Community Change
Disease, Lesions and Parasites	Reproductive Success and Development

Table 3-A Noted effects of toxic contaminants and nutrient overenrichment

This table lists the generalized effects of toxic contaminants and nutrient overenrichment on fish species as noted in the available literature. Studies have demonstrated specific responses to toxic contaminants (such as DDT) that have negative impacts such as larval mortality and developmental impairments (see below for more details on these specific impacts). Nutrient overenrichment may result in effects similar to toxic contaminants such as increased mortality; in addition to changes in phytoplankton communities and other ecological factors that may reduce growth and trigger community shifts.

3.1. Toxic Contaminants

Table 3-B shows the four major pollutant categories identified by the EPA (Buschsbaum et al. 2005). Contaminants within these categories have been shown to have deleterious effects on fish and wildlife across the globe.

1) Metals
2) Petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs)
3) Polychlorinated biphenyls (PCBs)
4) Pesticides

Table 3-B Major pollutant categories identified by the Environmental Protection Agency

Fish obtain contaminants either directly from water, through ingestion of contaminants present in or on prey, or from contact with or ingestion of bottom sediments (Buchsbaum et al. 2005). Reproductive and developmental toxicity, immunotoxicity, liver damage, neuro-behavioral effects and others can result from toxic contamination (Eisler 1986; Walker and Peterson 1994; Eisler and Belisle, 1996; Fisher et al., 1994; Fingerman and Russell, 1980; in Monosson 1999).

For the purposes of this section, we will focus on the impacts of these four pollutant categories on the three effects noted in Table 3-A: larval mortality; reproduction and development impairments; and, disease, legions and parasites.

Larval mortality

All four primary pollution categories (Table 3-B) can greatly affect larval mortality (Buchsbaum et al. 2005). For example, concentrations of silver, a metal contaminant, reduced the percent-viable hatch in flounder embryos and resulted in larval mortality (Klein-MacPhee et al. 1984 in Buchsbaum et al. 2005). Cod larvae have also been shown to be susceptible to DDT and DDE, and malformed and dead embryos and larva were found to increase with increasing concentrations of DDT (Dethlefsen 1976 in Buchsbaum et al. 2005). In Gulf of Maine sea scallops, overloads of metals interfered with intracellular metal regulation, lowering organism health and leading to reproductive failure (Buchsbaum et al. 2005).

A laboratory study by Peachy (2005) examined the synergism between hydrocarbon pollutants and UV radiation on the larvae of four crab species. Peachy states that xenobiotics, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs), and metals are associated with sediments and have the greatest impact to the benthic stages of the invertebrate life cycle. Exposure to PAH and UV radiation in tandem resulted in crab larvae mortality, however no effects on larval crab mortality due to PAH or UV radiation independently were noted (Peachy 2005). This suggests that the synergistic effects of anthropogenic and natural stressors for coastal marine organisms with complex life history strategies can be significant, and may be difficult to detect unless all potential impacts are carefully considered.

Reproduction and Development Impairments

Toxic contaminant pollution has been determined to impair reproduction in marine fish. For example, Thurberg and Gould found that chronic exposure of cod to oil contamination resulted in reproductive impairment (Buchsbaum et al. 2005). A report prepared by Emily Monosson for the NOAA Damage Assessment Center reviewed laboratory studies focused on the effects of PCBs on marine and freshwater fish reproduction, immunology, and development. The report indicates that concentrations of AroClor1254 ranging from 5 ppm to 70 ppm adversely affect fish reproduction and development. A second type of PCB, at concentrations of only 0.3 ppm to 5 ppm, was determined to reduce egg deposition, pituitary gonadotropin[2], as well as reduce larval survival. Importantly, this report noted that the range of concentrations found harmful in the lab is also found in similar concentrations in fish captured from the Hudson River (Monosson 1999).

Black et al. (1988) examined exposure of adult winter flounder to contaminant-polluted natural environments prior to spawning for potential impacts on flounder progeny. They examined flounder from Narragansett Bay, RI, New Bedford Harbor in Buzzards Bay, MA, and Apponagansett Bay, MA, rearing their progeny under clean laboratory conditions. The observed response in the most contaminated group from New Bedford Harbor had a smaller size at hatch. However, after eight weeks, compensatory growth had eliminated the differences (Black et al. 1988). A second study that focused on flounder demonstrated that fish with high liver concentrations of PCB had small larvae (Nelson et al. 1991).

Certain toxic contaminants present in the environment have demonstrated the ability to mimic the function of sexual hormones. Known as endocrine disrupters, these chemicals have resulted in changes in sexual behavior, sterility, impaired immune function, and disturbed sexual differentiation (such as feminized or masculinized sex organs) (Colburn et al. 1996). A portion of the research involving endocrine disrupting chemicals has focused on Atlantic salmon. Madson et al. (2004), in an abstract presented to the 5th International Symposium on Fish Endocrinology, suggest that exposure to environmental and chemical estrogens may impair smolt development and may delay migration in Atlantic salmon.

Endocrine disrupters have caused male fish species to have smaller reproductive organs, as well as ovarian tissue growing in testicles. Male flounder collected from five English estuaries and from the North Sea displayed increased levels of a protein associated with egg yolk produced in the livers of mature female fish (Lye et al.,1999; Allen et al., 1999 in Buchsbaum et al. 2005). There appears to be a sincere interest in the effects that these hormone-mimicking chemicals have on fish species and, possibly, on fish populations, however more research on a broader array of species is needed. Given the severity of demonstrated impacts, and the potentially dramatic effect that these reproduction and developmental impairments may have at the population level, such research may provide vital evidence in establishing a relationship between coastal pollution and marine fisheries productivity.

Disease, Lesions, & Parasites

A study conducted by Johnson et al. (1993) examined relationships between hepatic lesions and chemical contaminant concentrations in sediments, stomach contents, and tissues of winter flounder collected from 22 northeast coastal sites. Aromatic hydrocarbons and chlorinated pesticides such as DDT and chlordanes were the most important risk factors for hepatic disease in winter flounder; however, they were unable to single out which one had the greatest impact because all were found together (Johnson et al. 1993). That being said, it was clear that relationships between chemical contaminants and lesions were strongest for lesions that developed early in the life cycle.

[2] gonadotropins are the major pituitary hormones responsible for regulating gametogenesis i.e. sexual maturation http://www.nwfsc.noaa.gov/research/divisions/reutd/phys_endo/endocrine.cfm

Winter Stress Syndrome (WSS) is a condition of severe lipid depletion in fish brought on by external stressors; some scientists believe this to be an important factor to consider in fish health (Lemly 1996). Contaminant stress from heavy metals, pesticides and synthetic organic compounds, in addition to biological stresses like parasites, have the potential to cause or exacerbate WSS in fish populations throughout temperate regions of the world (Lemly 1996). The author indicates that changes in temperature and levels of contamination, potentially from wastewater discharges, may increase fish mortality, and he further speculates that winter flounder and other species that over-winter in estuaries are at risk (1996). WSS should be recognized as an important seasonal cause of mortality for juvenile fish in temperate waters, and the synergistic impacts of toxic contamination and WSS may be an important, though apparently under-studied, source of adverse-effect and even mortality for those species at risk.

Other impacts of chemical contaminants on marine fish are a higher incidence of small inclusions (micronuclei) in fish red blood cells, Lymphocytosis, and high incidence of fin rot disease in New York Bight species such as windowpane, winter, and yellowtail flounders (Buchsbaum et al. 2005). Freeman et al., (1983) found that of 100 live cod collected from Halifax Harbor, 73 had histopathological lesions in their livers. These were not directly attributable to any one chemical contaminant, but the result was significant in that these lesions have a dramatically lower rate of natural occurrence.

Speculation on the relationship between contaminant pollution and fish parasites also exists. It is likely true that parasitic infections make fish more susceptible to the stresses created by pollution. However, the opposite belief appears to hold as well: stress caused by pollution may result in making fish more prone to parasitic infection (Buchsbaum et al. 2005). Unfortunately, there were very few studies in the New England region focusing on the relationship between chemical contaminants and disease, lesions and parasites.

Smatterings of studies conducted demonstrate an adverse relationship between toxic contamination and marine fish disease and mortality. Additional studies will be needed to quantify the extent and magnitude of these demonstrated adverse impacts, particularly studies that investigate links to effects at the population level. Such studies are important, as the potential risk involved appears to justify the expense of further investigation.

3.2. Nutrient Overenrichment

The scientific community has focused significantly on nutrient overenrichment and its effects on primary production and food web supporting organisms. Eutrophication (the excessive nutrient-induced increase in the production of organic matter) drives conditions in aquatic environments that can negatively impact aquatic organisms. Symptoms of estuarine eutrophication may include biological stress and changes in benthic or pelagic community structure. These conditions may affect habitat important to commercial fisheries (Bricker et al. 1999). According to Howarth et al. (2000), eutrophication in coastal areas is of primary concern to the health of fish populations.

A degree of uncertainty exists regarding the effects of nutrient overenrichment on secondary productivity. For example, researchers have provided evidence that nutrient overenrichment may increase secondary productivity in coastal marine systems (Nixon and Buckley 2002).

Others however have indicated that due to weak coupling between nitrogen loading and phytoplankton with higher trophic levels, anthropogenic nutrient loading to coastal waters is unlikely to increase fish biomass (Micheli 1999). While research on this particular issue continues, it appears that nutrient overenrichment may have a wide range of impacts on marine systems.

The following is a summary of concerns associated with nutrient overenrichment within the coastal zone. Research has documented that intensified loads of nutrients to the coastal zone can result in fish mortality, and in certain situations may have teratogenic effects (that is, effects relating to or causing malformation of an embryo). These two effects are summarized here.

Mortality, Community Change

A 2000 National Research Council report entitled "Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution" concluded that nutrient over-enrichment generally degrades the marine food web that supports commercially valuable fish (NRC 2000).
The USCOP report: Blueprint For the 21st Century, indicates that nutrient pollution leads to fish kills due to oxygen depletion, and the greatest impacts occur in estuaries and nearby coastal regions (USCOP 2004). Others have noted that changes in nutrients, light, and oxygen favor some species over others and cause shifts in the structure of phytoplankton, zooplankton and bottom dwelling communities (Howarth 2002, Riegman 1995 in Islam 2004). Howarth et al. indicate that changes in phytoplankton communities and other ecological factors may trigger reduced growth and recruitment of fish species and lower fishery production (Howarth 2002).

Reproductive Success and Development

Very few studies have addressed the effects of nutrient overenrichment and fish development. However, two recent studies reported that aquatic hypoxia can act as an endocrine disrupter and as a teratogen. Scientists who conducted a laboratory study with Carp (*Cyprinus carpio*), a freshwater fish species, report that hypoxia disrupts the endocrine function affecting gonad development, impairs fertilization success and reproductive output, and reduces hatching success and larval survival (Wu et al. 2003). In a second laboratory study, authors report that hypoxia disrupts the balance of sex hormones in early embryonic development of zebrafish (Shang and Wu 2004). Hypoxia has also been shown to retard growth in plaice (Peterson et al. 1995 in Shang and Wu 2004).

Much of the information regarding the impacts of nutrient overenrichment on fishery productivity is speculative. This indicates the need for continued assessment of the impacts of nutrient loading in combination with various other environmental factors such as light and temperature.

3.3. Conclusion

Based on a review of available literature, chemical contaminants appear to increase larval fish mortality, affect reproduction, and impair development. They are associated with increased occurrences of disease, lesions and parasites. Nutrient overenrichment may result in fish mortality, adversely impact benthic habitats and accelerate or cause changes in aquatic communities. There is also early evidence suggesting that hypoxia may influence fish reproduction and development.

What is most evident is a lack of studies and quantitative data on the ways in which coastal pollution affect both marine fish species at the population level. When looking to extrapolate information from other regions, it became apparent that this paucity is not isolated to New England. The bulk of the available information focuses on chemical contaminant affects on individual fish, and these studies occur most often in fresh water systems as opposed to the marine environment. At this point in time, information on how pollution affects fish populations is speculative.

This presents challenges for fishery managers and scientists wishing to adopt an ecosystem-level view towards fishery management. There is an obvious and pressing need for increased effort in laboratory and field studies associated with this issue, particularly focused on commercial species, their benthic environment, and their prey.

The good news is that concern for the impacts of nutrient overenrichment on the marine ecosystem appears to be growing. As demonstrated above, nutrient overenrichment is believed to lead to conditions that may greatly affect the marine ecosystem and the development and growth of marine fish species. Attention from scientists addressing this issue in a fisheries context will assist managers with decision-making.

While a causal link between coastal pollution and adverse effects on marine fish populations managed by the NEFMC cannot be affirmed at this time, this fact is most certainly not due to exhaustive research. Rather, increased efforts examining these relationships in more detail are needed. The documented impacts at the individual species level, combined with the potential for adverse synergistic impacts, as yet unstudied, make this a field ripe for exploration.

4.0 Discussion

A primary goal of this report was to identify potential links between coastal pollution and the productivity of fish species currently managed in New England to provide a knowledge base, both to better assist mangers in formulating management prescriptions and to encourage scientists to take up the issue with some vigor. The information presented here does not elucidate a clear link, or a smoking gun. It does, however, provide fishery managers, scientists and interested stakeholders with an understanding of the complexity of the relationship between coastal pollution and New England fisheries productivity and, hopefully, the topical areas in most dire need of attention.

As a result of a thirty year history of environmental regulation often aimed at reducing the effects of toxic contaminants in the environment, there is a great deal of information that can be accessed to assist in identifying areas that have been responsible for serious toxic inputs in to the marine environment. This allows us to pinpoint National Priory List sites such as New Bedford Harbor and the Portsmouth Naval Shipyard, increasing our understanding of areas that may be linked to coastal pollution. Lists of cities with combined sewer systems overflows known to carry harmful toxics and increased nutrient loads provide a level of understanding that may allow us to begin to address areas that are likely to have impacts on New England fish populations. It is also apparent that efforts are being taken, and data is being collected, at local levels. This will help us further develop our understanding of the impacts of specific sources of pollution on the coastal marine environment.

In addition to information that is useful in identifying toxic contaminant sources, significant efforts are being aimed at identifying the effects of nutrient overenrichment in New England's coastal zones. Scientists and environmental regulators have identified areas in New England such as Long Island Sound and Boston Harbor that are at times greatly impaired by nutrient pollution. Analyzing impaired water bodies using data from TMDL reports will be helpful in enhancing our understanding of where these inputs originate from, and what their effects truly are.

There is a great deal of information associated with identifying non-coastal sources acting as pollution inputs as well. NPL sites as well as leaky fuel containers both may be considered harmful to the coastal environment. Inherent differences between these two types of sources make identifying links to marine pollutants a difficult endeavor. Therefore, various websites containing valuable lists of contaminated sites and databases containing the information associated with the varying levels of detail have been provided to facilitate future efforts to appropriately identify coastal pollution sources.

To better assist marine resource managers and scientists, the large, detailed pool of information that has been collected by federal agencies, state and local governments, and various NGOs should be made available in an easily accessible manner. For example, visual representation of coastal pollution sites for New England was not readily available for inclusion in this report. Such a representation would assist managers and potential researchers in identifying areas that may be affecting important marine habitats.

Researching the links between coastal pollution and marine fishery productivity leaves much to be desired. One area in particular, however, has been shown here to demand serious and immediate treatment, and that is the impacts of chemical contaminant on fish populations. Past efforts have focused primarily on individual species effects. Given the near-shore proximity of several NEFMC-managed species at particularly vulnerable life stages, the impetuous for such attention need not come from the local or state level. Federal leadership in addressing the pollution issue is necessary. Furthermore, the highly limited amount of information on the synergistic, additive and/or cumulative affects of multiple chemical interactions is of great concern. It seems more than likely that the true impacts of chemical contamination will be difficult to detect in a single-chemical laboratory environment, but the net effect of multiple stressors under field conditions may be more easily to identify—and more insidious.

It is also important to note that while conducting the literature review for this paper, a lack of communication between researchers (both governmental and academic) and managers became evident. The gap between these groups needs to be closed to provide managers with the science necessary to create sound policy. The acknowledged difficulty in bridging this gap, especially when, as in this instance, complex jurisdictional and political boundary issues are involved, should not dissuade managers from signaling their need for both the data and the communication structures that will surely be needed to provide it.

5.0 Recommendations

The NEFMC would likely be wise to bring forth any concerns arising from the information provided by this report. Along these lines, three recommendations are provided.

First, to address the varied levels of detail associated with coastal pollution sites, managers may find it helpful to create a working visual representation of currently known areas that input or have in the past input pollutants into the marine environment, including sources that lead to nutrient overenrichment. This would require filtering through Federal, State, and Local databases--a very large task indeed. However, it will be extremely beneficial to enhancing the understanding of areas of concern—those areas that are most likely to result in negative impacts. Additionally, the Council should advocate for the establishment of a data repository that can be accessed by state and federal government agencies, stakeholder groups, and private organizations. Such a repository would ideally contain easily accessible databases, with a likely focus on GIS-compatible files and other mapping data.

Second, it is imperative that the NEFMC, should it concur with the conclusions contained herein, vocalize its support of initiatives to increase the amount of funding and scientific research looking into links between coastal pollution and effects at the population level—perhaps by encouraging cooperative research along these lines.

Finally, the NEFMC should utilize its power to establish a forum for discussing issues surrounding coastal pollution and fishery productivity. The scale of marine coastal pollution does not mate easily with political or jurisdictional boundaries. As a regional organization, the Council could play a vital role in bringing involved participants together. Appropriate forums are needed to clarify goals and to build trust and working relationships. The enormity of the issues themselves means that there are numerous organizations and agencies with voices, data, and vital interests. It should not be difficult to imagine just such a forum. At the very least, the Council should strive to involve its members and/or staff, whenever possible, in events associated with the coastal pollution issue.

6.0 Conclusion

Undoubtedly the efforts to incorporate ecosystems-based approaches to fisheries management will be a serious challenge. However, we feel that there is sufficient evidence to warrant further efforts in examining the relationships between coastal pollution and marine fisheries productivity. However, at this point in time efforts to properly address vital issues are not reaching their full potential. It is our hope that the information presented in this report will, at it’s most basic level, increase awareness of the links between coastal pollution and New England fisheries, and may, if we are all lucky, facilitate future, more successful efforts.

References Cited

Anderson, Tom. 2002. This Fine Piece of Water: An Environmental History of Long Island Sound. Yale University Press. New Haven & London. 256pp.

Black, D.E., D.K. Phelps, and R.L. Lapan. 1988. The effect of inherited contamination on egg and larval winter flounder, *Pseudopleuronectes americanus*. *Marine Environmental Research*. 25: 45-62.

Bricker , S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Silver Spring, MD: 71pp.

Buchsbaum, R., J. Pederson, W. E. Robinson (eds). 2005. The Decline of Fisheries Resources in New England: Evaluating the Impact of Overfishing, Contamination, and Habitat Degradation. MIT Sea Grant College Program, Cambridge, MA, MITSG 05-5.

Colburn, T., Dumanoski, D. and Myers J.P. 1996. Our Stolen Future. Abacus. London. 306pp.

Freeman, H.C., Sangalang G., and B. Fleming. 1982. The sublethal effects of a polychlorinated biphenyl (Aroclor1254) diet on the Atlantic cod (*Gadus morhua*). *The Science of the Total Environment*. (24) 1-11.

Finlayson, Christy. 2003. Inventory of Environmental Monitoring Program, Draft. Gulf of Maine Council on the Marine Environment, Environmental Quality Monitoring Committee. December 2003.

Garcia, S.M., and K.L. Cochrane. 2005. Ecosystem approach to fisheries: a review of implementation guidelines. *ICES Journal of Marine Science*, 62: 311-318.

Gardner, G.R., Pruell, R.J., and L.C. Folmar. 1989. A Comparisson of Both Neoplastic and Non-Neoplastic Disorders in Winter Flounder (*Pseudopleuronectes americanus*) from Eight Areas in New England. *Marine Environmental Research* (28) 393-397.

Hameedi, M.J., A.S. Pait, and R.A.Warner. 2002. Environmental Contaminant Monitoring in the Gulf of Maine. A discussion paper presented at the Northeast Coastal Monitoring Summit, Durham, NH December 10-12, 2002. Accessed on December 29, 2005. http://www.gulfofmaine.org/nciw/ec-monitoring.pdf .

Howarth R., D. Anderson, J. Cloern, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Marcus, K. McGlathery, A. Sharpley, and D. Walker. 2000. Nutrient pollution of coastal rivers, bays, and seas. *Issues in Ecology*. No.7.

Islam, M.S. and M. Tanaka. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine Pollution Bulletin* 48: 624-649.

Jickells, T.D. 1998. Nutrient biogeochemistry of the coastal zone. Science 281 (5374): 217-222.

Johnson, L.L., C. Stehr, O.P. Olson, M.S. Myers, S.M. Pierce, C.A. Wigren, B.B. McCain, and U. Varanasi. 1993. Chemical contaminants and hepatic lesions in winter flounder (*Pleuronectes americanus*) from the Northeast coast of the United States. *Environ. Sci. Technol*. 27: 1759-2771.

Lemly, A.D. 1996. Wastewater discharges may be most hazardous to fish during winter. *Environmental Pollution*. 93: 2: 69-174.

Percival, R. C.H. Schroeder, A.S. Miller, and J.P. Leape. 2003. Environmental Regulation: Law, Science and Policy. 4th Edition. Aspen Publishers, New York, NY.

Madson, S. S., K. Bangsgaard, B. Korsgaard, and C. Nielsen. 2004. The effect of estrogens on smoltification and migration in Atlantic salmon, *Salmo salar*. Abstract presented at the 5th International Symposium on Fish Endocrinology. Castellón, Spain September 5-9. <http://www.5isfe.uji.es/>.

Micheli, Fiorenz. 1999. Eutrophication, fisheries, and consumer-resource dynamics in marine pelagic ecosystems. *Science*. 285: 1396-1398.

Monosson, E. 1999. Reproductive, Developmental and Fish Immunotoxic Effects of PCBs in Fish: A summary of Laboratory and Field Experiments. Prepared for the Damage Assessment Center, National Oceanic and Atmospheric Administration.

National Research Council. 2000. Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. National Academy Press, Washington D.C.

Nixon, S. and B.A. Buckley. 2002. "A strikingly rich zone" – Nutrient enrichment and secondary production in coastal marine ecosystems. Estuaries 25(4b): 782-796.

Nelson, D.A., J.E. Miller, D. Rusanowsky, R.A. Greig, G.R. Sennefelder, R. Mercaldo-Allen, C. Kuropat, E. Gould, F.P. Thurberg and A. Calabrese. 1991. Comparative reproductive success of winter flounder in Long Island Sound: A three-year study (biology, biochemistry, and chemistry). *Estuaries* 14 (3): 318-331.

O'Conner, J.M. and R.J. Huggett. 1988. Aquatic pollution problems, North Atlantic coast, including Chesapeake Bay. *Aquatic Toxicology*, (11) 163-190.

Peachy, Rita. 2005. The synergism between hydrocarbon pollutants and UV radiation: a potential link between coastal pollution and larval mortality. *Journal of Marine Biology and Ecology*. 315: 103-114.

(Rivilin @@@).

Pew Oceans Commission. 2003. *America's Living Oceans: Charting a Course for Sea Change*. A Report to the Nation. May 2003. Pew Oceans Commission, Arlington, Virginia.

Nelson 1995?

Howarth 2002?

Shang, E.H.H and R.S.S. Wu. 2004. Aquatic hypoxia is a teratogen and affects fish embryonic development. *Environ Sci Technol* 38: 4763-4767.

United States Commission on Ocean Policy (USCOP) 2004. An ocean blueprint for the 21st century. Final report. Washington D.C. 524pp.

USEPA (Environmental Protection Agency) 2004a. Report to Congress: Impacts and Control of CSOs and SSOs. EPA 833-R-04-001. U.S. Environmental Protection Agency. Office of Water. Washington D.C.

USEPA (United States Environmental Protection Agency) 2004b. The incidence and severity of sediment contamination in surface waters of the United States. Vol. 2. National sediment quality survey. EPA-823-R-04-007. U. S. Environmental Protection Agency. Office of Science and Technology. Washington D.C.

USEPA (Environmental Protection Agency) 2005. National Coastal Conditions Report II. EPA-620/R-03/002. U. S. Environmental Protection Agency. Office of Research and Development/Office of Water. Washington D.C.

Vandermeulen, H. 1998. The development of marine indicators for coastal zone management. *Ocean and Coastal Management*. 39: 63-71.

Wu, R.S.S., B.S. Zhou, D.J. Randall, N.Y.S. Woo, and P. K. S. Lam. 2003. Aquatic hypoxia is an endocrine disrupter and impairs fish reproduction. *Environ. Sci. Technol.* 37: 1137-1141.

NOAA Coastal Hazardous Waste Site Review and

1994 EPA Combined Sewer System Overflow Control Policy

Duva pers. comm. 7/15/05

Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration, Coastal Hazardous Waste Site Reports. July 10th, 2005. http://response.restoration.noaa.gov)

New Bedford Harbor U.S EPA Waste Sire Cleanup and Reuse in New England. www.epa.gov/region1/nbh/. Last updated June 21, 2005.

WATERS. U.S. EPA http://www.epa.gov/waters/data/downloads.html
Last updated on Tuesday, July 26th, 2005

Total Maximum Daily Loads, United States Environmental Protection Agency. Last updated on Monday, October 3rd, 2005. Accessed on December 29, 2005
http://www.epa.gov/owow/tmdl/intro.html%23definition

TMDL Reports Text Links, United States EPA
http://www.epa.gov/owow/tmdl/states.html
Last updated on Wednesday, February 16th, 2005 August 17, 2005

Atlas of Americas Waters U.S. EPA http://www.epa.gov/owow/tmdl/atlas/index.html
August 17, 2005

Watersheds http://www.mass.gov/dep/brp/wm/tmdls.htm

The estuaries project Mass DEP
http://www.mass.gov/dep/smerp/

Connecticut Department of Environmental Protection
http://www.dep.state.ct.us/wtr/wq/1998_303d.htm

Water Quality Restoration Plans State of Rhode Island Department of Environmental Management Office of ware Resources
http://www.dem.ri.gov/programs/benviron/water/quality/rest/

Total Maximum Daily Load Program New Hampshire Department of Environmental Services Watershed management Bureau http://www.des.state.nh.us/wmb/tmdl/index_old.html

Impaired waters, Department of Environmental Protection, Land and Water Quality
http://www.maine.gov/dep/blwq/docmonitoring/impairedwaters/

http://www.dep.state.ct.us/wst/remediation/sites/sites.htm Department of Environmental Protection, lists of contaminated or potentially contaminated sites http://dep.state.ct.us/cgnhs/prgactiv.htm#GIS GIS feature class data such as a leachate and wastewater discharge inventory

http://magic.lib.uconn.edu/ The University of Connecticut

http://www.edc.uri.edu/rigis/

http://www.mass.gov/mgis/gis_toc.htm The site contents page leads to data layers on groundwater discharge and locations of oil and hazardous waste disposal sites

http://www.granit.sr.unh.edu/cgi-bin/load_file?PATH=/data/datacat/index.html
Point data depicting National Pollution Discharge Elimination System (NPDES) outfall sources, point and non point pollution sources, and Toxic Release Inventory (TRI) data, consisting of a single coverage describing the facility releasing the chemical and the nature of the release.

http://apollo.ogis.state.me.us

Contaminated Sediment Water. United States Environmental Protection Agency. Last updated on Thursday, November 17th, 2005. Accessed on December 29, 2005. http://www.epa.gov/waterscience/cs/aboutcs/locating.html

http://www.gulfofmaine.org/nciw/ancms2002.asp Atlantic Northeast Coastal Monitoring Summit. *Regional Monitoring Framework- Nutrients Strawman.* Gulf Of Maine Council on the Marine Environment. Accessed on September 1, 2005.

www.epa.gov1. United States Environmental Protection Agency. Contaminated Sediments in Water: How to Locate. Accessed on December 29th 2005. Last updated on Thursday, November 17th, 2005 www.epa.gov/waterscience/cs/aboutcs/locating.htm

"Total Maximum Daily Loads." United States Environmental Protection Agency Last updated on Monday, October 3rd, 2005. Accessed on December 30, 2005 http://www.epa.gov/owow/tmdl/intro.html#definition

"Coastal Hazardous Waste Site Reports" Office of Response and Restoration, National Ocean Service. National Oceanic and Atmospheric Administration. Revised September 23, 2005. Accessed on January 2, 2006 http://response.restoration.noaa.gov/topic_subtopic_entry.php?RECORD_KEY%28entry_subtopic_topic%29=entry_id,subtopic_id,topic_id&entry_id(entry_subtopic_topic)=96&subtopic_id(entry_subtopic_topic)=5&topic_id(entry_subtopic_topic)=2

"Superfund Information Systems" CERCLIS database. United States Environmental Protection Agency. Last updated on Thursday, August 18th, 2005. Accessed July/August 2005. http://www.epa.gov/superfund/sites/cursites/

Federal Register United States Environmental Protection Agency. Combined Sewer System (CSO) Control Policy Vol 59 no 75 Tuesday April 19th 1994:18688-18698.

Oxford English Dictionary. Second Edition 1989. Oxford University Press, USA. <http://dictionary.oed.com>

Appendix 1: Coastal Environmental Health Indicators and Monitoring Programs

This section is intended to expose the reader to existing data sources, monitoring programs, and indicators used to assess coastal environmental health in New England. Two areas of concern are addressed: sediment condition and water quality. Indicators used to address these areas of concern are detailed here, with a brief description of each indicator's purpose, followed by the corresponding Federal, State, municipal, and non-governmental organizations who are conducting monitoring programs utilizing each indicator.

Table 6-A depicts the most important indicators utilized in the New England region. Bottom sediments are representative of benthic condition and overall marine environmental health. Levels of sediment contamination, sediment toxicity, and total organic carbon are frequently measured. Additionally, benthic organisms and fish tissue samples are used throughout New England to represent the condition of local sediments. The blue mussel *Mytilus edulis* as well as crustaceans are tested for chemical concentrations and heavy metals. Monitored indicators of water quality are dissolved inorganic nitrogen- (DIN) and dissolved inorganic phosphorus (DIP), chlorophyll a, dissolved oxygen (DO), water clarity, and suspended contaminants. Finally, fish tissue samples from species such as Atlantic cod and flounder are used to indicate the presence of contaminants in marine environments.

Area of concern	Indicator
Sediment condition	Sediment toxicity
	Contamination level
	Total organic carbon TOC
	Benthic organisms (shellfish and crustacean)
	Fish Tissue (muscle tissue, organ samples, lesions, tumors)
Water quality	Dissolved Inorganic Nitrogen (DIN) and Phosphorus (DIP)
	Chlorophyll a
	Water clarity
	Suspended contaminants
	Fish tissue (muscle tissue, organ samples, lesions, tumors)

Table 6-A – Frequently used indicators for two primary areas of concern

A myriad of monitoring programs at the Federal, State, municipal and non-governmental levels utilize these indicators to determine the health of the coastal environment. The Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP), NOAA's National Status and Trends Program (NS&T), and the National Coastal Assessment (NCA) have comprehensive monitoring programs. For instance, when addressing sediment condition, data is collected from indicators on the physical and chemical characteristics of sediments, the bioavailability of contaminants, levels of contaminant residues in the tissues of aquatic organisms, and the health of benthic communities (www.epa.gov1).

The following is a list of the most common coastal marine environmental health indicators monitored in New England, the associated monitoring programs, and their sponsor agencies.

The reader should also be aware that the Gulf of Maine Council on the Marine Environment has researched and documented this topic to great length. Appendix 2 is a detailed draft report by Christy Finlayson containing an inventory of over 250 environmental monitoring programs in the Gulf of Maine and Long Island Sound. For those wishing to delve deeper into the data, this extensive report is a valuable supplement to the information provided below, as is much of the information provided on the Gulf of Maine Council's website http://www.gulfofmaine.org .

1.1 Sediment Quality Indicators

Sediment condition is frequently utilized as an indicator of chemical contamination. Contaminants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals adsorb into suspended particles in the water and are deposited on benthic substrates. As will be detailed in section three of this report, chemical contaminants can impair reproduction and larval development, and result fish mortality. The presence of contaminants, toxicity levels, the amount of total organic carbon (TOC), and benthic organisms are used as indicators of coastal environmental health. Fish tissue samples may also be used as an indicator of sediment quality; however this will be discussed when indicators of water quality are addressed

Sediment Contaminants

According the EPA there are no absolute chemical concentrations that correspond to sediment toxicity. "Effects ranges" are used by the EPA and others to determine sediment contamination. Effects range median is the median concentration of a contaminant observed to have adverse biological effects in the literature studies reviewed by the EPA. Effects range low is a more protective indicator of contaminant concentration which is the 10^{th} percentile concentration of a contaminant represented by studies demonstrating adverse biological effects (EPA 2005). The NCA, NOAA Status and Trends (NS&T) Program, the Long Island Sound Study (LISS), and the United States Geological Survey (USGS) utilize sediment contamination indicators as part of monitoring programs.

Sediment Toxicity

The NCA measures sediment toxicity levels by exposing and measuring the survival of the marine amphipod *Ampelisca abdita* to exposed sediments. These levels are then utilized to determine potential levels that may be harmful to other organisms.

Total Organic Carbon (TOC)

It is believed that silty sediments high in TOC in some cases are potential sources of contamination. TOC is a measure of the organic carbon content of sediment expressed as a Percentage, and is used to normalize the dry-weight sediment concentration of a chemical to the organic carbon content of the sediment. According to the EPA National Coastal Conditions Report II, areas where TOC concentration is greater than 5% is rated *Poor*, whereas areas rate *Good* have a TOC less than 2% (2005).

Benthic Organism Indicators

Bottom dwelling organisms such as clams, crustaceans and worms are often used as indicators of disturbances in the marine environment. Such organisms usually do not move great distances and therefore are believed to be good indicators of the health of the surrounding environment. The EPA's EMAP develops tools necessary to monitor and assess the status and trends of national ecological resources, and often provides data collected from monitoring benthic organisms. The NCA has regional benthic indices of environmental conditions that reflect changes in diversity and populations size of pollution tolerant and intolerant species (site this).

The Mussel Watch Project, part of the NS&T Program at NOAA's Center for Coastal Monitoring and Assessment, monitors for 16 major and trace elements as well as over 75 organic contaminants in bivalves. There are 14 Mussel Watch sites in the Gulf of Maine that use the blue mussel (*Mytilus edulis)* as an indicator (Hameedi et al. 2002, noaa.gov).

Gulfwatch is a monitoring program in the Gulf of Maine that also utilizes the blue mussel as an indicator of trace elements and contaminants. The program monitors 56 sites located near industrial wastewater discharge points, municipal outfalls, and urban centers (Hameedi et al. 2002). As mentioned earlier, amphipod mortality tests utilize small crustaceans as indicators of sediment toxicity.

1.2 Water Quality Indicators

Inputs to coastal environment such as sewage and runoff may lead to harmful eutrophic conditions, potentially responsible for shifts in marine community structure. Concern over nutrient overenrichment has increased in recent years, and chemical contamination continues to be an issue in coastal and estuarine management (USCOP 2005, Pew Oceans Commission 2003, Islam et al. 2004). The following indicators provide insight into water quality trends.

Nutrients

Dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) are required for the natural growth of phytoplankton, however when found in excess can have detrimental impacts on the coastal environment (USEPA 2005). The National Estuarine Eutrophication Assessment prepared by Bricker et al assessed surface maximum DIN levels as high if they were equal to or greater than 1mg/L and low if they were less than 0.1mg/L. Surface maximum levels of DIP were considered high if they are equal to or greater than 0.1mg/L and low if there are less than 0.01mg/L (1999).

Agencies and programs that monitor DIN and DIP in New England are the Massachusetts Water Resources Authority (MWRA), the NCA, the NPDES permit program, State water quality monitoring programs, the University of New Hampshire, Plum Island Long-Term Ecological Research Site, and others.

Chlorophyll a

This indicator is a measure of excess plant production which may decrease light availability and lower concentrations of dissolved oxygen, thus debilitating marine organisms (USEPA 2005). Agencies and monitoring programs analyzing chlorophyll a are the MWRA, the NCA, the Gulf of Maine Ocean Observing System (GoMOOS), National Estuarine Research Reserve System (NEERS) and others (www.gulfofmaine.org).

Water Clarity

The penetration of light through the water column to bottom habitats is important for submerged aquatic vegetation and benthic organisms. Water clarity varies naturally within regions and is determined based on regional reference conditions (USEPA 2005). Associated monitoring programs are MWRA, various State water quality programs, the National Discharge Elimination Program (NPDES), Save the Sound, and others.

Dissolved Oxygen

Low levels of dissolved oxygen can result in a condition known as hypoxia which is stressful for some benthic organisms. Anoxia is a condition resulting from a lack of oxygen which has resulted in fish kills in Long Island Sound (Anderson 2002). Concentrations below 2 mg/L are believed to be stressful to many marine organisms, and many states use a threshold average of 4 to 5 mg/L to set water quality standards (USEPA 2005). Low oxygen levels may occur naturally, therefore detailed site-specific studies are necessary to better understand when conditions may be occurring unnaturally.

Various federal and state programs, such as the MWRA, NEERS, NCA, Penobscot Bay Water Quality Monitoring (Marine Maritime Academy), and the LISS utilize this indicator in monitoring programs. A more complete list may be found in Appendix 2.

Chemical Contaminants

Chemical contaminants are suspended in the water column prior to deposition on benthic substrates. The National Pollutant Discharge Elimination System (NPDES) permit monitoring, as well as State-level water quality assessment programs such as Total Maximum Daily Loads (TMDLs), monitor amounts of contaminants in surface waters. The NPDES permit program controls water pollution by regulating point sources that discharge pollutants into United States waters. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards (Total Maximum Daily Loads 2005). These programs provide a wealth of information that may be useful in quantifying the amounts of pollutants that make their way into coastal water bodies.

Fish Tissue Indicators

Chemical contaminants may enter marine organisms via direct uptake from contaminated water, consumption of sediment, or consumption of previously contaminated organisms (EPA 2004b). Fish tissue taken from flesh, and organs such as the liver, is frequently used as an indicator. Fish tissue contamination data has been used for issuing human consumption advisories, however, as mentioned earlier, little is know on precise chemical concentrations that may affect fish productivity or have community level effects on fish populations.

In a recent study, Atlantic cod livers and gonads were sampled from six locations within Georges and Stellwagen Banks and Wilkinson Basin. An objective of the study was to provide baseline concentrations for the selected sites and cod stocks for future comparisons (Monoson pers. comm. 8/15/2005). Tissues from other benthic fish species such as flounder are often analyzed. Incidence of lesions, tumors, and disease are examined and utilized as indicators of coastal environmental health (Gardner et al. 1989, Hammeedi et al. 2002, Johnson et al. 1993, O'Conner and Huggett 1988).

1.3 Conclusion

This section has presented a brief inventory of coastal environmental health indicators important to the New England region. This is provided to familiarize the reader with the types of information that are available and their potential relationship to fish species and populations.

Indicators of sediment quality such as sediment toxicity provide valuable information on the presence of potential toxic contaminants that may impair reproduction and larval development in marine fish species. Dissolved organic nutrients such as nitrogen and phosphorus and dissolved oxygen are important indicators utilized to determine water quality. High levels of nutrients can lead to eutrophic conditions that may result in fish mortality. Fish tissue samples are frequently used as an indicator of water quality, and with localized fish populations they may provide information regarding the presence of toxic chemicals in the marine environment.

Analyzing multiple indicators simultaneously will likely provide mangers with a greater understanding of coastal environmental health. For example, fish tissue samples used as an indicator of area contamination may be flawed due to the mobility of the organism. Analysis using a combination of indicators may provide an increased level of detail, taking us closer to a level of accuracy and specificity that may prove sufficient for mangers and scientists to incorporate these important issues into stock assessments and management advice. Therefore, the information that is collected through these programs, if focused on properly selected indicators and monitoring programs germane relevant to the interface of pollution and marine fisheries, may eventually assist in developing effective coastal and offshore management programs.

Monitoring programs should be established to match the scale of the problem. The scale of the pollution issue varies from small localized areas to the greater New England region and the coastal-terrestrial interface. To provide management with necessary data and information, monitoring programs established for the large marine ecosystem as well as riverine systems that act as tributaries to coastal zones will be most beneficial.

The continued use of current indicators and the establishment of innovative monitoring programs will greatly assist in with the identification of conditions and trends that will assist in the decision making process.

Appendix 2 – *To be added*

Christy Finlayson. 2003. Inventory of Environmental Monitoring Program, Draft.
Gulf of Maine Council on the Marine Environment, Environmental Quality Monitoring Committee. December 2003.