Fisheries

[This page left intentionally blank]

Fisheries in an Ecosystem Context

1. Some Underlying Themes

* Inshore fish populations are affected by fisheries harvesting and land use activities in coastal watersheds (habitat loss/degradation, toxic pollution, eutrophication, etc.) and coupling with offshore physical, biological oceanographic processes (NAO, thermal gradients, offshore nursery grounds supporting inshore stock recruitment)-interaction with other working groups.

* Offshore fish populations are affected by fisheries harvesting and climate change interaction with climate working group on potential impacts of climate change on the lower levels of the food web supporting fish.

* Focus on fisheries ecology, biodiversity, ecological integrity of ecosystem and associated socioeconomic concerns.

* Potential clients for fisheries indicator working group output: EPA Coastal Condition Report, Gulf of Maine Council (GOMC) State of the Gulf Report; state/federal fisheries agencies.

* Dr. Spencer Apollonio's book on "Hierarchical Perspectives on Marine Complexities: Searching for Systems in the Gulf of Maine", which discusses ecological hierarchy theory and emergent properties of specific spatial/temporal scales of the physical environment in relation to the associated biotic components (plankton, nekton, marine mammals/seabirds). Similar ideas on the characteristic spatial/temporal scale of physical forcing factors and biota have been put forward by Drs. John Steele and Jurgen Sundermann (2003).

* Consider other living marine resources (LMRs) in addition to target and non-target fish populations: marine mammals, seabirds, other nekton?

* Ecosystem context includes essential fish habitat (EFH), predator/prey interactions, biodiversity, status of stocks (based upon biological characteristics), physical/chemical hydrographic characteristics, etc.

2. Key Questions and Indicators

* What is the status of fish stocks?
* What is the impact of fish harvesting on non-target species?
* What is the impact of gear types on habitats and species?
* What are the socioeconomic drivers in fisheries?

(a) Abundance and Distribution

* Fisheries-Independent Surveys (bottom trawls for demersal species, hydroacoustic surveys or midwater trawls for pelagic species, and beach seines for estuarine species) provide indices of relative abundance for target and some non-target species which can be used in stock assessments to provide estimates of absolute abundance; provides information on spatial/ temporal distribution which can be displayed as maps and analyzed by geographic information systems (GIS) to show changes over time, or multivariate statistical tools to derive other indicators. (See Link et al. (2002) for an example of deriving ecosystem-based fisheries management reference points/control rules; Bremner et al. (2003) for an example of using benthic macrofauna biological traits analysis for examining fishing impacts).

* Fisheries-Dependent Data on landings and locale: catch per unit effort (CPUE) can provide an estimate of abundance for target species; onboard observers can get information on bycatch of marine mammals, sea turtles, non-target fish species and possibly seabirds depending upon the gear deployed. For example, based upon bycatch in relationship to marine mammal abundance (OSP), U.S. federal fisheries are categorized into levels 1 (high), 2, or 3 (infrequent) to assess impacts on strategic marine mammal stocks; vessel monitoring systems (VMS) on some commercial fishing vessels provide information on fishing locations.

* Biological sampling through fishery-independent and dependent surveys (observers or port sampling) can provide information on age and growth, life stage and maturation status, and other data on the condition (weight/length ratio $K=W/L^3$; liver/somatic index = ratio of liver weight to total weight, or RNA:DNA ratio as growth indicators; gonadosomatic index = ratio of gonad weight to total weight for fish; the scope for growth can be used as an indicator for filter feeding mollusks) of fish species: size-at-age distribution and proportion of population in different age classes can be used as an index of overfishing. Rochet and Trenkel (2003) discuss a range of community indicators along a gradient from single species management to multispecies approaches and suggest using indicators, such as mean length and weight in community and proportion of noncommercial species in catch.

(b) Food Web Impacts -analysis of fish stomachs provides information on predator/prey interactions and their temporal/spatial changes: this data is used to estimate natural mortality in stock assessments and describe open water EFH in fisheries management. Even though ecosystem health is difficult to define operationally, researchers have defined indices for biodiversity (species richness and evenness) and biotic integrity (Linda Deegan's Estuarine Biotic Integrity Index) which could be used to evaluate food web impacts (See discussion in Rochet and Trenkel on why population-based indices are more useful in single species fisheries management.). Issues to be resolved include choosing the baseline for comparison for biodiversity and integrity indices and linking causes to perceived changes.

(c) Essential Fish Habitat (EFH) is often based upon benthic habitats defined by relative abundance of species in bottom trawl surveys or multibeam maps of geological bottom types plus key descriptive information on key water column parameters (depth, salinity, temperature, and dissolved oxygen). There is a lack of quantitative understanding of the functional value of different EFH (levels 3 and 4 in NMFS classification) and fisheries scientists use our qualitative understanding (NMFS levels 1 and 2) to define EFH in federal jurisdictional waters (3-200 miles). EFH data is used to define habitat areas of particular concern (HAPC) to allow for special protection, and by fisheries agencies to comment on the potential impact of non-fishing, anthropogenic activities (dredge spoil disposal, oil/gas development, gravel mining, wind farms, pipelines, etc.).

Areas such as "no take" marine reserves provide descriptive information on impacts of fishing gear on EFH and non-target LMRs. The challenge is to convert this descriptive information into useful indicators. For example, Marine Protected Area (MPA) indicators include: size-at-age distribution of fish within, fish biomass within, fish biodiversity within, epibenthic biomass and biodiversity within, and export of larvae and juveniles/adults to external ecosystem. If one uses biodiversity, it is necessary to operationally define the biotic components of interest to managers: seabirds, sea turtles, marine mammals, nekton, macrobenthic epifauna and infauna, etc., since the biodiversity of the water column is dominated by the microbial loop and of the sediments by the meiofauna and microfauna which are poorly understood.

In estuaries, submerged aquatic vegetation (SAV), wetlands, mud flats, and sandy bottoms provide EFH for specific fish species. For example, the linkage between bay scallops and eelgrass beds could be used to develop an index between the mapped loss of eelgrass and the declines in bay scallop harvests. Unfortunately most finfish are habitat generalists, so that this approach is not applicable. There are certain guilds of fish that co-occur, such as sea robins which are ambush predators for juvenile cod and haddock near net snag areas that one can potentially map. There is a need for more research on the functional value of habitat. Identifying research priorities linking specific LMRs to the functional value of EFH and top priority habitats for multibeam surveys could be a useful approach.

(d) <u>Socioeconomic Indicators:</u> direction will depend on economists participating in working group. Fisheries management agencies collect data on the characteristics of the fishing fleet, landings, changes in coastal fishing communities, etc. which can be converted into indices of effort, direct and indirect value (ex-vessel cost/return, tonnage) of commercial and recreational landings, level of participation of commercial and recreational fishers in harvesting different species, level of other local and regional income generated from fishing, etc. Since fisheries agencies manage fishermen/women (fishers) and not fish, there is a need to convert this socioeconomic data into useful information by identifying appropriate indices of socioeconomic behavior.

There is much less information available on the natural capital value of fish stocks as a natural trust resource managed by federal/state fisheries agencies and the impacts of fishing and other anthropogenic activities on this natural capital. Dr. Steve Edwards (NMFS/NEFSC) has conducted some research on the natural capital aspects of sea scallop stocks and the sustainable development literature discusses approaches linking economic activities to their ecological consequences. (See Parris and Kates, 2003). Some appropriate indices for natural capital values are needed that could be used in cost/benefit analysis to assess the impacts of anthropogenic activities on LMRs. Tools are needed to evaluate the efficacy of moving from single species to EbM (ecosystem-based management) approaches. There will be tradeoffs between costs of monitoring/ analysis and the approaches (tactical versus strategic) for harvesting and natural resource trust responsibilities at different points along this gradient. The increased complexities of multispecies management approaches require better visualization tools to aid decision-makers (Collie et al., 2003).

3. The fisheries working group agenda will be based upon: interests and expertise of participants; fisheries-related topics discussed in aquatic habitat, climate change, eutrophication, and toxic contaminants working groups; concept paper which discussed the four potential questions of interest suggested by the Steering Committee; web-based survey for workshop; and feedback from Steering Committee members who brief their senior policy makers on issues which should addressed in the fisheries working group.

The working group participants will need to decide the proper balance between ecosystems-based fisheries management (harvesting, multispecies interactions, impacts on essential fish habitat, effects of bycatch on nontarget species, etc.) and examining fisheries in an ecosystem context (climate change, nutrients, toxics, land use change, stochastic environmental change, and fisheries harvesting impacts on food webs). Given the broad range of potential clients for the output from the fisheries working group, we will need to prioritize our discussion to those useful to managers/senior policy makers. The overall goal is to identify indicators which can link monitoring/data gathering efforts to information needs required to manage fisheries in a more holistic context than the current single species approaches. The working group will develop recommendations for consideration by the Senior Managers Panel and other working groups and hopefully receive some constructive feedback.

4. References.

Appolonio, S. 2002. Hierarchical Perspectives on Marine Complexities: Searching for Systems in the Gulf of Maine. Columbia University Press; New York; 279 pp.

Bremner, J., C.L.J. Frid, and S.I. Rogers. 2003. Assessing marine ecosystem health: The long-term effects of fishing on functional biodiversity in North Sea benthos. Aquatic Ecosys. Health & Mngmt. 6:131-137.

Collie, J.S., H. Gislason and M. Vinther. 2003. Using AMOEBAs to display multispecies, multifleet fisheries advice. ICES J. Mar. Sci. 60:709-720

Deegan, L.A., J.T. Finn, S.G. Ayvazian, C.A. Ryder-Kieffer, and J. Buonaccorsi. 1997. Development and validation of an estuarine biotic integrity index. Estuaries 20:601-617.

Edwards, S.F. In press. Accounting for rents in the U.S. Atlantic sea scallop fishery. In Our Living Oceans-Economic Report.

Link, J., J.K.T. Brodziak, S.F. Edwards, W.J. Overholtz, D. Mountain, J.W. Jossi, T. D. Smith and M.J. Fogarty. 2002. Marine ecosystem assessment in a fisheries management context. Can. J. Fish. Aquat. Sci. 59:1429-1440.

Parris, T.M. and R.W. Kates. 2003. Characterizing and measuring sustainable development. Annu. Rev. Environ. Resour. 28:13.1- 13.28.

Rochet, M-J. and V.M. Trenkel. 2003. Which community indicators can measure the impact of fishing? A review and proposals. Can J. Fish. Aquat. Sci. 60:86-99.

Sundermann, J. 2003. The changing North Sea: knowledge, speculation, and new challenges. Oceanologica 45:247-259.

[This page left intentionally blank]

Contaminants

[This page left intentionally blank]

Northeast Indicators Workshop
January 6-8, 2004

Contaminants Concept paper

CONCEPTUAL

Types & intensity of sources:
Contaminants enter the marine ecosystem through a variety of mechanisms; including atmospheric deposition, direct discharges from industrial and municipal waste streams, combined sewage overflows, accidental spills, ballast water and other direct marine vessel discharges, runoff from land, especially in urbanized areas covered with impervious surfaces, and agricultural, residential and recreational (golf courses) areas, human disturbances, aquaculture facilities, etc. Historic contamination can be rendered unavailable via burial or be reintroduced as a result of dredging or resuspension of sediments associated with wind and wave action, boat motor propellers and bathing, or through the natural process of biodegradation

Transport mechanisms within marine systems
An understanding of the hydrodynamics of estuaries, bays and the systems within the region (e.g. Gulf of Maine) is essential for knowing the potential transport and fate of contaminants in the marine environment. As contaminants are introduced, either by rivers and streams, deposition from air, through stormwater runoff, or directly from waste discharges, many undergo transformation with respect to chemical speciation that may affect transport. For chemicals of environmental concern (COEC), complexation with different ligands, or sorption onto colloids or particulate matter will influence their fate and transport. Those associated with fine particles, colloids, or dissolved can be carried long distances into and within the marine environment. Contaminants that are delivered to the surface waters by dry and wet atmospheric deposition may have distributions that are fairly ubiquitous and far-reaching (e.g., mercury). Finally, transport of contaminants to the GOM marine environment may involve introduction via ballast water, boat hulls, bait and even migratory animals.

Processes affecting availability
Once in the environment, contaminants are subject to a variety of biological, physical and chemical processes that affect their availability and forms. Indigenous microorganisms can beneficially degrade organic contaminants or reduce populations of harmful microbes through predation and competition. Microorganisms and physico-chemical processes can also transform chemical contaminants into more (toxification) or less (detoxification) harmful substances, or change chemicals into more or less available forms. Microbial contaminant concentrations may decrease or increase with death and growth, and the viability and virulence may be changed by environmental conditions. Contaminants may be bound to particles, organic matter and charged inorganic surfaces, complexed with colloidal material, or have reduced solubility or bioavailablity by complexation with sulfides and other ligands. Many COEC (e.g. lead, polycyclic aromatic hydrocarbons) are particle-reactive and eventually end up buried in sediments.

Ecosystem function of contaminants
Nutrients such as nitrogen and phosphorus, are essential macro-nutrients to plants, but can have harmful ecosystem impacts at elevated concentrations. Some trace metals, considered to be toxic contaminants at high concentrations, are actually essential nutrients at low concentrations (e.g., Zn, Fe). Microbial contaminants, especially naturally occurring pathogens, also have some function in the environment, despite their deleterious effects on humans.

Exposure routes
The environmental processes that affect contaminants also dictate their availability to biota. For instance, changes in solubility of chemical contaminants can occur as a result of exposure to differing environmental conditions. Photooxidation can cause loss or changes in chemical speciation. Binding of chemical and microbial contaminants to solid surfaces renders them less available for exposure to biota, except when particles are taken up as part of the feeding activities of organisms. Metabolic processes in exposed biota can also transform contaminants in ways that result in detoxification, excretion, etc.

Multiple contaminants
In many contaminated areas, biota are exposed to multiple contaminants and thus the cummulative effect of exposure to discharged wastes or environmental conditions is more complex than what might be expected from exposure to a single contaminant. Different types of contaminants can also affect the availability and eventual exposure of biota to other types of contaminants. Thus, conceptualization of the sources, fate and effects of contaminants in the region environment is complex. Further research, monitoring, risk assessment and modeling will help to clarify these issues.

SIDE BAR ISSUE

Climate change effects and other factors
The general consensus that long-term climate change will result in warmer temperatures and more severe weather will influence the presence of contaminants in the GOM. Perhaps the most drastic changes will occur with the present mix of species. Increased temperatures are suspected to be contributing to increases in disease incidence in numerous seafood species, probably as a result of stress and more favorable conditions for microbial pathogens. Other effects on the climate, including temperature, dissolved oxygen, salinity, etc. will affect the balance of species in the ecosystem. Stormwater runoff, an important transport mechanism for contaminants in coastal areas will probably increase in the future as well. Factors affecting runoff include climate change-induced increases in severe weather and increases in impervious surface coverage with continued development within coastal watersheds.

MANAGEMENT ISSUES

The first level question managers often need to address is whether COEC are present and at what concentrations. Some guiding questions are:

- What are the concentrations of COEC in biota, sediments, air and water in the region?

- Are there new or emerging contaminants to consider?
- Where are COEC present and are there areas with high concentrations?
- Are concentrations of COEC changing with time?

Another basic consideration is the origin of the contaminants.
- What and where are the sources of contaminants?
- Are there localized source sites and do they affect surrounding areas? To what extent?

As information is being and/or has been compiled on exposure and sources, the impacts of contaminants need to be documented. The most important impacts for contaminants are typically public health effects and toxic or otherwise deleterious effects on important organisms in the region's ecosystems (NOTE: need to emphasize both human health and ecosystem level impacts).

- How many people have become infected or ill from contaminants?
- Are there effects on biota resulting from elevated levels of contaminants?
- Are there effects on biota resulting from low contaminant levels?
- Is biomagnification occurring?

Finally, as managers respond to documented effects and efforts are made to reduce or eliminate sources of contaminants, it is important to document whether actions are actually improving conditions, as intended?

- Is there evidence of improved conditions through time and space as a result of contaminant source reductions?
- Are resource harvesting and recreational uses affected?

Probably the next level entails linking available models to estimate loads and/or effects and to conduct risk analysis and management. For instance, estimates of point and non-point loading rates may be obtained by use of point source permits (NPDES, CAA) data and land use activities within the region (See Paul. J.H. et al. 2003). In addition, EPA fate and transport models can be used to link loading rates to potential biological effects on humans and biota. Another suggestion is to conduct risk analysis and characterization (i.e., application of EPA watershed-based ecological risk assessments which can be used to compare contaminants with other human stressors on valued ecosystem components) and risk management through the development of management strategies that incorporate political and socioeconomic factors.

POSSIBLE INDICATORS

- Microbial indicators of fecal contamination (e.g., fecal coliforms, enterococci, coliphage viruses, source-specific bacterial species) and other source-related indicators (brighteners, isotope ratios, rare element work in MA Bay);

- concentrations of COEC in biota;
- bio toxicity tests of media;
- biomarkers of exposure or effects from contaminant exposure
- sensitive indicator species
- biotic integrity indices
- concentrations of COEC in sediments, air and water
- loading measurements and estimates
- Number/frequency of beach closures:
- Number/frequency of seafood consumption warnings;
- acreage of shellfish closures;
- effects evidence: habitat degradation, biotic community impacts (e.g., species diversity, shifts in dominance, loss or rare species)

ONGOING INDICATOR MONITORING PROGRAMS

National Coastal Assessement, National Shellfish Sanitation Programs (NSSP)& state/provincial SSPs, beach monitoring
NOAA Mussel Watch, Benthic Surveillance and Bioeffects Study
Gulfwatch, GoMOOS
NPDES, PSP monitoring
Casco Bay and New Hampshire Estuary Project (sediment, mussel, lobster sampling)
Ongoing national air monitoring programs (MDN, NADP, IMPROVE)
Maine SWAT Program,
Other NEP and state toxics monitoring programs
Citizen volunteer monitoring groups

Eutrophication

[This page left intentionally blank]

Concept Paper for Northeast Indicators Workshop, January 6-8, 2004
Management Priority and Corresponding Indicators: Eutrophication

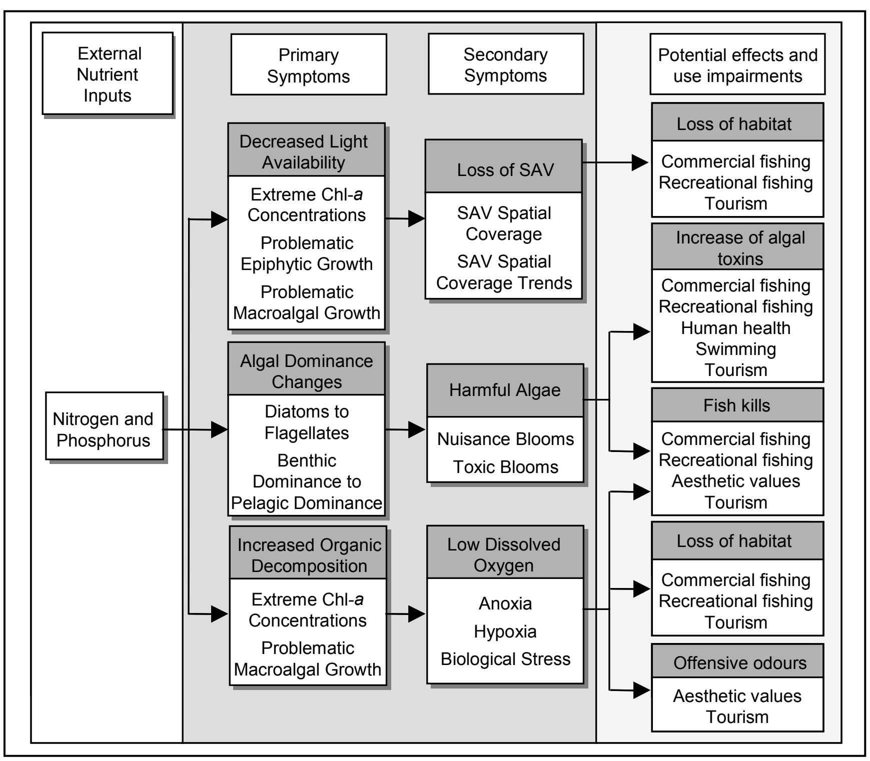
Background: National and Regional Significance

Nutrient pollution has recently been identified as the greatest threat to US coastal water quality (Boesch et al, 2001; NRC, 2000; CSO, 1999). Sources of nutrients include atmospheric, groundwater, point and non-point with potential consequences ranging from ecological changes to socio-economic impairments (e.g. fisheries), to serious human health threats (See Fig. 1).

Symptoms of eutrophication include low dissolved oxygen, excessive and unsightly algal blooms, and losses of submerged aquatic plants that serve as habitat for coastal fisheries. These impacts cause economic losses to tourism, and to commercial and recreational fisheries (Lipton and Hicks, 1999, 2003; Lipton, 2003). Additionally, weakening or destroying native flora and fauna provides the opportunity for colonization by invasive species.
Results of the National Estuarine Eutrophication Assessment (NEEA; Bricker et al., 1999) show that nationally, significant problems are observed in 60% of estuaries. On a regional basis, North Atlantic systems are much less impacted than those along other coasts. In Contrast to other regions, the largest nutrient sources to many of these systems is from the ocean, rather than the land.

Though there are localized impacts, eutrophication is not a major issue in this region (CICEET, 2001). The NEEA assessment of systems as highly eutrophic is a result of the application of indicators and thresholds that may not be reflective of conditions in this region. However, both the NEEA and CICEET reports indicate that conditions will likely worsen in the future as land based sources increase if something is not done now to limit nutrient inputs to these water bodies.

Figure 1: Eutrophication model (from: Bricker et al., in press)



Clearly there is a need to monitor and assess causes and consequences of nutrient related water quality conditions to provide the basis for effective management of this problem. Equally needed is a re-evaluation of the methods used to assess conditions in Gulf of Maine systems.

Key Assessment and Management Questions

A program to address issues of nutrient related eutrophication should consider the following questions:

- What is the extent and severity of eutrophication in the region?
- What are appropriate indicators and indicator threshold levels (ie above/below which a problem is indicated) of eutrophication for this region?
- What are the appropriate temporal and spatial scales over which these indicators should be measured?
- Which estuaries are impacted? Are there hotspots in the region?
- What is the rate of eutrophication, is it changing, and to what extent can the severity and extent be expected to improve/worsen within the next 20 years?
- To what extent are observed eutrophic conditions caused by human activities?
- What are the sources of high nutrient levels (land, offshore current, effluent, etc.) and how successfully could they be controlled?
- To what extent do eutrophic conditions impair human uses of estuaries and what are the important impaired uses?
- What is the economic cost of eutrophication in the region?
- Have management controls been implemented? How successful are they?
- Where should management efforts be targeted to achieve the greatest benefit toward remediation and protection from further degradation?
- What data gaps and research and monitoring needs are most critical in terms of improving the ability to assess and respond to eutrophication?
- How can the results of this indicator workshop be translated into a regional/national strategy?

Potential Indicators and Assessment Methods

The 1999 National Estuarine Eutrophication Assessment report (Bricker et al., 1999) developed an index of eutrophication using a combination of observed condition, spatial coverage and frequency of occurrence of problem levels of 6 indicator variables. Three were considered to be early indicators of eutrophication (Chl a, epiphyte, macroalgae) and three were considered indicators of well developed eutrophication (depleted dissolved oxygen, loss of SAV, occurrence of HABs).

Modifications have been made to the methodology (Bricker et al., in press) including use of a model that identifies primary nutrient sources using end member and average estuarine nutrient concentrations. Additional improvements are being made on a national basis including development of a type classification for estuaries so that appropriate indicator variables and indicator threshold levels can be applied by type of estuary (NEEA Update doc, In press).

There is also a regionally based CICEET Development Project underway to re-evaluate indicator variables and thresholds to assure accurate assessment for Gulf of Maine systems (Bricker et al., In prep.). This project is also developing a socioeconomic index, to complement the condition index, that will provide insight to the costs of nutrient related eutrophic conditions on human uses of these systems. Some of the recommended indicator variables for consideration for Northeast estuaries are shown in Table 1.

Table 1: Indicator variables recommended at a National workshop in September 2002 (NEEA Update, In press) and at a CICEET Development Project workshop in June 2003 (Bricker et al., In prep.).

Input Variables (all year or annual value)	**Physical-chemical Variables (annual cycle)**	**Biological Variables (annual cycle)**
• Nutrient loading • Freshwater flow	• Temperature (surface/bottom (profile) in stratified areas)* • Salinity (surface/bottom (profile) in stratified areas)* • Dissolved Oxygen (concentration/saturation: surface & bottom water or water column in specific circumstances, sample depth, total depth, time of the day, tidal stage) • Turbidity (Secchi, NHU, TSS, K_D) • Nutrients dissolved (inorganic & organic components (NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}, Si, Total nutrients (TN, TP, Si), N:P:Si ratios), • Sediment organic content • CDOM*	• Chlorophyll a (annual maximum value and/or maximal area under curve for specific time period) • Phytoplankton Indicator species (4 – 5 spp): e.g. diatoms, foraminifera, dinoflagellate cysts • Ratio diatoms : flagellates • Seagrass/SAV: Spatial coverage Ratio coverage : potential coverage • Macroalgae: Spatial coverage at max growth/max coverage Dominant/indicator species, relative abundance (*Ulva, Gracilaria*) • Epiphyte* biomass / area of SAV leaf or surface

* NOTE: These two variables should perhaps be sampled at the same level of distinction that DO is sampled in systems where stratification is known. (Ex.: surface & bottom water or through the water column, sample depth, total depth, etc.)

Selected References

Boesch, D.F., R.H. Burroughs, J.E. Baker, R.P. Mason, C.L. Rowe, R.L. Siefert. 2001. Marine Pollution in the US. Prepared for Pew Oceans Commission, Arlington, VA.

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 National Centers for Coastal Ocean Science. Silver Spring, MD. 71pp.

Bricker, S.B., J.G. Ferreira, T. Simas. An Integrated Methodology for Assessment of Estuarine Trophic Status. Ecological Modelling. In press.

Bricker, S., C. Krahforst, J. Pennock, D. Keeley, M. Dionne, J. Latimer, A. Mason. Data acquisition and development of metrics and indices to describe the status and track trends of nutrient related water quality in estuaries and coastal waters. FY03 Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) Development Proposal.

Coastal States Organization (CSO). 1999. Technology and Information needs of the Coastal and Estuarine Management Community. NOAA, OOCR and CICEET.

Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). 2001. Workshop Report 2001: Managing Nitrogen

Impacts in the Gulf of Maine. 9pp + Appendices 1-6.

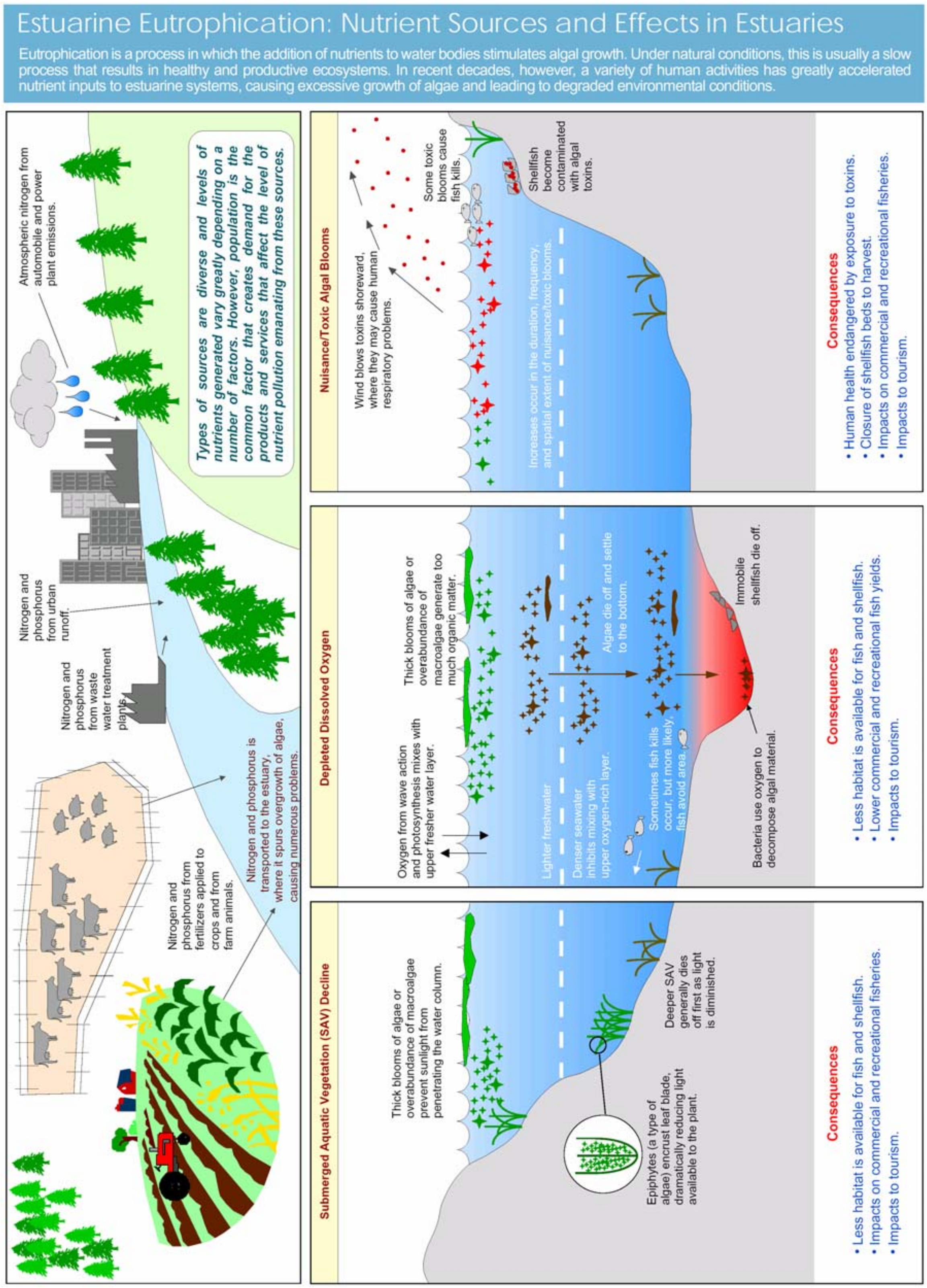
Lipton, D.W. and R. Hicks. Linking water quality improvements to recreational fishing values: The case of Chesapeake Bay striped bass. In: Evaluating the Benefits of Recreational Fisheries. Fisheries Centre Research Reports 7(2). University of British Columbia. 1999.

Lipton, D.W. and R. Hicks. 2003. The cost of stress: Low dissolved oxygen and recreational striped bass (Morone saxatilis) fishing in the Patuxent River. Estuaries 26(2a): 310-315.

Lipton, D.W. The Value of Improved Water Quality to Chesapeake Bay Boaters. Working Paper, Department of Agricultural & Resource Economics, University of Maryland, College Park, MD. 2003.

National Oceanic and Atmospheric Administration (NOAA) In press. National Eutrophication Assessment Update: Workshop Summary and Recommendations for Development of a Long-term Monitoring and Assessment Program. Proceedings of a Workshop September 4-5, 2002 at the Patuxent National Wildlife Research Refuge, Laurel, Maryland. 17pp.

National Research Council (NRC). 2000. Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. Natl. Academy Press, Washington, D.C. 405pp.


Estuarine Eutrophication: Nutrient Sources and Effects in Estuaries
Eutrophication is a process in which the addition of nutrients to water bodies stimulates algal growth. Under natural conditions, this is usually a slow process that results in healthy and productive ecosystems. In recent decades, however, a variety of human activities has greatly accelerated nutrient inputs to estuarine systems, causing excessive growth of algae and leading to degraded environmental conditions.
Nitrogen and phosphorus from fertilizers applied to crops and from farm animals.
Nitrogen and phosphorus is transported to the estuary, where it spurs overgrowth of algae, causing numerous problems.
Nitrogen and phosphorus from waste water treatment plants.
Nitrogen and phosphorus from urban runoff.
Atmospheric nitrogen from automobile and power plant emissions.
Types of sources are diverse and levels of nutrients generated vary greatly depending on a number of factors. However, population is the common factor that creates demand for the products and services that affect the level of nutrient pollution emanating from these sources.
Submerged Aquatic Vegetation (SAV) Decline
Thick blooms of algae or overabundance of macroalgae prevent sunlight from penetrating the water column.
Epiphytes (a type of algae) encrust leaf blade, dramatically reducing light available to the plant.
Deeper SAV generally dies off first as light is diminished.
Consequences
• Less habitat is available for fish and shellfish.
• Impacts on commercial and recreational fisheries.
• Impacts to tourism.
Depleted Dissolved Oxygen
Oxygen from wave action and photosynthesis mixes with upper fresher water layer.
Thick blooms of algae or overabundance of macroalgae generate too much organic matter.
Lighter freshwater
Denser seawater inhibits mixing with upper oxygen-rich layer.
Sometimes fish kills occur, but more likely, fish avoid area.
Algae die off and settle to the bottom.
Bacteria use oxygen to decompose algal material.
Immobile shellfish die off.
Consequences
• Less habitat is available for fish and shellfish.
• Lower commercial and recreational fish yields.
• Impacts to tourism.
Nuisance/Toxic Algal Blooms
Wind blows toxins shoreward, where they may cause human respiratory problems.
Some toxic blooms cause fish kills.
Shellfish become contaminated with algal toxins.
Increases occur in the duration, frequency, and spatial extent of nuisance/toxic blooms.
Consequences
• Human health endangered by exposure to toxins.
• Closure of shellfish beds to harvest.
• Impacts on commercial and recreational fisheries.
• Impacts to tourism.

[This page left intentionally blank]

Coastal Development

[This page left intentionally blank]

V 2.0 11/17/03

Concept Paper: Land Use
Northeast Indicators Workshop, January 6-8, 2004

Chester Arnold, University of Connecticut, Bruce Carlisle, Massachusetts Coastal Zone Management Program,, and Jeff Schloss, University of New Hampshire

BACKGROUND

National and Regional Significance of Land Use Change

The widespread impacts of land use change on our environment are increasingly evident. A recent NASA-funded study concludes that the contribution of human-induced land cover change on climate is at least as important as that of carbon dioxide (Pielke *et. al*, 2002). A report on the impact of urbanization on groundwater supplies estimates losses to groundwater recharge in 20 American metropolitan areas to be in the tens of billions of gallons per year (Otto et. al, 2002). The Nature Conservancy reports that up to one-third of the country's animal and plant species are at risk of extinction due mainly to habitat loss and degradation from land use changes (Stein and Flack, 1997).

Coastal waters are no exception. The Pew Commission (2001, 2002) reports that over 20,000 acres of coastal habitat disappear each year, and that every 8 months an amount of oil equivalent to the *Exxon Valdez* spill enters coastal waters via runoff. EPA's latest National Water Quality Inventory reports that 51% of assessed estuaries and 78% of assessed Great Lakes shoreline are impaired, with urban runoff being the second leading pollutant of estuaries (EPA, 2000). The National Coastal Condition Report reached similar conclusions, giving the status of the nation's estuaries a "fair" grade, and the Northeast a "poor" grade, based on seven basic criteria of coastal condition (EPA, 2001).

State of Land Use Change in America and in the Region

America is an urbanizing country. According to the latest estimates by the USDA Natural Resources Inventory (NRCS, 2003), between 1982 and 2001 about 34 million acres – an area the size of Illinois – were converted to developed land from forest and farm land. The majority of this urbanization is occurring in coastal areas. More than half of the U.S. population lives in coastal counties, and NOAA projects that by 2010, more than 75 percent of the U.S. population is expected to live within 50 miles of the coast (Culliton *et al*., 1990). The Pew Commission (2003) reports that the resident population along the coast is expected to increase by 25 million people by 2015.

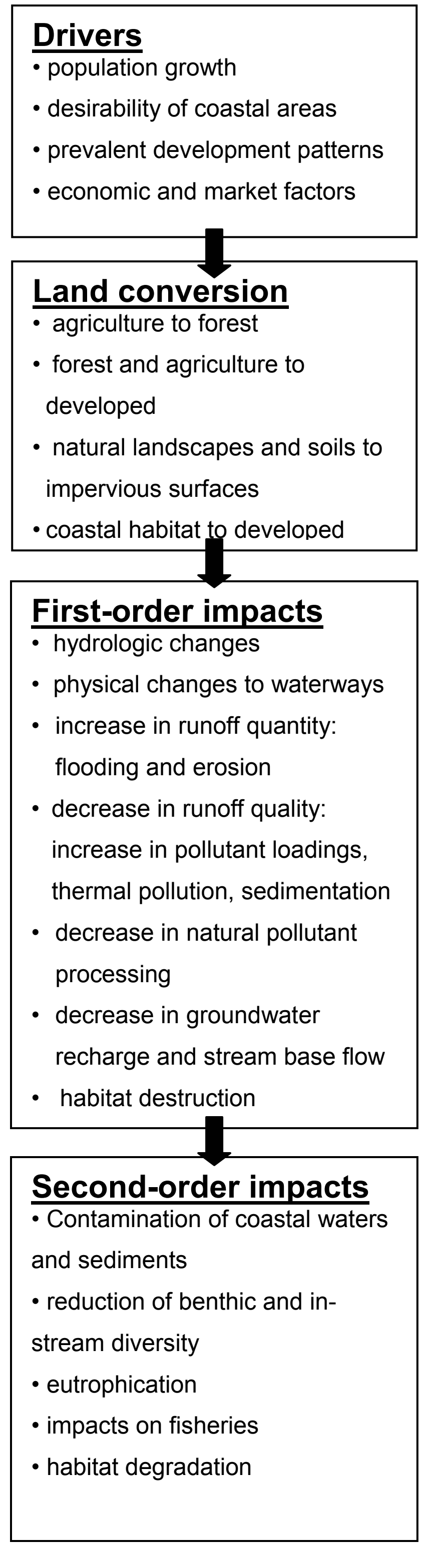
Population growth, however, is not the sole driver of the urbanization process. As many have reported, the post World War II land-consumptive form of development often known as "sprawl" generates land conversion rates that far outstrip population growth. For instance, a study in the Charleston, SC area found that over the 21-year period from 1973 to 1994, urban land use growth exceeded population growth by a 6:1 ratio (Allen and Lu, 1998). A recent NOAA-funded report estimates that by 2025, the nation's top 20 coastal and Great Lakes metropolitan regions are likely to increase their "urban footprints" by 46%, expanding an additional 9,000 square miles (McGrath, 1999).

While the Northeast has the distinction of being the one area of the country that is gaining in forested land (due to the rapid abandonment of active farmland), it is also the most urbanized portion of the country. According to the USDA National Resources Inventory (1997, updated yearly), the East Region (New England plus NY, NJ, PA, DE, MD and WV) gained 4 million acres of developed land during the 1982 to 1997 period, and has nearly twice the national average of developed land and almost 4 times the national population density. The Northeast accounts for about 35% of the nation's coastal population (Culliton *et al.,* 1990).

Status of Research

The impacts of urbanization on coastal resources are well documented but not necessarily well understood. Studies of nonpoint source loadings and their relationship to land use, for instance, have only been in existence for about 20 years, and the majority of such studies have concentrated on agricultural, rather than urban, runoff. Key research areas relevant to issues of monitoring and assessment include:

- ***Impervious surface and other landscape indicators***. A rapidly growing body of literature suggests that impervious surfaces are a key indicator of urbanization and its impacts on aquatic resources (Brabec *et al*., 2002; Arnold and Gibbons, 1996; Schueler; 1994), although a recent literature review points out that studies on the impacts of impervious cover on wetlands and coastal resources are relatively few (Schueler, 2003). The use of impervious cover as an indicator and basis for land use regulation has been growing. However, lately concerns have been raised that an over-emphasis on limiting imperviousness at the site level may promote low density, large lot development. Other, related indicators have been used in attempts to characterize or measure urban growth patterns or the intensity of "sprawl." These include everything from complex landscape analyses (Wilson *et al*., 2003) to individual landscape features like stream crossings (Booth *et al*., 2003) to socioeconomic measures (Ewing *et al.,* 2003). In the region, the New Hampshire Estuary Program recently completed a report that considers a number of coastal land use indictors (Trowbridge, 2003). Some researchers are investigating other land cover factors, such as the percentage of forest cover, as possible "reverse" indicators of potential watershed health, rather than of impairment
- ***Riparian buffers***. It is becoming generally recognized that riparian zones have high potential to function as nitrogen sinks, because of their position at the interface between terrestrial and aquatic components of the landscape and because they are often dominated by wet, anaerobic soils that support denitrification (Gold *et al.,*2001). However, many uncertainties remain on the temporal and spatial variation of riparian N processing, as well as the ability of buffers to reduce the impacts of other pollutants – including thermal pollution.
- ***Loading models and risk assessment tools***. Pollutant loading models built upon runoff models, and driven in large part by land use information, have come into increasing use across the country. Examples in the Northeast include a nutrient loading model in Waquoit Bay, Massachusetts (Bowen *et al*., 2002) and a sediment contaminant loading model in the mid-Atlantic and Southern New England (Paul *et al*., 2003). The MANAGE model developed at the University of Rhodes Island is a watershed risk-assessment tool that evaluates pollution risks associated with various land use and landscape features. (URI web site). In the Midwest, the *Long-Term Hydrologic Impact Assessment (L-THIA)* model developed at Purdue uses land use and soil characteristics, combined with



thirty years of precipitation data, to determine the average impact that a particular land use change or set of changes will have on both the annual runoff and the average amount of several non-point source pollutants (Bhaduri *et al.*, 2000).

KEY ASSESSMENT AND MANAGEMENT QUESTIONS

Key Considerations

"Land use" is a term encompassing a wide range of processes and impacts that overlap with the other major categories of indicators being discussed as part of this effort (diagram, page 2). Thus, a coordinated effort to assess and monitor land use change must be very closely integrated with the other monitoring and assessment efforts being considered under this initiative. In addition, several key issues must be considered:

- *Basic and Applied Research Base*: How far can we extrapolate our modest research base on the links between land use and coastal resource health? What can be done to improve our understanding of such critical topics as the relationship of land use to pollutant loadings, and the effect of nonpoint source "best management practices" on reducing NPS impacts?
- *Scale*: At what scale(s) must land use be monitored and assessed? There is probably a need for both large-scale watershed indicators and finer-scale water body-specific indicators, depending on the management questions to be addressed.
- *Methods*: What technologies are most appropriate, accurate, and feasible to produce regionally comparable data? Advances in remote sensing science and technology have made possible landscape characterizations that were impossible even 5 years ago. What are the trade-offs between resolution, repeatability, and price, and what is the best combination of remote and field monitoring techniques? What can we do to ensure comparable and uniform regional data?
- *End purpose*: Compounding the issue of urbanization and its impacts is the fact that land use is a local issue, decided primarily at the county and municipal level. As such, controlling or influencing land use is not particularly amenable to federal or state laws. A recent report by the General Accounting Office concluded that education, technical assistance and incentives were the most effective means to reduce the air and water quality impacts of land use decisions (U.S. GAO, 2000). Given this fact, what is to be done with the data once collected and interpreted? Who are the primary target audiences for this data, and how can the information be used to help influence land use change and its impacts?

Key Management Questions

Basic management questions that remain after the key considerations (above) have been considered include:

- What are the type, rate and pattern of land use and land use change?
- What are the broad watershed-scale impacts of these uses and changes?
- What are estimated pollutant loadings to the coast associated with these uses and changes?
- What are the localized biotic and abiotic effects effects of these uses and changes?
- What nonpoint source BMPs are being implemented, and where?
- What are the effects of these BMPs?
- What is the role and relative importance of natural areas (riparian buffers, vegetated landscapes) in preventing and/or ameliorating the impacts of land use change?
- What policies and programs can help to influence land use change and/or reduce the impacts of such change?

POTENTIAL INDICATORS & ASSESSMENT METHODS

In general, land use monitoring is sporadic and greatly variable. Fine scale monitoring is very labor intensive. Large scale monitoring is primarily dependent on remote sensing technologies that have evolved with time, thus making temporal comparisons of different data sets problematic. Despite these problems, however, the potential is great for the use of remote sensing technology to make regular, relatively inexpensive temporal assessments. USGS, EPA and a consortium of other federal agencies have developed the National Land Cover Data (NLCD) program, which created a nationwide land cover dataset for 1992 and is completing a comparable set for 2000. In the region, the University of Connecticut Center for Land use Education and Research is just completing a four-date RS-based land cover change study covering the period from 1985-2002, and will follow next summer with a similar temporal tracking of impervious cover. The University of New Hampshire Complex Systems Research Center has done impervious surface estimates for the 1990-2000 period for the coastal region of New Hampshire (Justice and Rubin, 2003). In Massachusetts, the Natural Heritage and Endangered Species Program and the UMass Extension Service have completed *BioMap*, which identifies critical habitat and natural buffer areas, and are developing the *Conservation Assessment and Prioritization System* (CAPS), a GIS-driven decision-support system designed to assess the biodiversity value of every location based on natural community-specific models.

Indicators addressing the impacts of land use change include both biological and physical indicators of aquatic health, and physical and social indicators of the degree of watershed development. This concept paper focuses on the latter, since the former are expected to be included in the other topical areas being considered at this conference. For discussion purposes, the potential indicators listed below are broken down into two major scale-dependent categories. "*Overall land use*" refers to broad land use changes from which broad conclusions can be reached, based on our knowledge about the relationship of land use to resource health. "*Specific landscapes*" refers to particular habitat or other resource areas of interest that may require more frequent and/or higher resolution, finer-scale monitoring.

<u>Overall land use</u>

- % urban/forest/farm land and changes over time
- % impervious surface and changes over time
- demographic data (population, density, housing starts, etc.)
- pollutant loadings models and coefficients
- type and pattern of urban growth; examples include:
    - acres urban land/capita
    - acres impervious cover/capita
    - total road miles
    - road crossings
    - watershed landscape fragmentation indices
    - "reverse indicators" such as % forest cover, riparian continuity indices

<u>Specific Landscapes</u>

- Miles intact stream buffers (how wide?)
- Acres tidal wetland, eelgrass or other critical habitat
- Acres & location of invasive species
- Acres & location of permanently protected natural lands ("open space")
- acres and location of restored habitat
- specific landscape integrity indicators (fragmentation, direct disturbance [fill, hydrologic alterations, etc.], indirect disturbance)

REFERENCES

Allen, J. and K.S. Lu. 1998. Modeling and Predicting Future Urban Growth in the Charleston Area. Published on the web at: http://www.strom.clemson.edu/teams/dctech/urban.html#

Arnold, C.L and C.J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. *Journal of the American Planning Association* 62(2):3243-258.

Beach, D. 2002. Coastal Sprawl: The Effects of Urban Design on Aquatic Ecosystems in the United States. Pew Oceans Commission, Arlington, Virginia.30 pp.

Bhaduri, B., Harbor, J., Engel, B. and Grove, M. 2000. Assessing watershed-scale, long-term hydrologic impacts of land use change using a GIS-NPS model. *Environmental Management,* 26(6), p. 643–658.

Booth, D.B., M. Alberti, C. Avolino, and C.S. Sossa. 2003. Determinants of Urban Stream Degradation. Proceedings of the Streams Channel Protection and Restoration Conference, October 6-8, Columbus, OH. Pp 9-14.

Bowen, J. 2002. Waquoit Bay Watershed Ecological Risk Assessment: The Effect of Land-derived Nitrogen Loads on Estuarine Eutrophication. EPA/600/R-02/079.

Brabec, E., S. Schulte and P.L. Richards. 2002. Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning. *Journal of Planning Literature* 16(4):499-514.

Culliton, T.J., M.A. Warren, T.R. Goodspeed, D.G. Remer, C.M. Blackwell, and J.J. McDonough III. 1990. Fifty years of population change along the nation's coasts, 1960-2010. National Oceanic and Atmospheric Administration Coastal Trend Series, 2nd rep. 41 pp.

Ewing, R., R, Pendall and D. Chen. 2003. Measuring Sprawl and Its Impact. Report of the Smart Growth America organization. 31 pp.

Gold, A.J., P.M. Groffman, K. L. Addy, D.Q. Kellogg, M. Stolt and A.E.Rosenblatt. 2001. Landscape attributes as controls on groundwater nitrate removal capacity of riparian zones. Journal of the American Water Resources Association. 37:1457-1464.

Justice, David and F. Rubin. 2002. Developing Impervious Surface Estimates for Coastal New Hampshire. A Final Report to the New Hampshire Estuaries Project. December, 2002. 25 pp.

McGrath, D.T. 1999. 2025 Urban Land Area Forecasts for the U.S. Top 20 Coastal Metropolitan Regions. Report of the Indiana-Illinois Sea Grant College Program.15pp.

Otto, B., K. Ransel and J. Todd. 2002. Paving our Way to Water Shortages: How Sprawl Aggravates Drought. Report of American Rivers, NRDC, and Smart Growth America. 34 pp.

Paul, J.F., R.L.Comeleo, and J. Copeland. 2003. Landscape metrics and estuarine sediment contamination in the mid-Atlantic and Southern New England regions. *Journal of Environmental Quality* 31: 836-845.

Pew Oceans Commission. 2003 America' Living Oceans: Charting a Course for Sea Change. Summary Report and Recommendations for a New Ocean Policy of the Pew Oceans Commission.35pp.

Pielke, R.A. Sr., G. Marland, R.A. Betts, T.N. Chase, J.L. Eastman, J.O. Niles, D.S. Niyogi, and S.W. Running. 2002. The influence of land-use change and landscape dynamics on the climate system: relevance to climate-change policy beyond the radiative effect of greenhouse gases. *Phil. Trans. R. Soc. Lond*. 360:1705-1719.

Schueler, T.R. 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Center for Watershed Protection, Ellicott Cit, MD142 pp

Schueler, T. R. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1(3): pp. 100-11. Published by the Center for Watershed Protection, Ellicott City, MD.

Trowbridge, P. 2003. Environmental Indicators Report: Land Use and Development. Re[port of the New Hampshire Estuaries Project, 35 pp.

U.S. Department of Agiculture, Natural Resources Conservation Service. 2003. National Resources Inventory 2001 Annual Report: Urbanization and Development of Rural Land.

U.S. Environmental Protection Agency (EPA). 2000. *Water quality conditions in the United States*. EPA Report 841-F-006. Office of Water, EPA, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 2001. National Coastal Condition Report. EPA Publication EPA-620/R-01/005.204 pp.

U.S. General Accounting Office, United States. 2001. Environmental Protection: Federal Incentives Could Help Promote Land Use That Protects Air and Water Quality. GAO-02-12, October 31, 2001. http://www.gao.gov/

University of Rhode Island Extension Water Quality Program website: http://www.uri.edu/ce/wq/mtp/html/manage.html

Wilson, E.H., J. D. Hurd, D.L. Civco, S. Prisloe, and C. Arnold . 2003. Development of a geospatial model to quantify, describe and map urban growth. *Remote Sensing of Environment* 86: 275-285.

[This page left intentionally blank]

Climate Change

[This page left intentionally blank]

Concept Paper/Fact Sheet
Northwest Atlantic Indicators Workshop
January 6-8, 2004
Regional Indicators for Climate Change

BACKGROUND

National and Regional Significance of Climate Change

"Climate change", "global warming", and the "greenhouse effect" have come to be household words in the society of the industrially developed nations of the world including the United States and Canada. The climate of the 21st century is likely to be significantly different from that of the 20th century. Whether the differences are a result of anthropogenically-induced climate change (man made impacts) or a result of natural long term cycles of climate and weather patterns or a combination of both is a matter that will be debated for years to come. Never-the-less, to US and Canadian citizens living and working in the northwest Atlantic region, these changes will be perceived mostly through the observation of increases in extreme weather events, changes in coastal landscapes, the appearance or disappearance of warm and cold water fish and shellfish, and shifts in maritime economy and uses. The Kyoto protocol and future initiatives, together with actions taken by the Canada and the US, are expected to reduce the impacts of the changes, but significant changes will still occur. Warming events such as the observed melting of the Greenland ice sheet and Canadian arctic icepack have been in the news recently.

Marine fish and crustacean species have experienced die-off and disease events along the North Atlantic seaboard of the US & Canada that many scientists have attributed (wholly or in part) to extreme warming or cooling events. For instance, an estimated 700 tonnes of Atlantic cod froze to death in late March 2003 off the Newfoundland coast. Scientists believe an extreme cooling event occurred to quickly for the fish to produce the natural antifreeze in their systems that would have prevented them from being killed by such chilly temperatures. The north Atlantic oscillation is thought to be shifting and having an impact on coldwater species, impacting migration patterns and range of warm and coldwater species. New invasive species that thrive in warmer waters and other warm water species of the Atlantic normally found off the southeastern continental US are now being found in northern waters never before seen.

Other indirect impacts are also anticipated. According to the Intergovernmental Panel on Climate Change (IPCC, 2001), rising sea levels as the ocean warms causing thermal expansion of ocean water and polar ice melt could innundate approximately 50% of North American coastal wetlands and a significant portion of dry land areas that currently are less than 50 cm above sea level. In some areas, wetlands and estuarine beaches may be caught between advancing seas and engineering structures. A 50-cm rise in sea level would cause a net loss of 17–43% of U.S. coastal wetlands, even if no additional bulkheads or dikes are erected to prevent new wetland creation as formerly dry lands are inundated. Furthermore, in the United States, 8,500–19,000 km2 of dry land is within 50 cm of high tide, 5,700–15,800 km2 of which is currently undeveloped. Several states in the United States have enacted regulations to adapt to climate change by prohibiting structures that block the landward migration of wetlands and beaches.

Rising sea level is likely to increase flooding of low-lying coastal areas and associated human settlements and infrastructure. Higher sea levels would provide a higher base for storm surge events; a 1-m rise would enable a once in 15-year storm to flood many areas that today are flooded only by a once in 100-years storm. Sea-level rises of 30 cm and 90 cm would increase the size of the 100-year floodplain in the United States from its 1990 estimate of 50,500 km2 to 59,500 km2 and 69,900 km2, respectively. Assuming that current development trends continue, flood damages incurred by a representative property subject to sea-level rise are projected to increase by 36–58% for a 30-cm rise and by 102–200% for a 90-cm rise.

Saltwater is likely to intrude further inland and upstream. Higher sea level enables saltwater to penetrate farther upstream in rivers and estuaries. In low-lying areas such as river deltas, saltwater intrusion could contaminate drinking water and reduce the productivity of agricultural lands

Reference

IPCC (2001). IPCC Special Report on The Regional Impacts of Climate Change
An Assessment of Vulnerability, Chapter 8: North America ,IPCC.
http://www.grida.no/climate/ipcc/regional/index.htm .

Consequently, coastal tidal wetlands are disappearing globally, with the northeastern US being no exception. The Pew Commission (2001, 2002) reported that over 20,000 acres of coastal habitat disappear each year, much of it attributed to development, rising sea level or subsiding land, and invasive species invasions. Changing precipitation patterns may compound searise effects, impacting the distribution and extent of brackish tolerant plant and animal species.

State of Climate Change in America and in the Region
The conception of adaptation strategies at a regional level to climate change requires a detailed analysis that is at present not often possible to realize because of the high level of uncertainty of future climatic events and their impacts in terms of amplitude and occurrence. Thus, even if historic climatic variations may not be representative of future conditions and may not allow a correct estimate of the level of risk, it is important to make the link with the historical climate statistics. In particular, for extreme climatic events, it is not desirable to wait until the signal becomes "statistically significant" before acting. It is indeed a question of developing an approach of management of risks at the regional level in an uncertain world.

To provide environmental managers with effective tools to minimize the human impact on climate change, there is a need to monitor and assess regional parameters of the northwest Atlantic ecosystem that reflect the causes and consequences of climate change.

KEY ASSESSMENT AND MANAGEMENT QUESTIONS
Key Considerations
“Climate Change” and “Seasonal weather patterns” are terms encompassing a range of processes and impacts that are tied to a global system that cannot be controlled by man. However, research data has suggested that anthropogenically generated physical and chemical pollutants can contribute to an altering of climactic and seasonal patterns both globally and regionally. The question environmental managers must ask themselves is ‘What strategies and management practices can be implemented that will have the most effective and long term benefits in minimizing climactic aberrations and assist (if possible) in shifting climate patterns back to historically healthy conditions’.

- What impervious surface patterns and structures can be changed to reduce stormwater temperatures entering coastal rivers, streams and near-shore waters?
- What management actions should be measured that could impact surface water temperatures and acidity? (i.e. extent of riparian buffers, riparian vegetation type and effectiveness in cooling waters and removing acid promoting compounds.)
- At what scale(s) must land use and imperviousness be monitored and assessed? At what scale should off shore waters be monitored for surface & deep-water temperatures?
- At what scale must acid rain be monitored? What are the best bio-indicators, chemical indicators, and physical parameters to monitor to aid managers in measuring the results and effectiveness of implemented pollution prevention actions.
- Which marine organisms are the best “canary” to monitor in terms of climactically induced thermo, haline, and DO impacts?
- Which commercially important marine species appear to be most impacted by climate changes and which geographical locations are best to monitor for migration and mating pattern shifts.

- Which recreationally and commercially important marine species would be best to monitor and benefit from set harvesting seasons and when should seasons be adjusted in response to temperature/climate induced seasonal migrations (both inshore/offshore and north/south) and mating and larval maturation rates.

The questions for type of monitoring methods are similar to Land Use issues. Advances in satellite & remote sensing science and technology have made possible observing and recording ocean surface temperatures and identifying extent, direction, and intensity of ocean currents.

- ➢ What are the trade-offs between resolution, repeatability, and price, and what is the best combination of remote and field monitoring techniques?
- ➢ What can we do to ensure comparable and uniform regional data?
- ➢ What technologies are most appropriate, accurate, and feasible to produce regionally comparable data?

Even though regime shifts in the NW Atlantic Ocean are less dramatic than those found in the Pacific Northwest that have impacted the Pacific salmon and sardine fisheries, they are probably manifested at the planktonic levels in the food chain passing upwards thru the pelagic forage fish and culminating in effects on seabirds, piscivorous fish and cetaceans. In the NW Atlantic there appears to be a relationship between the North Atlantic Oscillation (NAO), salinity variability, zooplankton and cod (Link, J.S. et al. 2002. Status of the Northeast U.S. Continental Shelf Ecosystem. Northeast Fisheries Science Center Ref. Doc. 02-11). Ken Drinkwater (Can. DFO) has shown similar relationships between the NAO, St. Lawrence River discharge, and pelagic fish species, while Bob Kenney (URI/GSO) has examined NAO relationships with cetacean species. The NAO cycles operate on shorter time scales than the regime shifts, but longer time scales than the seasonal weather patterns. Given the potentially different spatial/temporal scales for these events, it may be that the modelling approaches and field indicators from monitoring programs may differ in the type of management response required.

POTENTIAL INDICATORS & ASSESSMENT METHODS

Potential indicators relevant to this issue include, primarily, biological and physical indicators of aquatic health, and physical and socio-economic indicators of the maritime and fisheries industries. The potential indicators listed below are broken down into two major areal components - near shore and open ocean impacts.

Near Shore

- Trends of seasonal water temperatures over time
- Trends of regional ozone depleting gases and uv penetration in surface waters
- Trends of regional and seasonal CO_2 levels over time
- % tidal wetlands and changes due to subsidence and salt water intrusion over time
- % impervious surfaces and changes over time
- Trends of measured sea level rise (or fall)
- Trends of major weather events in the Northwest Atlantic Region
- Seasonal shifts of surface water temperature over time
- Seasonal stormwater temperature trends over time
- Annual precipitation trends in the watersheds of the northeast coastal region
- Freshwater flow trends from USGS gauging stations over time
- Trends of salt wedge extension up coastal river channels over time
- Trends of warm temperate invasive species
- Trends of parasitic and pathogenic warm water species on native near-shore flora and fauna
- Trends of new warmwater migratory finfish in near-shore waters
- Trends of warmwater algal species and blooms (species diversity and biomass)
- Trends of presence (or absence) of cold water finfish and shellfish species

- Trends of coldwater/warmwater species diversity of other near shore marine organisms (i.e. tunicates, crustaceans, jellyfish, etc.)
- Trends in changes of breeding timing and gestation duration of recreationally and commercially significant finfish and shellfish
- Trends of low dissolved oxygen (hypoxic) events in estuarine embayments related to warmer water temperatures both at the surface and near the benthos.
- Changes in depth and intensity of annual thermocline/halocline (a.k.a. pycnocline)
- Trends in the presence or absence of demersal vs. pelagic finfish.

Offshore – Open Ocean

- Trends of the North Atlantic oscillation over time
- Trends of the Gulf Stream and Labrador current over time
- Trends of nor'easter activity and other major weather events in the North Atlantic
- Seasonal shifts of surface water temperature over time
- Trends of new warm water migratory finfish in off-shore waters
- Trends of coldwater/warmwater finfish species diversity over time
- Trends of warm water/cold water algal species and blooms (species diversity and biomass)
- Trends of unusual finfish and marine mammal kills associated with temperature shift events and/or warm water pathogens
- Trends of finfish by catch (i.e. shifts in cold water to warm water species)
- Commercial fisheries shifts to warmer water species
- Trends of cold water fisheries catch over time
- Trends of dissolve oxygen levels in feeding areas
- Trends of ozone emissions from surface water
- Changes in migratory patterns inshore to offshore and north to south, and shifts in range of warm and cold water species
- Trends in changes of breeding timing and gestation duration of commercially significant finfish and shellfish
- Trends in the presence or absence of demersal vs. pelagic finfish.

- **End purpose:** What is to be done with the data once collected and interpreted? Who are the primary target audiences for this data, and how can the information be used to help influence changes to land use, impervious surface types, auto emissions, and sources of thermal and acidic pollutants. How can the data aid in adjusting socio-economic practices and patterns to benefit from climate change impacts beyond our control? What kind of 'early warning system' can managers develop to aid the maritime industry and other socio-economically tied communities in adjusting to and managing future changes in marine resource abundance and diversity?

Aquatic Habitat

[This page left intentionally blank]

Concept Paper: Aquatic Habitats
Northeast Indicators Workshop, January 6-8, 2004

Background: National and Regional Significance

Aquatic habitats in the northeastern coastal zone can be broadly classified into three general subsystems. Riverine habitats of coastal watersheds include the tidal reaches of rivers and creeks, often with associated freshwater and brackish tidal wetlands and submerged vascular plant beds. Intertidal and near shore habitats include rocky, cobble, gravel, and sandy shores, salt marshes, mudflats, seagrass beds, macroalgal beds, shellfish reefs, and the water column. Deep estuarine and marine environments include pelagic and benthic habitats.

Several centuries of development pressure throughout the northeast has resulted in extensive degradation and loss of natural coastal habitats. For example, more than half of the original tidal wetlands in the Gulf of Maine region have been filled or converted to agricultural lands (GOMC 2002), and a large proportion of the remaining wetlands have been degraded (Dionne et al. 1998, Roman et al. 2000). Although the historical distribution of seagrass habitat is unknown, early reports, navigational charts, and anecdotal information indicate that considerable seagrass loss has also occurred in the region. About 20% of the eelgrass distribution North of Cape Cod, Massachusetts, is estimated to have been lost since the time of European settlement; south of Cape Cod, this number is closer to 65% (Short and Short 2003). The northeastern United States (from Maine to Maryland) currently accounts for about one third of the nation's coastal population, and 16% of the entire national population (Culliton et al. 1990). The population density of this narrow coastal fringe is more than double that of any other region of the country, and it continues to grow. The consequence will be a continued assault on northeastern coastal habitats from human activities.

There are a multitude of human impacts to northeastern coastal habitats, with both acute and chronic effects (Wilk and Barr 1994, Wilbur and Pentony 1999, Roman et al. 2000, NPS 2003; Fig. 1). Disturbances from human activities include direct impacts of various physical alterations, indirect impacts of land management practices, and long-term impacts of a changing global climate. Effects of human activities can be exacerbated by natural disturbances, including severe weather events and biotic, geomorphic, and climatic processes. Collectively, these anthropogenic and natural disturbances produce a host of stresses on coastal ecosystems, from hydrologic, geologic, physical, and chemical alterations to introductions of new species and modifications to linkages within and among habitats. The ecological consequences are far reaching, ranging from changes in physical and biotic habitat structure to major shifts in ecosystem function. In many cases, the long-term and cumulative effects of multiple stresses on the structure, function, and sustainability of coastal habitats are unknown.

Key Assessment and Management Questions

A recent survey of New England coastal managers identified habitat degradation, loss, and restoration as the most important coastal management issue (CICEET 1999). The broad goals of habitat assessment and monitoring are to detect changes in attributes of coastal habitats, determine the relationship of observed changes to human and natural disturbances, and understand the effects of these changes on overall ecosystem structure, function, and sustainability (Roman and Barrett 1999). Fundamental management questions include the following:

- Is the extent and distribution of certain aquatic habitats (e.g. tidal wetlands, seagrasses) changing over time?
- What are the causes of change in distribution, extent, or abundance of certain habitat types?
- Is the ecological condition of certain aquatic habitats changing over time?

Inherent in these basic questions are many topics focused on specific management issues. For example:

- How is sea level rise affecting tidal wetlands?
- What is the effect of nutrient enrichment on seagrass habitat?
- What are the cumulative impacts of dock construction on intertidal and shallow subtidal habitats?
- How are harvesting practices affecting rockweed habitat?
- What are the effects of commercial dragging activities on seagrass beds and offshore benthic habitats?
- Are efforts to restore coastal habitats effectively recreating the functions and values of natural systems?

Potential Indicators

The relationships among major disturbances to aquatic habitats, ecosystem stresses, and ecological responses (Fig. 1) suggest indicators at a variety of scales (see also Neckles et al. 2002, NPS 2003). The following matrix of potential indicators spans levels of ecological organization (landscapes to organisms), relationships (causes of and responses to stress), and complexity (ecosystem structure and function). Some of these indicators are relevant to all habitat types and management issues, whereas others would be most useful when applied to specific habitats or issues. Shaded cells in the matrix represent likely areas of applicability for potential indicators.

	HABITAT TYPE												MANAGEMENT ISSUES			
	Riverine		Intertidal/Nearshore subtidal								Off-shore					
Potential Indicators	River/creek	Tidal freshwater wetlands	Ledge (rocky shore)	Cobble/gravel beach	Sand/mud flat	Salt marsh	Seagrass	Macroalgal bed	Shellfish reef	Water column	Pelagic	Benthic	Natural Disturbance	Indirect Human Impacts	Direct Human Impacts	Global climate change
Disturbance Indicators																
Sea level		■	■	■	■	■	■	■	■							■
Percent of shoreline armored		■			■	■	■	■	■					■	■	
Land use/land cover	■	■	■	■	■	■	■	■	■	■				■		
Housing density	■	■	■	■	■	■	■	■	■	■				■		
Point-source discharge permits	■	■	■	■	■	■	■	■	■	■				■		
Livestock abundance	■	■	■	■	■	■	■	■	■	■				■		
Tidal restrictions (number, distribution)		■				■								■	■	
Atmospheric N deposition	■	■	■	■	■	■	■	■	■	■	■	■		■		
Marinas/docks (number, distribution)		■			■	■	■	■	■						■	
Response Indicators																
Landscape structure																
Distribution, abundance, extent of habitat types	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Location/depth of edge of vegetation		■				■	■	■					■	■	■	■
Shoreline position	■			■	■				■	■			■		■	■
Landscape pattern – habitat interspersion/ fragmentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Ocean color										■	■		■			■
Sea surface temperature										■	■		■			■
Habitat biotic structure																
Autotrophic community composition	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Vascular plant density, percent cover, canopy height	■	■				■	■						■	■	■	■
Suspended chlorophyll conc.	■						■	■	■	■	■		■	■		■

	HABITAT TYPE												MANAGEMENT ISSUES			
	Riverine		Intertidal/Nearshore subtidal								Off-shore					
Potential Indicators	River/creek	Tidal freshwater wetlands	Ledge (rocky shore)	Cobble/gravel beach	Sand/mud flat	Salt marsh	Seagrass	Macroalgal bed	Shellfish reef	Water column	Pelagic	Benthic	Natural Disturbance	Indirect Human Impacts	Direct Human Impacts	Global climate change
Macroalgae distribution, abundance	■		■	■	■		■	■	■	■			■	■	■	■
Faunal community composition	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Faunal abundance	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Indicator species	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Habitat physical environment																
Tidal signal		■				■									■	
Sediment elevation/bottom topography	■	■			■	■	■	■	■			■	■	■	■	■
Water table level		■				■							■		■	■
Sediment organic carbon	■	■			■	■	■	■	■			■		■		■
Sediment grain size	■	■			■	■	■	■				■	■		■	■
Water column salinity	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
Porewater salinity		■				■							■	■	■	■
Water temperature	■	■	■	■	■	■	■	■	■	■	■	■	■			■
pH	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
Dissolved oxygen	■	■				■	■	■	■	■	■			■		
Turbidity/light attenuation	■						■	■	■	■	■	■	■	■	■	
Current speed, direction	■						■	■	■	■	■	■	■		■	■
Ecosystem function																
Plant biomass by species	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■
Plant growth rate	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■
Animal biomass by species	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Animal growth rate	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Animal diet	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Sediment accretion rate		■			■	■	■	■	■				■		■	■
Sediment redox potential	■	■			■	■	■	■	■			■	■	■		
Sediment sulfide	■	■			■	■	■	■	■			■	■	■		
Plant nutrient content		■	■	■	■	■	■	■	■			■		■		
Consumer stable isotope composition	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

References

CICEET. 1999. Technology and information needs of the coastal and estuarine management community. Cooperative Institute for Coastal and Estuarine Environmental Technology, Durham, New Hampshire.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, C. M. Blackwell, and J. J. McDonough III. 1990. Fifty years of population change along the nation's coasts, 1960-2010. National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, Maryland.

Dionne, M., D. Burdick, R. Book, R. Buchsbaum, and S. Fuller. 1998. Scoping paper 5: physical alterations to waterflow and salt marshes. Commission for Environmental Cooperation, Montreal, Canada.

GOMC. 2002. Action plan 2001-2006. Gulf of Maine Council on the Marine Environment.

Neckles, H. A., M. Dionne, D. M Burdick, C. T. Roman, R. Buchsbaum, and E. Hutchins. 2002. A monitoring protocol to assess tidal restoration of salt marshes on local and regional scales. Restoration Ecology 10:556-563.

NPS. 2003. Northeast Coastal and Barrier Network vital signs monitoring plan, Phase II. National Park Service Inventory and Monitoring Program, Northeast Coastal and Barrier Network, Kingston, RI.

Roman, C. T. and N. E. Barrett. 1999. Conceptual framework for the development of long-term monitoring protocols at Cape Cod National Seashore. USGS Patuxent Wildlife Research Center, Cooperative National Park Studies Unit, Narragansett, Rhode Island.

Roman, C. T., N. Jaworski, F. T. Short, S. Findlay, and R. S. Warren. 2000. Estuaries of the northeastern United States: habitat and land use signatures. Estuaries 23:743-764.

Short, F. T. and C. A. Short. 2003. The seagrasses of the western North Atlantic. pp. 207-215 in E. P. Green and F. T. Short, eds., World Atlas of Seagrasses. University of California Press, Berkeley, California.

Wilbur, A. R. and M. W. Pentony. 1999. Human-induced nonfishing threats to essential fish habitat in the New England region. pp. 299-321 in L. R. Benaka, ed., Fish habitat: essential fish habitat and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Wilk, S. J. and B. W. Barr. 1994. Multiple-use issues in estuarine and coastal habitat loss. pp. 51-53 in R. W. Langton, J. B. Pearce, and J. A. Gibson, eds., Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine. NOAA Technical Memorandum NMFS-NE-106, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts.

Figure 1. Northeastern coastal aquatic habitats: relationships among major disturbances (rectangles), stresses arising from those disturbances (ovals), and ecological responses (parallelograms). Adapted from National Park Service Inventory and Monitoring Program, Northeast Coastal and Barrier Network (NPS 2003).