Eutrophication

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

Background: National and Regional Significance

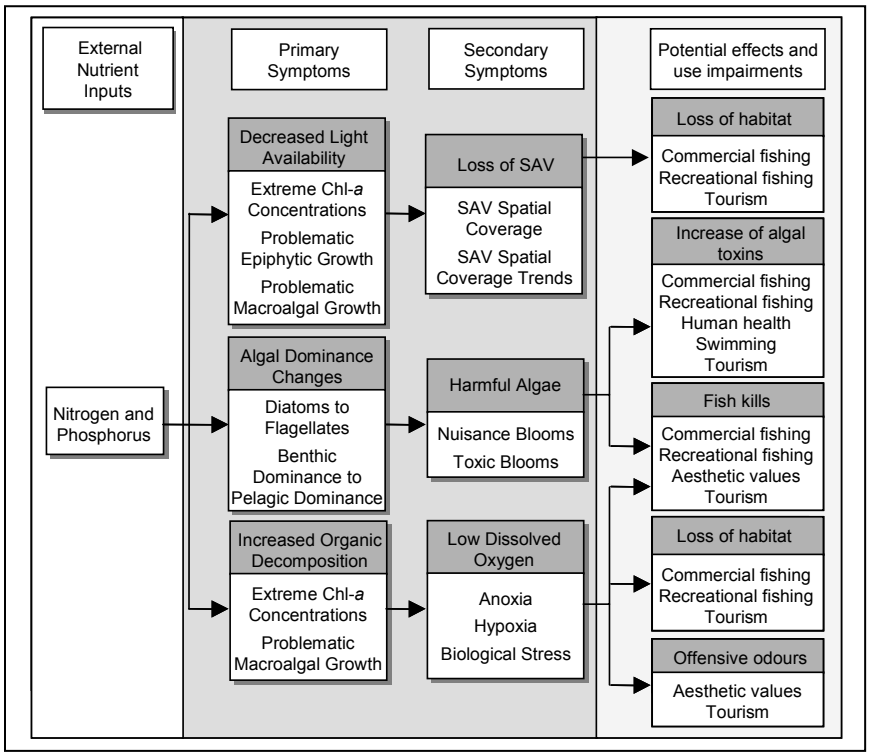
Nutrient pollution has recently been identified as the greatest threat to US coastal water quality (Boesch et al, 2001; NRC, 2000; CSO, 1999). Sources of nutrients include atmospheric, groundwater, point and non-point with potential consequences ranging from ecological changes to socio-economic impairments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

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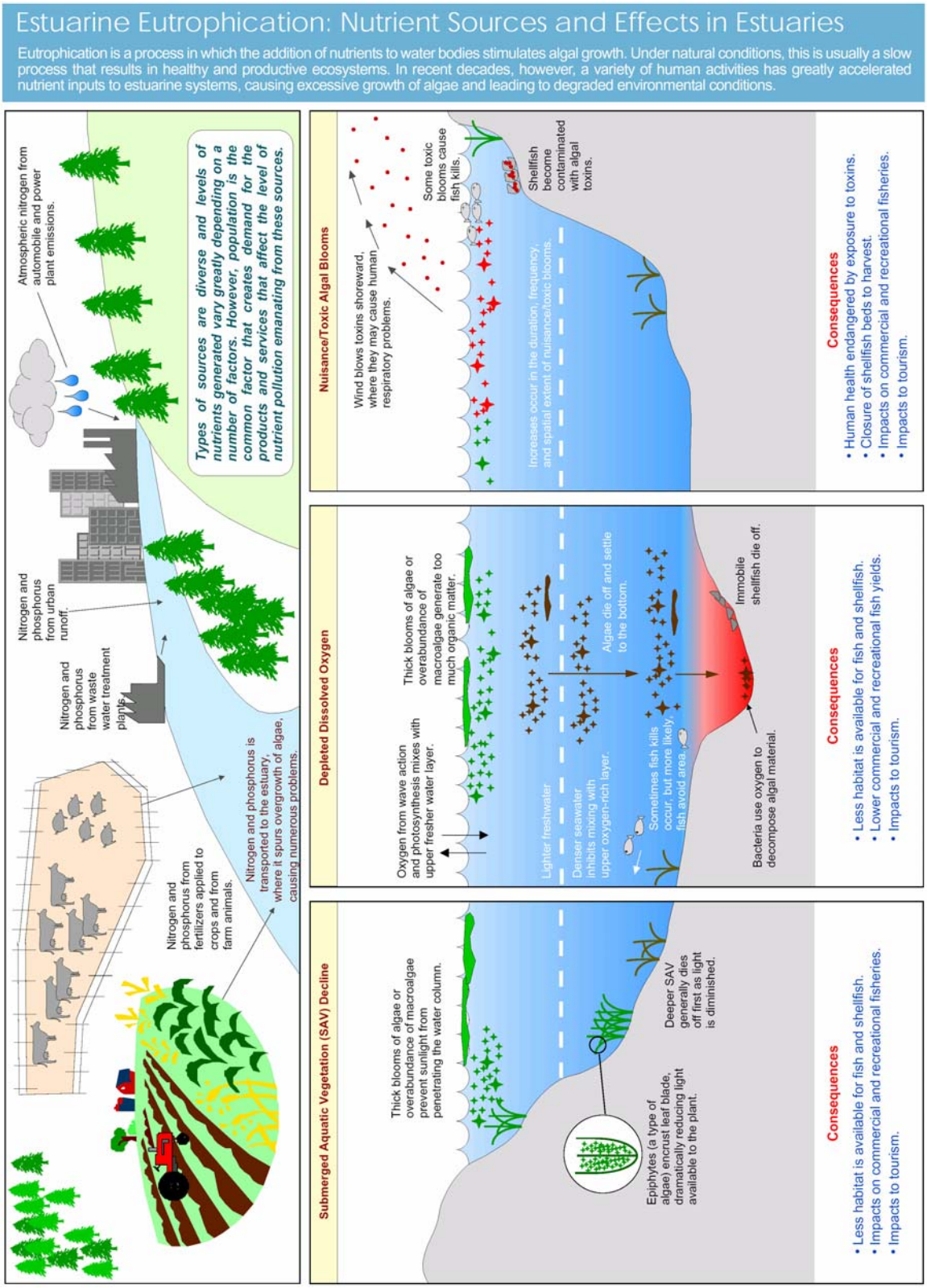
Estuarine Eutrophication: Nutrient Sources and Effects in Estuaries
Eutrophication is a process in which the addition of nutrients to water bodies stimulates algal growth. Under natural conditions, this is usually a slow process that results in healthy and productive ecosystems. In recent decades, however, a variety of human activities has greatly accelerated nutrient inputs to estuarine systems, causing excessive growth of algae and leading to degraded environmental conditions.
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.
Atmospheric nitrogen from automobile and power plant emissions.
Nitrogen and phosphorus from urban runoff.
Nitrogen and phosphorus from waste water treatment plants.
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.
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.
Algae die off and settle to the bottom.
Sometimes fish kills occur, but more likely, fish avoid area.
Immobile shellfish die off.
Bacteria use oxygen to decompose algal material.
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.
Increases occur in the duration, frequency, and spatial extent of nuisance/toxic blooms.
Shellfish become contaminated with algal toxins.
Consequences
• Human health endangered by exposure to toxins.
• Closure of shellfish beds to harvest.
• Impacts on commercial and recreational fisheries.
• Impacts to tourism.