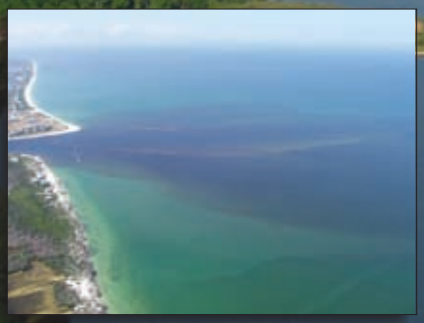


EFFECTS OF NUTRIENT ENRICHMENT IN THE NATION'S ESTUARIES:

A Decade of Change

National Estuarine Eutrophication Assessment Update

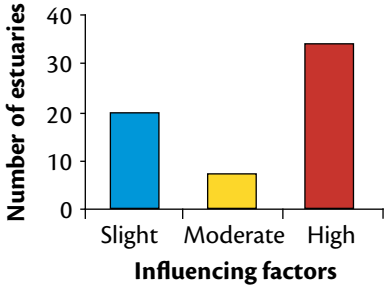
TABLE OF CONTENTS

KEY FINDINGS

1. The majority of estuaries assessed were highly influenced by human-related activities.

Highly influenced estuaries had high nitrogen loads compared to the estuary's dilution or flushing capacity (Figure 1). High nitrogen loads were largely attributed to the influence of expanding and dense coastal human populations.

Figure 1. Factors influencing eutrophication (nitrogen load and susceptibility) were high for the majority of assessed systems.



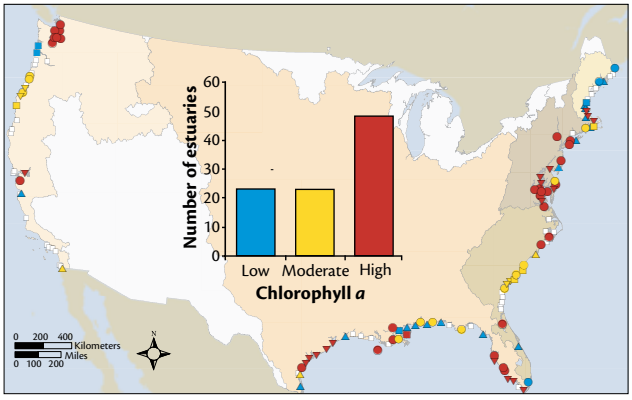
2. The majority of estuaries assessed had overall eutrophic conditions rated as moderate to high.

Eutrophication has a predictable suite of symptoms including increased chlorophyll *a*, macroalgae and nuisance/toxic blooms, decreased dissolved oxygen, and submerged aquatic vegetation loss (Figure 2).

3. The most commonly occurring eutrophic symptom was high spatial coverage and high frequency of elevated chlorophyll *a* levels.

Most estuaries also exhibited at least one other moderate to high symptom expression in addition to chlorophyll *a* (Figure 3).

Figure 3. A high chlorophyll *a* rating was observed in a large number of the Nation's estuaries.



4. Overall eutrophic condition and symptom expressions were geographically variable.

There were differences in eutrophic status among estuaries in close proximity (Figure 4). The net effect of this variability was that there was no national

Figure 2. A conceptualization of the relationship between overall eutrophic conditions, associated eutrophic symptoms, and influencing factors (nitrogen loads and susceptibility).

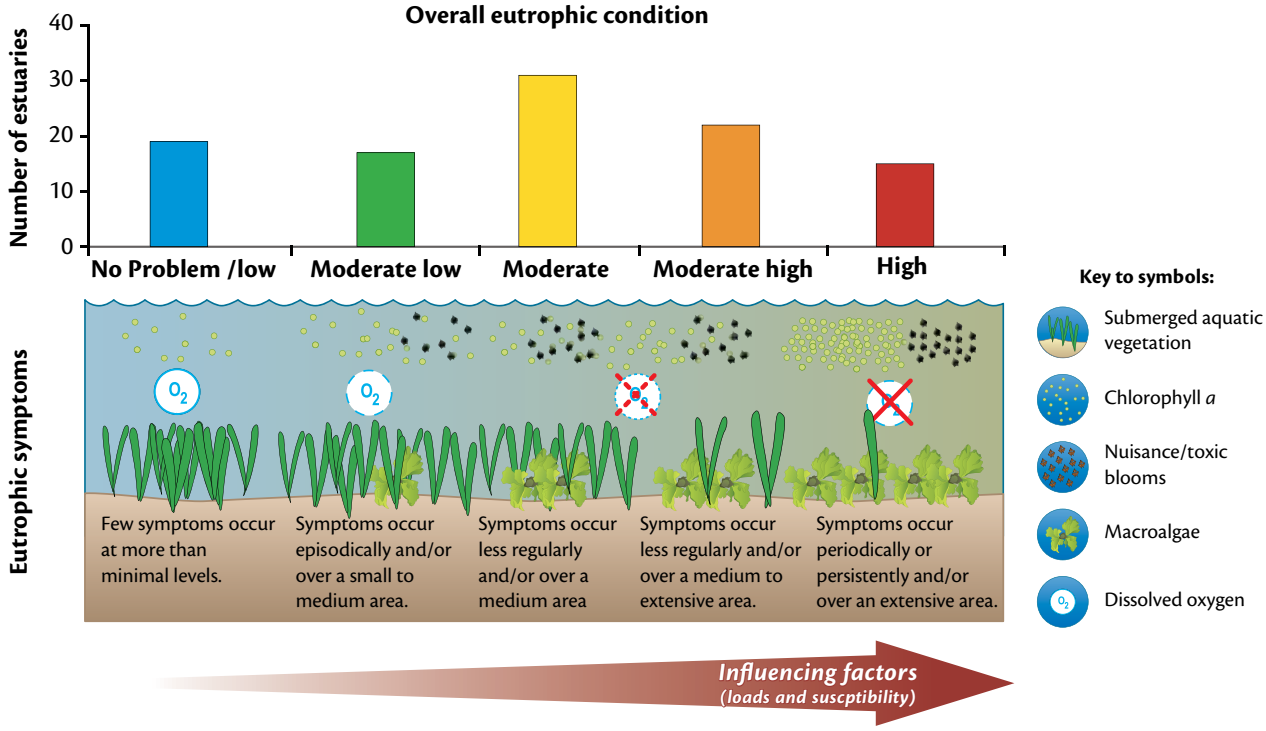
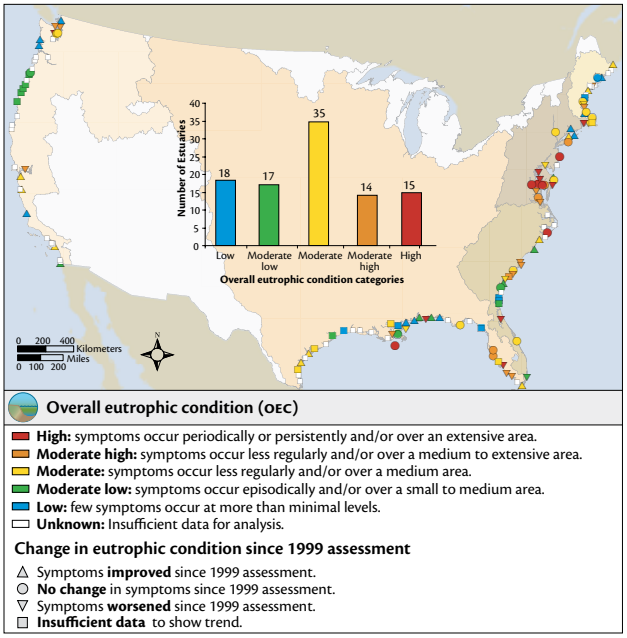


Figure 4. National overall eutrophic condition was geographically variable.

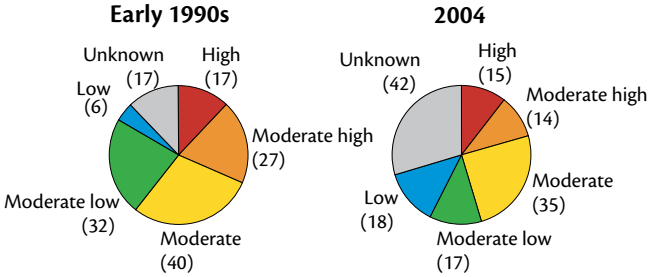


pattern of overall eutrophic conditions or symptom expressions except that the largest concentration of highly eutrophic systems was in the mid-Atlantic.

5. Comparison of eutrophic conditions assessed from the early 1990s to 2004 indicates similar levels of eutrophication.

Direct comparison of eutrophic status between assessments was impeded by reduced data availability in 2004 (70% of systems in 2004 vs. 88% in 1990s) due in part to changes in the data collection method (*see chapter 3: National assessment*). If only assessed systems are considered, conditions have improved in 13 estuaries, worsened in 13, and remained the same in 32 systems. In 1999, 69% of assessed systems (72% of assessed area) had moderate to high eutrophic conditions compared to 65% of assessed systems (78% of assessed area) in 2004 (Figure 5).

Figure 5. Number of estuaries in each eutrophication category in the early 1990s (1999 assessment) and 2004 (this assessment).



6. Considerations for management action, monitoring, research, and communication (Figure 6)

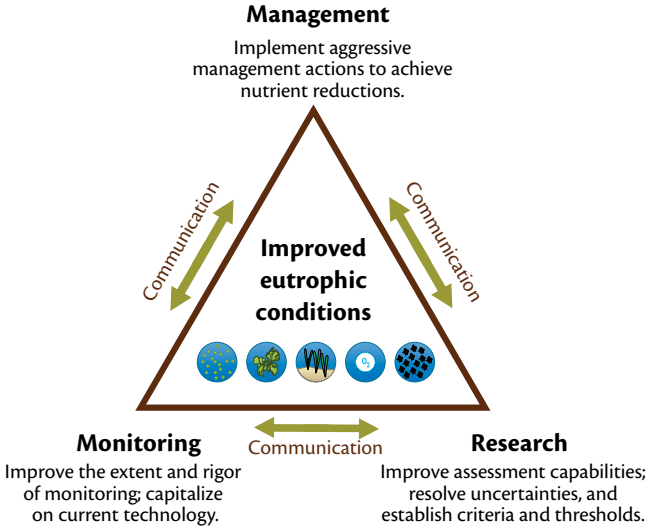
Management: Implement more aggressive action to achieve nutrient reductions for widespread reductions in eutrophic conditions. Notable improvements have been achieved (e.g., Tampa Bay and Boston Harbor) with aggressive management intervention, but these are isolated cases.

Monitoring: Capitalize on technology (e.g., observing systems, remote sensing) to improve comprehensive assessment of eutrophication in a coordinated and timely fashion. Future national assessments would benefit from rigorous, easily accessible data (both *in situ* and remotely sensed) provided on the web by local and regional assessment programs.

Research: Focus on improving monitoring and assessment of eutrophication, resolving uncertainties, and establishing criteria and thresholds. In particular, macroalgae and submerged aquatic vegetation indicators should be improved. Elucidate potential and evaluate current management options.

Communication: Engage resource managers, researchers, policy makers, and the community with frequent assessment updates at local, regional, and national levels. Environmental report cards, illustrative graphics, and maps, will foster interest and inform, and empower the public to support critical management action.

Figure 6. Improvements in eutrophic condition can only be achieved by management, research, and monitoring programs working together.



EXECUTIVE SUMMARY

Chapter 1: Introduction and Background

- The National Estuarine Eutrophication Assessment (NEEA) is a tool for evaluating both current eutrophic condition and the effectiveness of management actions aimed at reducing eutrophic condition.
- Eutrophication is caused by excess nutrients and is expressed by symptoms such as increased chlorophyll *a* and macroalgae, and decreased dissolved oxygen.
- Widespread coastal eutrophication has been reported in a previous national assessment (Bricker et al. 1999). As coastal populations continue to increase, experts are concerned that eutrophication and associated symptoms are also increasing. In response to this concern, it was decided that the 1999 assessment should be updated.
- This update of the 1999 assessment identifies current eutrophic status and changes since the early 1990s, tracks management progress, and identifies potential solutions for eutrophication.
- To facilitate this and future assessments, an online survey tool was developed. This tool allows investigators to share data and information effectively, providing a common language by which they can communicate with one another in a standardized manner.

Chapter 2: Approach

- The NEEA evaluates eutrophication by examining (1) influencing factors; (2) eutrophic symptoms; (3) overall eutrophic condition; (4) future outlook; and, (5) combining the results into one overall rating (ASSETS).
- In this report, factors influencing eutrophication are nitrogen load and the estuary's susceptibility to nitrogen (dilution and flushing rates).
- Overall eutrophic condition is based on assessment of 5 symptoms: chlorophyll *a*, macroalgae, dissolved oxygen, submerged aquatic vegetation and nuisance/toxic blooms. Eutrophic condition is determined by evaluating the occurrence, spatial coverage and frequency of these symptoms.
- Eutrophic condition is predicted for year 2020 (future outlook) based on expected changes in nutrient loads and the estuary's susceptibility to these loads.
- The influencing factors, overall eutrophic condition, and future outlook results are combined into an overall system rating (ASSETS).
- Completeness and reliability of the assessment is based on the temporal and spatial availability of data.

Chapter 3: National Assessment

- The majority of estuaries assessed were highly influenced by human-related activities. Influencing factor ratings were high from New York to Texas, low in the North Atlantic, and mostly unknown in the Pacific region.
- Eutrophication is a widespread problem, with the majority of assessed estuaries showing signs of eutrophication—65% of the assessed systems, representing 78% of assessed estuarine area, had moderate to high overall eutrophic conditions.
- The most common symptoms of eutrophication were high spatial coverage and frequency of elevated chlorophyll *a* (phytoplankton)—50% of the assessed estuaries, representing 72% of assessed area, had a high chlorophyll *a* rating.
- There were no regional or national patterns of highly eutrophic conditions found in systems along all coastlines. However, the mid-Atlantic region was the most impacted overall.
- Survey participants predicted worsening conditions by 2020 in 65% of estuaries and improvements in 20% of estuaries.
- Change analysis showed that conditions in most assessed systems remained the same since the early 1990s (32 systems, 77% assessed area). Changes were observed in smaller systems; 13 systems (9% assessed area) improved and 13 systems (14% assessed area) worsened.
- Assessment of eutrophic condition was impeded by reduced reporting in 2004 as there were inadequate data for 30% of surveyed estuaries, compared to only 12% of estuaries in the early 1990s. This was largely a result of the data collection method, the online survey for the 2004 data versus use of site visits and workshops in addition to a survey for the 1999 assessment.

Chapter 4: Regional Assessments

- This assessment divides the nation's estuaries into five regions: North Atlantic, mid-Atlantic, South Atlantic, Gulf of Mexico, and Pacific Coast. Estuaries are divided into these regions to facilitate discussion and application to management.

North Atlantic (Maine to Cape Cod)

- North Atlantic estuaries are small, deep, and well-flushed by tides, with generally small watersheds. Factors influencing eutrophication were low for all reported systems.
- North Atlantic estuaries were the least impacted nationally: no estuaries had a high overall eutrophic condition rating. However, the outlook for this region raises concern, with conditions predicted to worsen in most estuaries.

Mid-Atlantic (Cape Cod to Chesapeake Bay)

- Mid-Atlantic estuaries and coastal lagoons are relatively large, moderately deep, have a moderate watershed size, and are poorly flushed. Factors influencing eutrophication were high for the majority of estuaries.
- Mid-Atlantic estuaries were the most impacted nationally: the majority of estuaries recorded a moderate high or high overall eutrophic condition rating, with

more than one third of the estuaries having worsened since the early 1990s.

South Atlantic (North Carolina to Florida)

- South Atlantic estuaries are mostly of medium size, shallow, and well flushed. They have moderately sized watersheds with relatively high population. Factors influencing eutrophication were spatially variable, with high influencing factor ratings in over one third of the assessed estuaries.
- Problematic levels of chlorophyll *a* and dissolved oxygen were the main symptoms of eutrophication in this region, although the majority of estuaries had moderate or low eutrophic condition.

Gulf of Mexico (Florida to Texas)

- Gulf of Mexico estuaries are mostly large, shallow, and poorly flushed. They tend to have very large watersheds with low to moderate populations. Factors influencing eutrophication were high for most assessed estuaries.
- A small proportion of estuaries had high or moderately high overall eutrophic condition. Gulf of Mexico estuaries were characterized by high, and often worsening, chlorophyll *a* symptoms.

Pacific region (California to Washington)

- The Pacific region has numerous small, deep, and moderately well flushed estuaries with moderately sized watersheds. Very few estuaries in this region have nutrient load data available.
- Most estuaries with high to moderate eutrophic condition were located in Washington and central California with chlorophyll *a* and dissolved oxygen being the symptoms of concern.

Chapter 5: Case studies

- A diversity of national and international case studies are presented to illustrate the various impacts of eutrophication. In some cases, the associated management and monitoring responses are presented. Themes of the case studies include:
  - *Diversion of sewage effluent to offshore discharge reduced eutrophic symptoms (Boston Harbor).*
  - *Monitoring suggests anthropogenic and riverine sources of nutrients (Casco Bay).*
  - *Reduction in point source nutrients ameliorated hypoxia in the 1990s (Long Island Sound).*
  - *Trend reversal in water quality improvements likely caused by recent increase in diffuse nutrient load (Maryland Coastal Bays).*
  - *Predictable large scale hypoxia from nation's largest drainage basin due to nutrient loads (Mississippi-Atchafalaya Plume).*
  - *Deteriorating dissolved oxygen conditions occurring in a well mixed coastal waterway (Skidaway River Estuary).*
  - *Seagrass recovery after historic losses due to nitrogen load reductions (Tampa Bay).*
  - *Continuous water quality monitoring data helps to explain extreme events such as fish kills (Corsica River).*
  - *The complex factors causing low dissolved oxygen events require ongoing research, monitoring and modeling (Hood Canal).*
  - *Ecosystem transition occurred with initiation of brown tides (Laguna Madre).*
  - *Nutrients and climate change pose threat to coral reefs (Looe Key).*
  - *Holistic ecosystem evaluation needed to discern causes of chlorophyll a increases (San Francisco Bay).*
  - *Eutrophication symptoms, due to increased nitrogen load, include increased phytoplankton and macroalgae, and decline in seagrass (Waquoit Bay).*
  - *Rapid large scale increase in eutrophic symptoms (nuisance/toxic blooms, chlorophyll a, and dissolved oxygen) have occurred (Changjiang Estuary, China).*
  - *Threats from eutrophication to large scale aquaculture stimulate nutrient management (Jiaozhou Bay, China).*
  - *Seasonal macroalgae blooms lead to seagrass loss (Mondego River, Portugal).*
  - *Sewage plume mapping tracks nutrient reductions (Moreton Bay, Australia).*
  - *Flood protection measure can accentuate eutrophic symptoms (e.g., dissolved oxygen, macroalgae, and loss of submerged aquatic vegetation) (Venice Lagoon, Italy).*

Chapter 6: Improvements to the methods

- The NEEA aims to improve the methods used to assess eutrophic condition of the nation's estuaries. Some of these improvements are based on recommendations of survey and workshop participants.
- Some improvements currently being addressed (and summarized in the report) are: (1) exploring linkages with EPA's National Coastal Assessment; (2) developing indicators of socioeconomic/human-use impacts; (3) developing a type classification scheme for the nation's estuaries; and (4) improving methods of evaluating eutrophic condition, especially for submerged aquatic vegetation and macroalgae abundance.

Chapter 7: Conclusions and Considerations for Management

- Reducing eutrophic conditions in estuaries requires coordinated and integrated action that balances management action, efficient monitoring to assess the effectiveness of the management, targeted research, and a communication campaign aimed at engaging the broader community. Major recommendations are:
  - *Implement more aggressive management actions to reduce nutrients for improvements in eutrophic condition.*
  - *Capitalize on monitoring technological innovations (e.g., observing systems, remote sensing, web resources) to improve comprehensive assessment of eutrophication status in a coordinated and timely fashion.*
  - *Focus research on improving assessment capability, resolving uncertainty, and establishing criteria/thresholds.*
  - *Engage resource managers, researchers, policy makers, and the community with frequent assessment updates at local, regional, and national levels.*
  - *Develop tools to quantitatively relate the effectiveness of mitigation strategies in response to policy actions.*