USEFULNESS OF NATIONAL ESTUARY PROGRAM (NEP) DATA AS NATIONAL ENVIRONMENTAL INDICATORS

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EXECUTIVE SUMMARY

The National Estuary Program (NEP) was established by Congress in 1987 under Section 320 of the Clean Water Act, to promote and restore the health of nationally significant estuaries, while simultaneously supporting all beneficial uses of the estuary's natural resources. Under the NEP, the Administrator of the U.S. Environmental Protection Agency (EPA) is authorized to convene Management Conferences to identify priority problems within these estuaries and develop a Comprehensive Conservation and Management Plan (CCMP) to address those problems. Since the program's inception, 28 individual NEPs around the Nation have been established.

It is the responsibility of each NEP to track the progress of CCMP implementation and monitor associated ecological conditions in the estuary. Many NEPs share common priority problems, however, each NEP's goals and issue-specific actions are unique and, therefore, the specific data collected to track CCMP implementation progress and monitor ecological conditions, varies widely among the NEPs.

EPA Ocean and Coastal Protection Division (OCPD) determined the need to evaluate the usefulness of data being collected by individual NEPs as national environmental indicators. EPA decided to focus an initial evaluation on two key estuarine challenges: habitat degradation/loss and nutrient overloading. To achieve this objective, OCPD formed an NEP Indicators Workgroup that was comprised of representatives from individual NEPs, the Association of National Estuary Programs (ANEP), OCPD, and EPA Regional Offices.

The purpose of this report is to identify CCMP implementation data associated with habitat degradation/loss and nutrient overloading management programs at individual NEPs. The report evaluates opportunities to aggregate these data in a manner that would allow them to provide a measure of NEP progress (i.e., implementation of restoration actions and changes in ecological condition) nationally. An Information Request was sent to all 28 NEPs to collect information on the implementation of specific management actions, source reduction measures, and community outreach programs focused on reducing habitat degradation/loss and nutrient overloading. Each NEP was asked to score their progress of applying specific initiatives and how successful each initiative was in reducing habitat degradation/loss and nutrient overloading. The results of the 21 responding NEPs (75 percent response rate) were evaluated and, accounting for existing national estuarine monitoring and indicator programs related to habitat management and nutrient overloading, this report makes recommendations concerning good candidate and potential national environmental indicators to measure NEP progress.

<u>*Overview of Environmental Indicators*</u>

The purpose of an indicator is to summarize complex information into a simplified and useful manner to facilitate the measurement of status and trends. Indicators are used to convey information, quantify responses, simplify information about complex ideas, and be a cost-effective and accurate alternative to monitoring all individual components of a system. Indicators can be quantitative or qualitative in nature and are useful at many scales, both temporally and spatially. When tracked over time, an indicator can provide information on trends in the condition of a system.

In order to develop an appropriate environmental indicator, it must be directly linked to the cause, effect, or action it is tracking. Ideally, indicator development should be preceded by the development of an assessment question. An example assessment question relevant to the objective of this report is "What percent of the estuary is hypoxic?" The next critical step is the development of a framework or model of the system relevant to the assessment question. Using the example above, the estuary may be exhibiting hypoxic conditions due to lack of oxygen from algae growth, loss of seagrasses, industrial pollutant discharges, invasive species changing ecosystem dynamics, or nutrient overloading.

There are several examples of national monitoring/indicator efforts that are focused on estuarine ecosystems. The development of national environmental indicators for estuaries is very challenging, given the size and diversity of U.S. coastal systems. They are necessary, however, since many of the environmental protection goals of Federal agencies are national in scope and many of the Nation's estuaries cross county and state boundaries, requiring regional and interagency cooperation.

Indicator Development/Use at the Federal Level

Several Federal agencies, including the U.S. Department of Agriculture (USDA), the U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), and EPA, have been involved in environmental indicator development for decades. Similar to the Canadian and Dutch governments in the late 1980s, and international organizations such as the United Nations, World Bank, and the Scientific Committee on Problems of the Environment (SCOPE), these agencies have made efforts to simplify complex environmental information to make it more accessible to decision makers, natural resource managers, and the general public. Some examples of national monitoring/indicator efforts focused on estuarine ecosystems are highlighted in Section 3 of this report.

Usefulness of NEP Data as National Environmental Indicators

An Information Request form was sent to each of the 28 NEPs in December 2000 to determine if there exists common indicators that may be used to measure progress on habitat degradation/loss and nutrient overloading issues within the NEP. Each NEP was asked to score their progress of applying specific initiatives and how successful each initiative was in reducing habitat degradation/loss and nutrient overloading. A total of 21 of the 28 (75 percent) NEPs responded to the habitat management issues section and 20 of the 28 (70 percent) NEPs responded to the nutrient overloading issues section of the Information Request. Based on region, data was submitted through the information request by 73 percent (8 of 11) of the Northeast estuaries, 75 percent (3 of 4) of the Southeast estuaries, 86 percent (6 of 7) of the Gulf and Caribbean estuaries, and 67 percent (4 of 6) of the Pacific estuaries. The National Coastal Condition Report (USEPA 2001) and National Estuarine Eutrophication Assessment (Bricker et al. 1999) were used to supplement discussions of the Information Request responses. The National Estuarine Eutrophication Report is a comprehensive assessment by over 300 experts discussing nutrient enrichment and eutrophic conditions at U.S. estuaries. Eutrophication is the accelerated production of organic matter in a water body that is likely cased from increased algae production, depleted dissolved oxygen, and loss of SAV. The assessment was based on the results of surveys conducted by NOAA from 1992 to 1997, covering 138 estuaries (representing over 90 percent of the estuarine surface area of the conterminous U.S.) with supplemented information on nutrient inputs, population projects, and land use.

Both habitat degradation/loss and nutrient overloading were evaluated for each NEP by examining such areas as anthropogenic and environmental pressures (i.e., development, invasive species), the state of the estuary relative to these two indicators, societal responses to changes in these conditions that affect management issues and public education/involvement, and a summary of specific indicators used by the NEPs to manage their estuaries.

<u>Summary and Recommendations</u>

The results of the Information Request were summarized and organized according to the Pressure-State-Response (PSR) framework which is a conceptual framework developed by the Organization for Cooperation and Development (OECD). The summary presents an evaluation of good candidate and potential indicators based on the Information Request results and, to the extent allowed by the scope of this report, existing national estuarine monitoring and indicator programs related to habitat degradation/loss and nutrient overloading. This evaluation, however, is principally limited to the information gathered through the Information Request results from 21 of 28 NEPs. As such, the data gathered during this project can form a basis for moving forward in the indicator development process for the NEP. This process should begin with developing a set of assessment questions and identifying the target audience for indicator reporting. Once these issues are resolved, national level guidance could assist the development of appropriate local (NEP-specific), regional, and national environmental indicators that report NEP progress.

Habitat loss appears to be a common problem impacting a majority of the NEP estuaries, especially coastal wetland conditions along the Western, Gulf, and Great Lakes regions that were considered poor quality while the Northeast and Southeast regions had fair habitat recovery (EPA 2001). All regions experienced loss of wetland acreage. The most common habitat pressures are development, nutrient overloading, invasive species, and sediment loading, however, each of these pressures varies in importance depending on the estuary. In response to the habitat degradation/loss, conservation and restoration activities have been implemented by government, universities, and the community in most NEPs. Approximately 13 of the reporting NEPs, noted major improvements once mitigation, restoration, and wetland banking programs were implemented. A major contributing factor to the success of these programs is community involvement. Implementation of specific programs has restored or protected on average approximately 50 to 100 acres. Management actions to improve water quality appear to have an added benefit in reducing habitat loss. Actions to change zoning regulations, land use changes, reduce runoff, and install best management practices appear to have the highest impact on habitat restoration. The most common indicator used by a large majority (17 of 18) of reporting NEPs is the area of habitat (or habitat extent, i.e., total acres of habitat within the estuary). This indicator is also utilized, in various forms, by a number of Federal monitoring/indicator programs, and could serve as an excellent national environmental indicator for the NEP. This indicator has the advantage, as it is monitored over time, to measure change in habitat extent, possibly capturing the response of pressures and the results of management actions. One criticism of this indicator is that it does not directly address the functionality or condition of the restored habitat.

Approximately 65 percent of U.S. estuaries by surface area (Bricker et al. 1999), exhibit moderate to high expressions of eutrophic conditions. High conditions occur in estuaries along all coasts, but are most pervasive in estuaries along the Gulf of Mexico and Middle Atlantic coasts. Moreover, eutrophic conditions are anticipated to worsen in 70 percent of estuaries by 2020 (EPA 2001). It appears that both point and non-point sources are likely contributing to nutrient loading in estuaries. The most common point sources of excessive nutrients are discharges from wastewater treatment plants and rivers while non-point sources include septic tank systems, urban and suburban runoff, atmospheric deposition, and agricultural runoff. Nutrient loading pressures and associated eutrophic potential of estuaries is highly location-specific. Major progress has been made in implementing management actions to reduce nutrient loading from wastewater treatment plants. Community involvement appears to have some influence in promoting the replacement of septic tanks and upgrading the treatment plants. Public involvement was found to be an important factor in controlling non-point source releases to estuaries. Management actions that appear to have the highest impact at improving water quality include upgrades to existing stormwater treatment facilities, baseline monitoring, and improved wastewater treatment technology. The most common indicators used by NEPs are dissolved inorganic nutrients (11 of 15), chlorophyll-*a* (9 of 15) and

DO (8 of 15). The primary indicators employed included chlorophyll-*a*, macroalgal abundance, and epiphyte abundance; however, secondary indicators such as loss of SAV, presence of harmful algae, and low dissolved oxygen are also used to support the finding of eutrophic condition. DO is probably not a suitable indicator for determining nutrient overloading since it is difficult to interpret whether the observed effects are the result of natural processes or human pressures. Unlike the discussion of habitat degradation/loss indicators above, there does not appear to be one single indicator that can be applied to the NEP nationally for the pressures and state of nutrient overloading from data collected by the individual NEPs. Because of the diverse issues causing nutrient loading and the multitude of indicators that are being monitored by the various programs, it is difficult to form a cause and effect linkage in determining ecological response.

The overall conclusion from this Information Request is that, for the two issues under consideration (i.e., habitat degradation/loss and nutrient overloading), no suite of definitive indicators can be readily extracted from current individual NEP monitoring/indicator efforts to adequately report implementation progress and changes in ecological condition in the NEP. There are numerous comprehensive monitoring programs and existing and potentially associated indicators at the individual NEP level, but great variability among the programs makes aggregation across even a majority of programs difficult. What has been gained from the Information Request is a useful set of summary statistics on NEP initiatives and programs related to habitat degradation/loss and nutrient overloading.

1. INTRODUCTION

In 1987, Congress established the National Estuary Program (NEP) under Section 320 of the Clean Water Act to promote and restore the health of nationally significant estuaries, while simultaneously supporting all beneficial uses of the estuary's natural resources. Under the NEP, the Administrator of the U.S. Environmental Protection Agency (EPA) is authorized to convene Management Conferences to identify priority problems within these estuaries and develop a Comprehensive Conservation and Management Plan (CCMP) to address those problems. Since the program's inception, 28 individual NEPs around the Nation have been established.

It is the responsibility of each NEP to track progress in CCMP implementation and monitor associated ecological conditions in the estuary. Many NEPs share common priority problems, however, each NEP's goals and issue-specific actions are unique and, therefore, the specific data collected to track CCMP implementation progress and monitor ecological conditions varies widely.

EPA Ocean and Coastal Protection Division (OCPD) determined the need to evaluate the usefulness of data being collected by individual NEPs as national environmental indicators – inclusive of indicators associated with restoration actions undertaken and changes in overall ecological condition – of NEP progress. EPA decided to focus an initial evaluation on two key estuarine challenges: habitat degradation/loss and nutrient overloading. To achieve this objective, OCPD formed an NEP Indicators Workgroup (Workgroup) comprised of representatives from individual NEPs, the Association of National Estuary Programs (ANEP), OCPD, and EPA Regional Offices. The Workgroup determined that an in-depth investigation of NEP data, relative to habitat degradation/loss and nutrient overloading, was needed.

This report identifies CCMP implementation data associated with habitat degradation/loss and nutrient overloading management programs at individual NEPs. The report then evaluates opportunities to aggregate these data in a manner that would allow them to provide a measure of NEP progress (i.e., implementation of restoration actions and changes in ecological condition) nationally. An Information Request was sent to all 28 NEPs to collect information on the implementation of specific management actions, source reduction measures, and community outreach programs focused on reducing habitat degradation/loss and nutrient overloading. Each NEP was asked to score their progress of applying specific initiatives and how successful each initiative was in reducing habitat degradation/loss and nutrient overloading. The results of the 21 responding NEPs (75 percent response rate) are evaluated and, accounting for existing national estuarine monitoring and indicator programs related to habitat management and nutrient overloading, this report makes recommendations concerning good candidate and potential national environmental indicators to measure NEP progress.

2. AN OVERVIEW OF ENVIRONMENTAL INDICATORS

2.1 What is an Indicator?

The purpose of an indicator is to summarize complex information into a simplified and useful manner, to facilitate the measurement of status and trends. In a common analogy to the field of medicine, the patient represents a system or phenomenon of interest. This system is a complex collection of sub-systems with many compartments and interactions, just like the multitude physiological systems of the human body. Indicators act as “vital signs” used to measure the state of the system, just as temperature and pulse are used to assess the overall health of a patient.

Indicators are used to convey information, quantify responses, simplify information about complex ideas, and are assumed to be a cost-effective and accurate alternative to monitoring all individual components of a system. Indicators can be quantitative or qualitative in nature and are useful at many scales, both temporally and spatially. When tracked over time, an indicator can provide information on trends in the condition of a system.

Perhaps the most well known indicators are those describing the condition of the U.S. economy, such as the Dow Jones Index or Gross Domestic Product (GDP). To adequately capture the complexity of some system, multiple relevant indicators can be aggregated into an “index.” The GDP, for example, is an index that combines five individual indicators – (private) consumption, fixed investment, inventory adjustments, government purchases, and net exports (Figure 2-1).

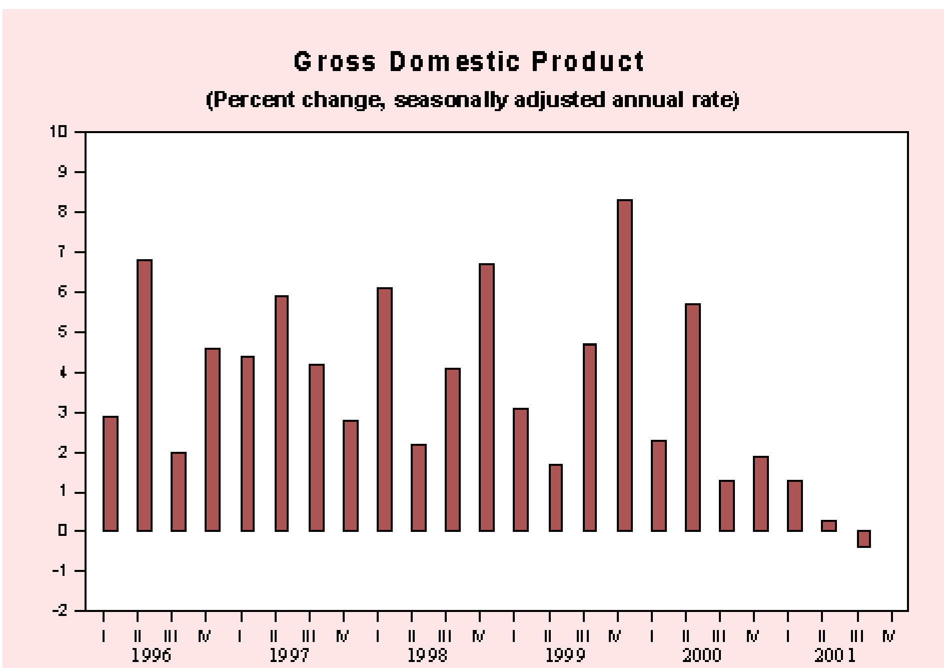

Figure 2-1. Example of a Common Economic Indicator (Bureau of Economic Analysis 2001)

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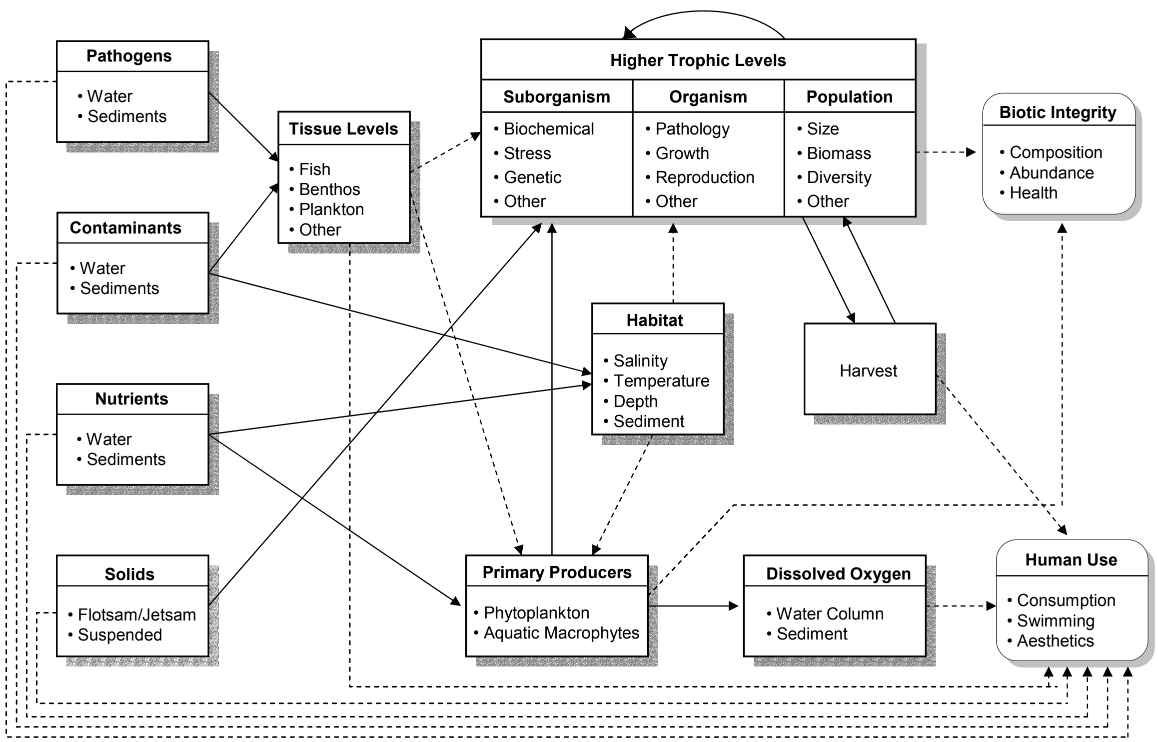
2.2 Environmental Indicator Development

In order to develop an appropriate environmental indicator, it must be directly linked to the cause, effect, or action it is tracking. Ideally, indicator development should be proceeded by the development of an assessment question. An example assessment question relevant to the objective of this report is "What percent of the estuary is hypoxic?" The next critical step is the development of a framework or model of the system relevant to the assessment question. Using the example above, the estuary may be exhibiting hypoxic conditions due to lack of oxygen from algae growth, loss of seagrasses, industrial pollutant discharges, invasive species changing ecosystem dynamics, or nutrient overloading.

Ideally, a conceptual model should be developed based on the current understanding of the structure and function of the system in question (an estuarine ecosystem example is provided in Figure 2-2). The model considers temporal and spatial dynamics, evaluates recuperative capacities of the resource to combat stressors, and identifies where stressors are introduced to the system and may potentially impact resources. The model should present a thorough understanding of the inputs and outputs of the system that will lead to a selection of indicators in which to perform the research. Common mistakes encountered while developing indicators include selecting indicators that are not linked to the assessment questions, developing indicators prior to posing an assessment question, and settling for indicators based on the currently available data.



Note: solid lines indicate material flows while dashed lines indicate interactions.

Figure 2-2. Conceptual model of Estuarine Ecosystem Redrawn from Holland, 1990 (Barber, 1994)

In order to evaluate if an indicator provides consistent information for evaluating both short- and long-term conditions and supporting management decisions, EPA has established guidelines using a four phase approach for evaluating potential and acknowledged indicators (USEPA 2000). The four phase criteria are as follows:

1. **Conceptual Relevance or Soundness**
   Is the indicator relevant to the assessment question and to the resource at risk?

2. **Feasibility of Implementation (Current and Future)**
   Are the methods for long-term sampling and measuring the environmental variables technically feasible, appropriate, and efficient for use in a monitoring program?

3. **Response Variability**
   Are human errors of measurement and natural variability over time and space sufficiently understood and documented?

4. **Interpretation and Utility**
   Will the indicator convey information on resource conditions that is meaningful to environmental decision-makers?

These phases describe an idealized progression for indicator development that flows from fundamental concepts, to methodology, to examination of data from pilot or monitoring studies, and lastly to consideration of how the indicator serves the program objectives. The guidelines are presented as sequential steps that can be used iteratively to refine the selected indicator.

Both the National Research Council (NRC 2000) and EPA Environmental Monitoring and Assessment Program (EMAP 1994) have put forth their own set of criteria for evaluating the appropriateness of indicators for environmental systems. Table 2-1 compares indicator evaluation criteria recommended by these two programs, with those suggested in USEPA 2000 guidelines. Although some of the individual criteria vary between the three sets of guidelines, all of the criteria share the four phases described above, with several of the criteria in these groups overlapping across programs. Generally, the essential elements for evaluating the suitability of an indicator are whether the indicator is measurable using available technology, is relevant and responds to the assessment question, and provides information for management decision-making.

2.3 Selected Indicator Frameworks

Indicator frameworks are used to structure, organize, and interpret systems, facilitating the identification of appropriate indicators. Several frameworks are used to organize and identify environmental indicators. One of the more prominent frameworks categorizes environmental indicators as pressures and stressors that degrade ecological condition, the state of ecological conditions, and society's responses at improving ecological condition. As seen in this categorization, environmental indicators can be used to measure ecological condition, but may be used to measure progress towards meeting goals, milestones, and objectives. These indicators are often referred to as “programmatic indicators,” measuring implementation of actions, funding milestones, and changing laws, policies, and regulations. The following subsections present several frameworks that can be used to organize environmental – both programmatic and ecological – indicators to monitor and track estuarine health and restoration efforts.

Table 2-1. Examples of Various Indicator Evaluation Guidelines[1]

General Criteria Group	USEPA (2000)	NRC (2000)	EMAP (1994)
Conceptual Relevance or Soundness	*Relevance to the Assessment*	*General Importance*	*Unambiguously Interpretable*
	Relevance to Ecological Function	*Conceptual Basis*	
Feasibility of Implementation (Current and Future)	*Data Collection Methods*	*Necessary Skills*	*Available method* *Minimal environmental impact*
	Logistics		*Amendable to synoptic survey*
	Information Management	*Data Archiving*	
	Quality Assurance		
	Monetary Costs	*Cost, Benefits, and Cost-Effectiveness*	*Cost effective*
		Data Requirements	
Response Variability	Estimation of Measurement Error		
	Temporal Variability – Within the Field Season *Temporal Variability – Across Years* *Spatial Variability*	*Temporal and Spatial Scales of Applicability*	*Index period stability*
	Discriminatory Ability	*Robustness* *Statistical Properties*	*High signal-to-noise ratio* *Ecologically responsive*
Interpretation and Utility	*Data Quality Objectives*	*Data Quality*	
	Assessment Thresholds		*Nominal-subnominal criteria*
	Linkage to Management Action		
			Retrospective
			Anticipatory
		Reliability	*Historical record*
			New information
		International Compatibility	

[1]Criteria that are common to more than one program are italicized.

2.3.1 PSR Framework

Used internationally and nationally, the Pressure-State-Response (PSR) framework is a conceptual framework developed by the Organization for Cooperation and Development (OECD) for environmental monitoring. The PSR framework (see Figure 2-3) represents the associations among the pressures exerted by human activities on the environment **(pressure)**; the changes in the quality and quantity of natural resources **(state)**; and the societal responses to these changes through environmental and other polices **(response)** (OECD 1993).

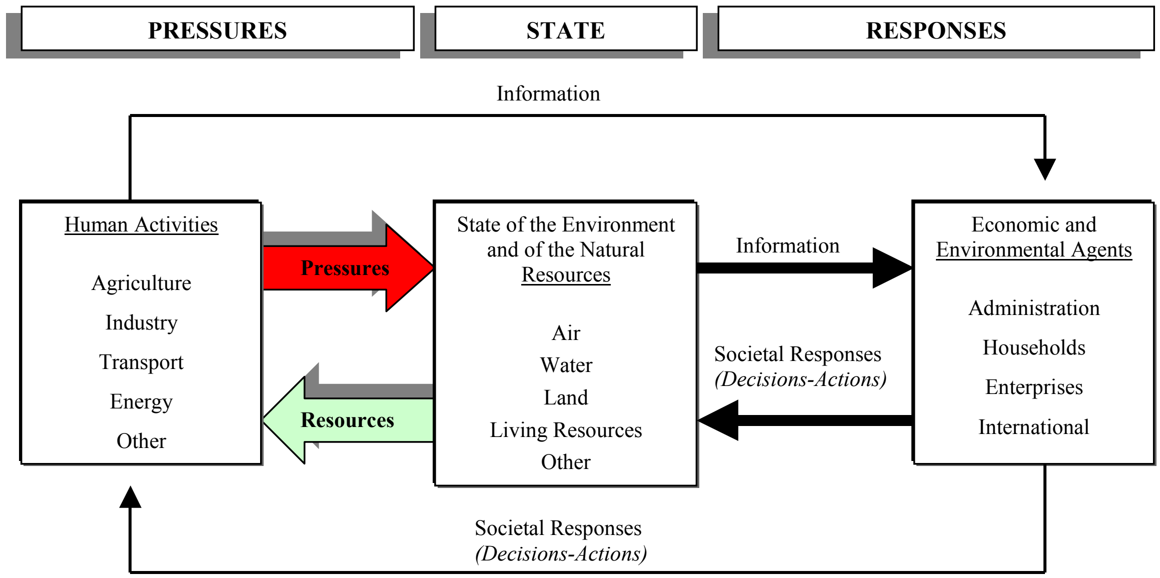


Figure 2-3. The Pressure-State-Response Conceptual Model (OECD 1993)

Pressure indicators are measurements of the pressures exerted on the environment by human activity, whether it is direct (i.e., proximate pressures) or indirect (i.e. indirect pressures). Examples of pressure indicators include emissions from cars, discharges from municipal wastewater treatment plants, and stormwater runoff from agricultural operations. State indicators describe the quality of the environment and the quality and quantity of natural resources. State indicators generally are measurable quantities, such as drinking water quality parameters, concentrations of air toxicants, the extent of viable wetlands, or the functionality or productivity of wetlands. Response indicators relate how society is responding to environmental changes and concerns by protecting and restoring the environment and preventing environmental damage. Societal responses may range from economic incentives such as taxation and subsidies to enforcement with legislative and management programs. The framework assumes that there is a causal relationship between each of the components that links human activity to environmental impacts.

2.3.2 PSR/E Framework

Building on the existing PSR framework, the EPA Office of Policy, Planning and Evaluation (OPPE) modified the PSR framework to include interactions among pressure, state, and response indicators, called "effects" indicators (PSR/E) (USEPA 1995). The principles of the PSR/E framework have been adopted by the EPA Office of Research and Development (ORD), which focuses its indicator research on the state and effects components of the PSR framework. ORD's indicators are science-based, rather than policy-based, and the guidance document *Evaluation Guidelines for Ecological Indicators* presents examples of three different types of indicators (USEPA 2000).

The first indicator type is a direct measurement indicator, such as dissolved oxygen or nutrient concentrations, which directly correlates the measurements of the indicator (dissolved oxygen) to the effect on the environment (hypoxia). The second type of indicator is an index indicator (multiple indicators), such as the index of benthic condition, which integrates measures of community composition and diversity and discriminates between impacted and un-impacted areas. The third indicator type is a complex, multimetric indicator that is a composite index which integrates various structural and functional attributes of an ecosystem and provides an overall assessment of ecosystem condition (USEPA 2000). An example of a multimetric indicator is the characterization of a stream fish assemblage that measures the effects of a variety of stressors across different time scales and levels of ecological organization, and evaluates the impact of fish consumption by the general public. The development of this type of indicator is based on the multimetric Index of Biotic Integrity (IBI) originally developed by Karr (Karr *et al.* 1986, Karr 1981). Therefore, each of these indicator types varies by the type of information and extent of analysis involved in its development.

2.3.3 Ecological Framework

Another environmental indicator framework is presented in the National Research Council's (NRC) guidance document, *Ecological Indicators for the Nation* (NRC 2000). Here, NRC proposes national indicators of ecological condition that are influenced by multiple stressors. These indicators may be used to estimate the ability of a nation's ecosystems to continue to provide goods (i.e., food and building materials) and services (i.e., flood protection and recreation) for the survival of the society. These indicators fall into three categories:

1. Indicators of ecosystem extent and status;
2. Indicators of ecological capital;
3. Indicators of ecosystem functioning.

Indicators of ecosystem extent and status include measurements of land cover and land use. Indicators of ecological capital measure the biotic and abiotic natural capital, or raw materials, of the Nation. Biotic raw materials include the number and distribution of native species, and the number of introduced or exotic and invasive species, while abiotic raw materials include soil and nutrients. Indicators of ecosystem functioning measure ecosystem processes or end results of processes, such as productivity and nutrient-use efficiency and nutrient balance. The interactions between raw materials and the ecosystem process are initially developed in a conceptual model of the estuarine ecosystem in order to develop relevant indicators to model the system.

3. ESTUARINE MONITORING/INDICATOR EFFORTS

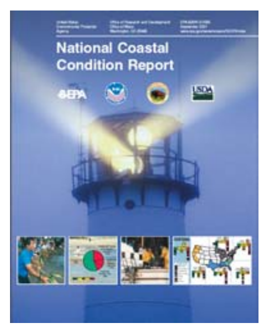
3.1 Indicator Development/Use at the Federal Level

Several Federal agencies, including the U.S. Department of Agriculture (USDA), the U.S. Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), and EPA, have been involved in environmental indicator development for decades. Similar to the Canadian and Dutch governments in the late 1980s, and international organizations such as the United Nations, World Bank, and the Scientific Committee on Problems of the Environment (SCOPE), these agencies have made efforts to simplify complex environmental information to make it more accessible to decision makers, natural resource managers, and the general public. Some examples of national monitoring/indicator efforts focused on estuarine ecosystems are highlighted below:

- The EPA National Coastal Assessment (NCA; initially referred to as Coastal 2000), through the EPA Office of Research and Development, is a national monitoring program implemented at the state level. The NCA uses a common set of survey indicators to assess the condition of coastal and estuarine resources in 24 coastal states. The NCA monitoring data can be aggregated at local, regional, and national levels.

- The Estuary component of EPA's Environmental Monitoring and Assessment Program (EMAP) is a large-scale research program to determine the current status, extent, changes, and trends in ecological indicators of the condition of the nation's estuarine resources on a regional and national basis. The indicators used include fish pathology, sediment toxicity, dissolved oxygen, marine debris, and the condition of benthic organisms.

In addition, several of these agencies have produced national indicator reports focused on estuaries and their ecological health. Some examples include:



- The EPA's National Coastal Condition Report uses several primary indicators to rate the coastal conditions based on various data sets, including NOAA National Status and Trends (NS&T) and seven years of EMAP data. The indicators used include water clarity, dissolved oxygen, coastal wetland loss, eutrophic condition, sediment contamination, benthic index, and fish tissue concentration.

- The NOAA National Estuarine Eutrophication Assessment characterizes the effect of nutrient enrichment in the Nation's estuaries. The assessment collected, compiled, and interpreted data from 138 estuaries into regional summaries to describe the scale and severity of nutrient enrichment conditions nationwide.

Table 3-1 presents an overview of environmental indicators utilized under selected Federal programs. The development of national environmental indicators for estuaries is very challenging, given the size and diversity of U.S. coastal systems. They are necessary, however, since many of the environmental protection goals of Federal agencies are national in scope and many of the Nation's estuaries cross county and state boundaries, requiring regional and interagency cooperation.

Table 3-1. Indicators Currently Used by Indicator-Based U.S. Federal Programs

EPA NCA / EMAP	EPA National Coastal Condition Report	NOAA National Estuarine Eutrophication Assessment
Biological Indicators	Water clarity	Overall eutrophic conditions
Benthic community assemblage	Dissolved oxygen	Nitrogen input
Fish community assemblage	Coastal wetland loss	Land use
Fish pathologies	Contaminated sediments	Population density
Fish tissue residue	Benthos	Estuary susceptibility
Submerged vegetation	Fish tissue contaminants	
Water column indicators	Eutrophic conditions	
Dissolved oxygen		
Salinity		
Temperature		
Depth		
pH		
Nutrients		
Sediment Indicators		
Grain size		
Total organic carbon		
Sediment chemistry		
Sediment toxicity		

3.2 Estuarine Monitoring and Indicator Development/Use in the NEPs

Section 320(b)(6) of the Water Quality Act of 1987 specifies that each NEP shall "...monitor the effectiveness of actions taken in pursuit of the plan," referring to implementation of Action Plans that comprise each individual NEP's CCMP. This responsibility includes documenting progress and results through monitoring implementation of the CCMP's Action Plans and the ecological condition of the estuary. Because monitoring the condition of an estuary is a complex undertaking, EPA requires that each NEP develop a Monitoring Plan describing how it will: (1) evaluate the impact of CCMP implementation, both estuary-wide status and trends and individual, project-level effectiveness, and (2) assess evolving environmental risks to the estuary. The Monitoring Plan presents strategies for implementation of each action plan including proposed methodologies and indicators to track programmatic and implementation progress and results. The Plan also presents a comprehensive plan to meet critical monitoring and indicator needs and coordinate a regional ecological monitoring program. In addition to the Monitoring Plan, periodic State of the Estuary Reports that describe the resource condition in great depth can be developed.

Because of the diversity of issues impacting the conditions of estuaries, many approaches and frameworks have been applied to monitoring program and indicator development across the 28 NEPs. To illustrate this diversity, case studies are provided in the following subsections.

3.2.1 Case Studies of Indicator Development

Chesapeake Bay

The Chesapeake Bay Program (CBP) has been conducting extensive monitoring in the areas of water quality, air deposition, living resources, and land use since 1984. The main objective of the program is to reduce nutrient loadings by 40 percent, to meet acreage restoration goals for submerged aquatic vegetation (SAV), and to achieve stream mileage goals for restoration of habitat for migratory fish. The program engages in extensive environmental monitoring and assessment to determine the extent to which these goals are reached.

The monitoring data collected are used to assess environmental conditions and trends in the bay and to develop environmental indicators. The program uses indicators as key measures of progress, facts to support goal-setting and program management, and as targets and endpoints for restoration effort. The indicators for the Chesapeake Bay Program fall into two main categories: administrative and environmental (Figure 3-1). While the CBP does not use "programmatic indicators" to gauge its success, it continually evaluates the extent to which policies are put into effect throughout the region and reports those findings as part of its operation.

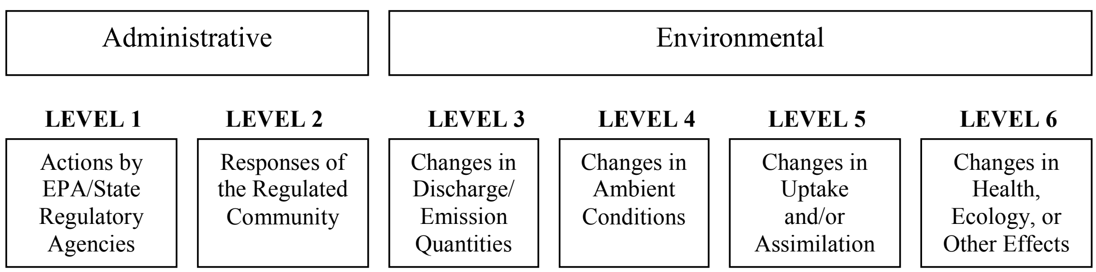


Figure 3-1. Hierarchy of Indicators in the Chesapeake Bay Program

The Chesapeake Bay Program includes three areas of focus for its environmental indicator use: nutrients, living resources, and toxic substances. A fourth category of indicators describe interactions (cross-cutting) of all three indicators focus areas and include indicators such as number of volunteer monitors, volumes of recreational boat wastes, and watershed land use (Figure 3-2).

Barataria-Terrebonne Estuary System

The Barataria-Terrebonne National Estuary Program (BTNEP) Indicators Development Workshop offered BTNEP stakeholders the opportunity to discuss and recommend a suite of indicators that objectively represent the ecological condition of the Barataria-Terrebonne Estuary System (BTES) and efforts to restore it. The objective of the workshop was to develop an easily understood and scientifically-valid suite of indicators which can be used to assess “associational” achievements of meeting CCMP Action Plan objectives.

Four categories of indicators were discussed by the workshop participants that encompass the seven Priority Problems identified in the CCMP, regional demographics, and the Sustained Recognition, Citizen Involvement, and Economic Growth Action Plans. The focus areas are as follows:

- Hydrologic Modification, Reduced Sediment Flows, Habitat Loss
- Changes in Living Resources
- Eutrophication, Pathogen Contamination, and Toxic Substances
- Quality of Life: Community, Economy, and Awareness

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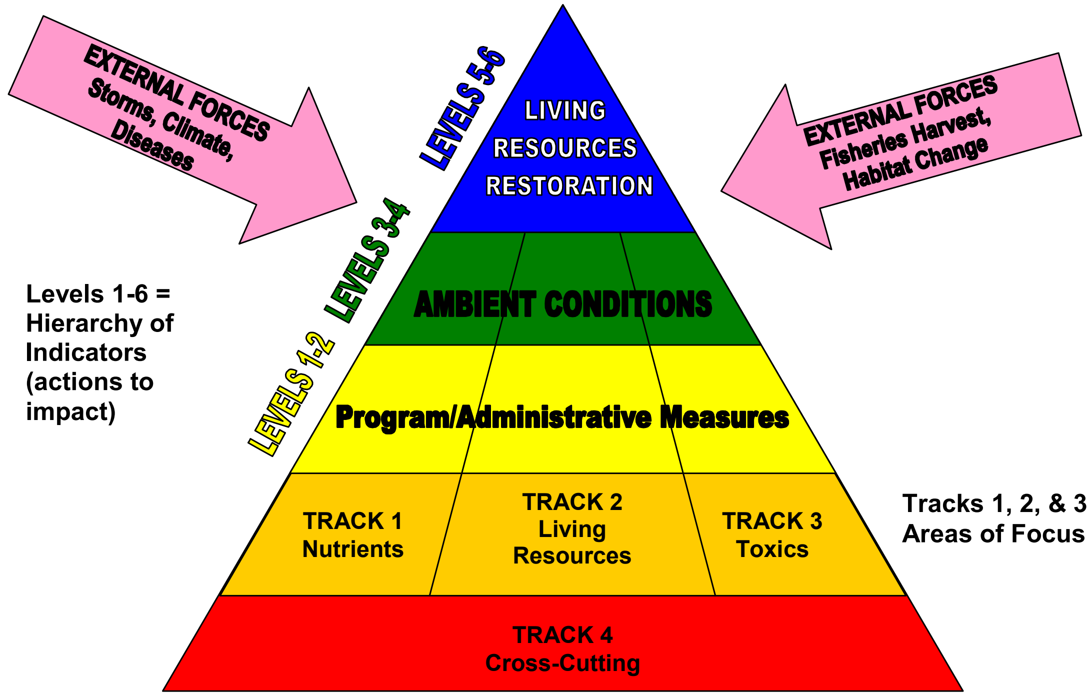

Figure 3-2. Relationship of Indicator Hierarchy and Tracks of Chesapeake Bay Program

For each indicator focus area, candidate indicators were categorized by data availability: (1) supported by datasets produced under current monitoring efforts; (2) supported by planned future monitoring; and (3) not supported by current or future monitoring efforts and therefore a critical indicator gap and need. The overall selection of indicators for immediate reporting was obviously restricted to those indicators already available through monitoring data with known quality and confidence.

SUPPORTED	FUTURE INDICATOR	GAP / NEED
Potential indicator supported by existing status and trends monitoring and assessment.	Potential indicator will be supported by planned future status and trends monitoring and assessment.	Potential indicator not supported by existing or planned status and trends monitoring and assessment.

This process identified critical indicator/monitoring gaps and identified near-future indicators, available through planned monitoring programs, that could be used in future reporting. For each indicator selected, participants were asked to discuss and recommend a format to present the data generated from each indicator; identify key points that explain the link between human stressors, ecological condition, and management responses for the indicator issue; and evaluate key caveats and qualifications of the dataset and visualization format. The outcome of meeting was the identification of 34 indicators in which data were available and may be used to support assessment of CCMP implementation progress.

3.2.2 Case Studies of Indicator Use

Two issues, habitat degradation/loss and nutrient overloading, are common concerns in the 28 NEPs. Among the indicators frequently used to monitor habitat degradation/loss are the aerial extent of the habitat itself, the condition of shellfishing areas, the status of specific wildlife populations, the presence/absence of harmful invasive species, and the quality of the water and sediments in the estuary. Nutrient overloading conditions are typically analyzed using some combination of the following indicators: concentrations of dissolved inorganic nutrients, chlorophyll-*a*, and dissolved oxygen; the status of plankton populations; the condition of benthic and eelgrass habitats; the degree of light penetration; and the status of wastewater discharge. The following subsections present case studies from NEPs that have faced these issues and the management approaches and indicators that have been used to address, monitor, and track these challenges.

3.2.2.1 Habitat Management Indicators

Habitat management indicators are used to measure the continued health and biodiversity of marine and estuarine systems. High-quality habitats offer breeding and nursery areas for a broad range of ecological species, migratory corridors, essential food and protective cover from predators, and enhanced water quality and flood protection. However, habitats may become degraded or lost through multiple sources including dredging, damming, conversion to industrial or commercial land use, increased nutrient overloading, and diking. All of these activities may cause increased algae growth, loss of seagrass acreage, increase sedimentation, and poor water quality. Examples of NEP sites that were successfully applied to appropriate indicators for monitoring habitat recovery are presented below.

Puget Sound

The Puget Sound NEP in Washington draws on an extensive list of indicators to assess the progress of the habitat management program. For example, the status of various wildlife populations dependent on Puget Sound can provide valuable information about the health of the estuary and its numerous habitats. Some populations of fish species, like salmon, rockfish, and Pacific herring, have been in serious decline in the sound, probably as a result of deteriorating aquatic conditions. Recent downward population trends for grebes, herons, ducks, and bald eagles, along with many other birds, are likely due to decreasing habitat suitability and declining resource abundance. The resident number of orcas (killer whales) in Puget Sound has been decreasing since 1995, and the population may be nearing extinction. Many researchers cite toxic contaminants and a reduced food supply as contributing factors.

An additional habitat management indicator utilized by the Puget Sound NEP is the presence or absence of invasive species. An invasive species of particular concern to Puget Sound is cordgrass of the genus *Spartina*, of which three species have been introduced. *Spartina* spp. compete with native vegetation and can alter important fish and wildlife habitat. As of 1999, NEP control efforts have resulted in substantial reductions in the aerial extent of *Spartina* spp, allowing native vegetation and communities to recover.

Casco Bay

The Casco Bay NEP in Maine uses the condition of shellfish beds as an indicator of effective habitat management. Shellfish are bottom-dwelling filter feeders and, therefore, can be used as a reliable measure of water and sediment quality. The number of beds open for commercial or recreational harvesting is the basis for the annual assessment of changes in water and sediment quality. Between 1994 and 2000, 36,902 acres of formerly closed areas were opened for harvesting. Change in native eelgrass coverage is also used as an indicator of habitat quality and, every five years, the acreage of eelgrass is measured estuary-wide. Eelgrass supports nearshore food webs and serves as valuable habitat for a variety of marine and terrestrial species. In the latest 1993-1994 mapping survey, it was found that the amount of eelgrass coverage is increasing (S. Barker, personal comm.).

Delaware

The Delaware NEP also uses shellfish bed status as a measure of the program's habitat management actions. In 1992 and again in 1994, the number of areas opened for harvesting dramatically increased due to improving water quality throughout the estuary, resulting in a total of 377,579 open acres in 1998. As of 1998, approximately 70,000 acres remained closed primarily as a result of their proximity to wastewater treatment plants and stormwater outfalls. In addition, the NEP relies on the status of particular wildlife populations to indicate changes in habitat quality. Numbers of adult American shad returning to spawn in the Delaware River have increased substantially since the 1970s, and preliminary 2000 data suggest that 350,000 adults returned in that year alone. The dynamics of the spawning run are affected by factors such as temperature and stream flow, and the increase in numbers is a result of improving water quality in general.

Tampa Bay

The major indicator of progress for the Tampa Bay NEP in Florida is increasing critical habitat acreage. Between 1995 and 1999, the program restored 1,340 acres of native mangrove and saltmarsh habitat at a rate of 500 acres annually. The program is also working to rehabilitate roughly 250 acres per year of low-salinity habitat, which shelter critical fish nurseries. Finally, the NEP uses acreage of seagrass as a yardstick against which to measure program success. Seagrass increased at a rate of 2 percent per year from 1988 to 1994, although the rate has slowed in recent years. Much of the seagrass recovery is correlated with the reductions in nitrogen loadings to Tampa Bay. To maintain existing water quality and maintain seagrass recovery, the NEP has adopted a five year nutrient management goal to restrict nitrogen levels at 1992-1994 levels. Wildlife populations also serve as indicators for the Tampa Bay NEP. Fish species diversity and benthic organism health have seen the greatest improvement over the past several years. However, manatee deaths have increased and freshwater colonial waterbirds have experienced a decline in nesting frequency and success.

Massachusetts Bay

Shellfish bed status is used by the Massachusetts Bay NEP to measure the success of habitat management actions. Approximately 60 percent of the shellfish beds in Massachusetts and Cape Cod Bays are open to commercial and/or recreational harvesting while the remaining 40 percent is closed or restricted. The project is addressing the cleanup of shellfish beds by focusing efforts on identifying nonpoint source pollution, which is the major source of contamination entering the beds through discharges from storm drains. By using innovative remediation technology and local enforcement of septic systems, approximately 400 acres of shellfish beds were opened. With the installation of sand filtration systems along the North and South Rivers, bacteria counts upstream of shellfish beds has dropped measurably.

3.2.2.2 Nutrient Overloading Indicators

Excess nutrients, particularly nitrogen and phosphorus, can contribute to increased algae blooms, low dissolved oxygen, and fish disease. Dissolved oxygen levels below 5 parts per million is not likely to sustain ecological species and conditions with less than 2 part per million are considered hypoxic. Common sources of nutrient overloading include point and nonpoint sources, including wastewater treatment plant discharges, stormwater runoff, leaking septic systems, sediment runoff, atmospheric deposition, and groundwater discharges. Case studies of NEPs that use indicators to monitor nutrient overloading are provided below.

Massachusetts Bay

The Massachusetts Bays NEP employs a variety of indicators in the assessment of nutrient management in the estuary. For example, dissolved oxygen levels are utilized as an indicator of nutrient overloading. Excessive levels of nitrogen decrease the amount of dissolved oxygen in the water, causing hypoxia and leading to reduced fish growth, physiological stress of aquatic organisms, and, with extremely hypoxic conditions, death. The 1999 average dissolved oxygen level in Massachusetts Bays was the lowest measured in seven years of monitoring and was found to be below the warning threshold of 6.0 mg/L (Libby et al., 2000). The NEP also monitors phytoplankton composition and abundance as indicators of nutrient overloading in the estuary. Phytoplankton become more abundant as nitrogen levels increase so tracking these populations provides valuable information. Between 1992 and 1999, phytoplankton levels in general remained fairly stable (Libby et al., 2000).

Long Island Sound

The Long Island Sound NEP, which involves both the States of Connecticut and New York, measures the number of pounds per day of nitrogen discharged into Long Island Sound from point sources. From 1990 to 1999, point source nitrogen loads to the estuary decreased by 19.2 percent, partially due to denitrification technology established at some of the wastewater treatment plants that discharge into the Sound and its tributaries. The NEP also monitors the levels of chlorophyll-*a* in the estuary. Chlorophyll-*a* is found in phytoplankton and high levels of this green pigment can indicate a problem with nutrient overloading. Chlorophyll-*a* levels during the winter/spring algal bloom have dramatically decreased between 1992 and 2000 from an average of about 25 mg/L to an average of 2 mg/L.

Sarasota Bay

The Sarasota Bay NEP in Florida monitors water clarity to indicate nutrient overloading. Increased loadings of nutrients to the estuary can reduce the total amount of light that reaches the estuary floor in waters of a fixed depth. Low sunlight penetration has negative effects on photosynthetic seagrasses or other SAV and an overabundance of plankton leads to hypoxia. Secchi disk depth is another way the NEP assesses nutrient problems. The Secchi disk is lowered into the water and the depth at which the disk can no longer be seen from above the water's surface can indicate the level of water clarity.

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4. USEFULNESS OF NEP DATA AS NATIONAL ENVIRONMENTAL INDICATORS

4.1 Data Sources

The objective of the NEP Information Request, distributed in December 2000, was to determine if there exists common indicators that may be used to measure progress on habitat degradation/loss and nutrient overloading issues within the NEP. NEP responses to the Information Request were evaluated for comparability and, to the extent possible (as defined by the comparability of data), aggregated into national statistics.

4.1.1 The NEP Information Request

Information Request responses were cataloged and entered into an MS Access database, by individual NEP, to develop national statistics and to maintain the identity of NEP-specific data. The data from the Information Requests are presented and discussed according to the PSR framework, however, this does not imply a causal link between environmental and anthropogenic pressures that changes the state of the environment that results in habitat degradation/loss and nutrient overloading.

4.1.1.1 Total Participation

Twenty-one of the 28 (75 percent) NEPs responded to the habitat management issues section of the Information Request. Seventy percent (20 of the 28) of the NEPs responded to the nutrient overloading issues section of the Information Request.

4.1.1.2 Participation by Region

Based on region, data was submitted through the information request by 73 percent (8 of 11) of the Northeast estuaries, 75 percent (3 of 4) of the Southeast estuaries, 86 percent (6 of 7) of the Gulf and Caribbean estuaries, and 67 percent (4 of 6) of the Pacific estuaries (see Figure 4-1).

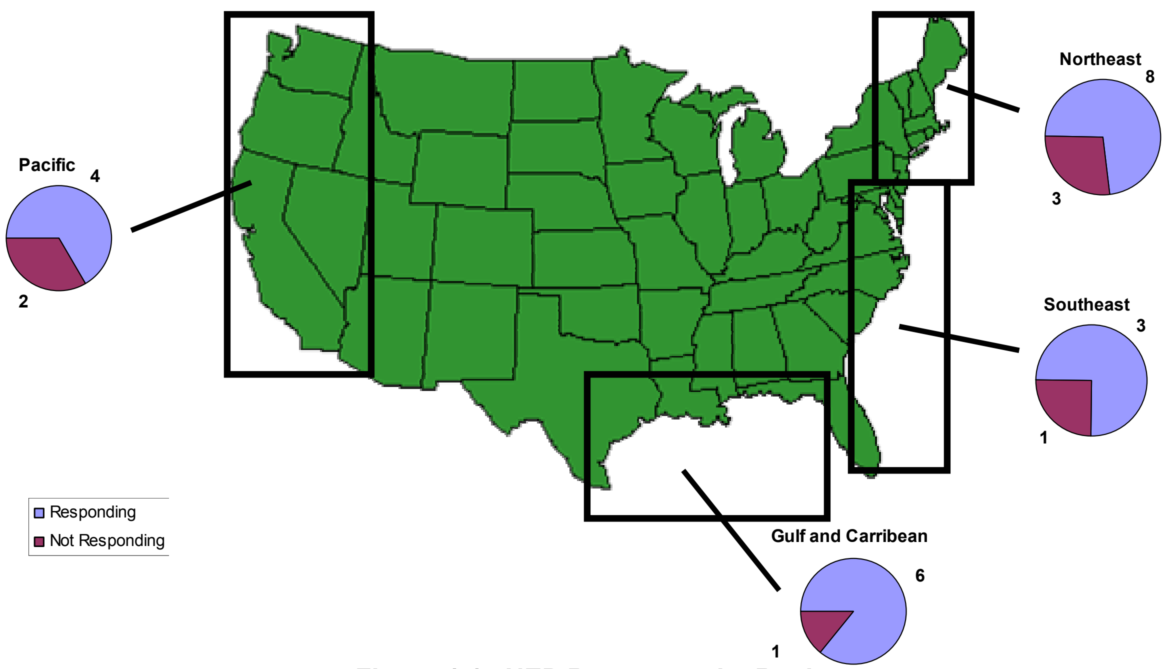

Figure 4-1. NEP Responses by Region

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4.1.2 Supplementary Information on National Environmental Indicators in Estuaries

The National Coastal Condition Report (USEPA 2001) and National Estuarine Eutrophication Assessment (Bricker et al. 1999) were used to supplement discussions of the Information Request responses. The National Estuarine Eutrophication Report is a comprehensive assessment by over 300 experts discussing nutrient enrichment and eutrophic conditions at U.S. estuaries. Eutrophication is the accelerated production of organic matter in a water body that is likely cased from increased algae production, depleted dissolved oxygen, and loss of SAV. The assessment was based on the results of surveys conducted by NOAA from 1992 to 1997, covering 138 estuaries (representing over 90 percent of the estuarine surface area of the conterminous U.S.) with supplemented information on nutrient inputs, population projects, and land use.

The National Coastal Condition Report was developed through a coordinated effort with EPA, NOAA, USFWS, and the U.S. Geological Survey to summarize the conditions of ecological resources in U.S. estuaries. This comprehensive study is based on data collected from 1990 to 2000 as part of EPA EMAP, NOAA's NS&T Programs, and other national databases, and represents conditions at over 1,000 selected sites (representing 70 percent of all estuaries areas in the continental U.S.). The study relied on seven primary indicators: water clarity, dissolved oxygen, coastal wetland loss, eutrophic condition, sediment contamination, benthic index, and fish tissue contaminants. Supplemental indicators such as algae concentrations, sediment toxicity, and fish pathology were also used, if available. Each of the indicators were provided a score of good, fair, or poor for each coastal area of the United States (Northeast, Southeast, Gulf of Mexico, West Coast, and Great Lakes). The indicator scores were then averaged to create a score for overall condition of each coast area. Figure 4-2 presents the overall score for each of U.S. coastal area.

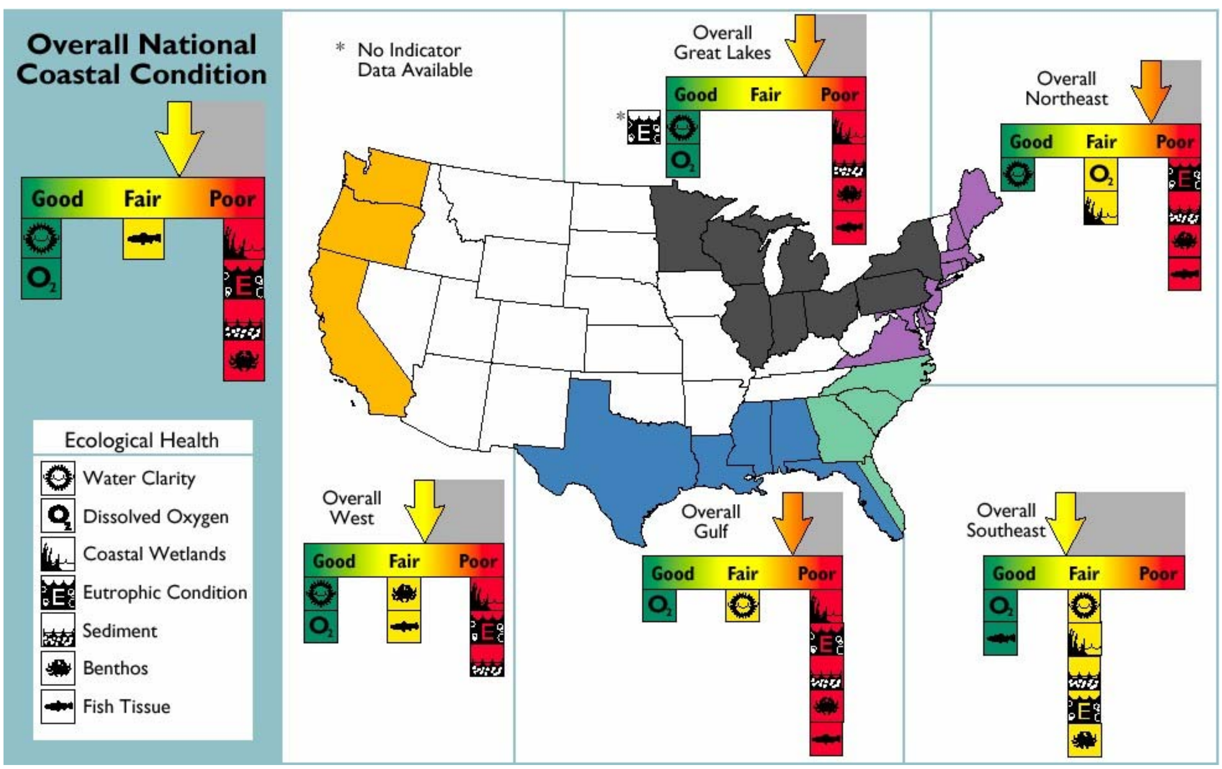

Figure 4-2. Overall National Coastal Conditions (USEPA 2001)

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4.2 Habitat Degradation/Loss

4.2.1 Pressures Causing Habitat Degradation/Loss

Coastal habitats are essential to the life cycles of fish, shellfish, migratory birds, and other wildlife, and also buffers coastal areas against storms and wave damage. In addition, these habitats filter and process residential, agricultural, and industrial wastes, which ultimately improves water quality. In recent years, habitat has been degraded due to human activities (e.g., flood control, agriculture, waste disposal, real estate development, shipping, commercial fishing, oil/gas exploration and production) and natural processes (e.g., sea level rise, sediment compaction, droughts, hurricanes, floods). Several CCMP Action Plans identify key anthropogenic and environmental pressures potentially causing habitat degradation and loss, including development, nutrient loading, introduction/removal of sediments, and introduced species. In the Information Requests, each NEP was asked to report the importance of each of these factors in potentially impacting the habitat recovery of their specific estuary system. The scores were ranked from "top priority issue" (High), "moderate importance" (Medium), "low importance" (Low), "unknown, but an issue" (UN), and "not applicable/not known and not expected to be a problem/factor" (NA/NN).

Figure 4-3 presents a summary of the responses with respect to potential causes that may impact habitat recovery. Based on the data, it appears that for over half of the estuaries that responded, habitat loss is attributed to development, nutrient loading, and introduced species. Sediment removal/introduction is a moderate to high priority for approximately 16 NEPs. Three Programs noted that all four of these factors are not the source of habitat degradation in their estuary; however, it is likely that these sites are not measuring habitat recovery as their primary indicator. The National Coastal Condition Report notes that nearly 50 percent of the existing wetlands of the conterminous U.S. were lost from 1780 to 1980s, with the greatest loss of habitat found in the Western States. Wetland losses from the southeastern states and the Gulf of Mexico are occurring at a rate of approximately 1 percent per year (USEPA 2001).

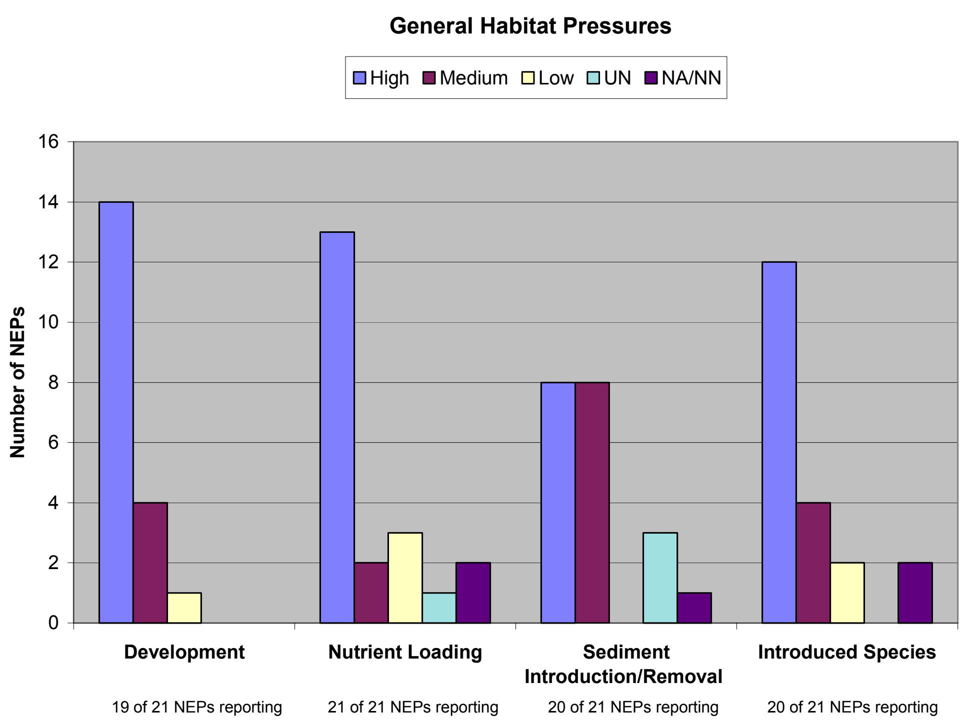

Figure 4-3. Reported Importance of General Habitat Pressures

4.2.1.1 Development

Fourteen of the 19 NEPs indicated that development was of high importance in habitat management. As shown on Figure 4-4, NOAA predicts that the population along the coastal cities of the United States will dramatically increase upwards of up to approximately 100,000 additional residents along the most popular coast lines (i.e., California, Hawaii, Washington, Florida, and Massachusetts) by 2010. This population increase corresponds well with responses from the Information Requests, where projected human population growth, residential development and sprawl, and the conversion of agricultural and forest land to residential use were the primary reasons for development pressures on NEP estuaries (Figure 4-5). Increased dredging and commercial port/marina development were moderately important while development of golf courses and industrial development were of low importance. Other factors that specific NEPs noted of importance include expansion of airports, reduction of natural sediment input to Mississippi River, and hydrologic modification.

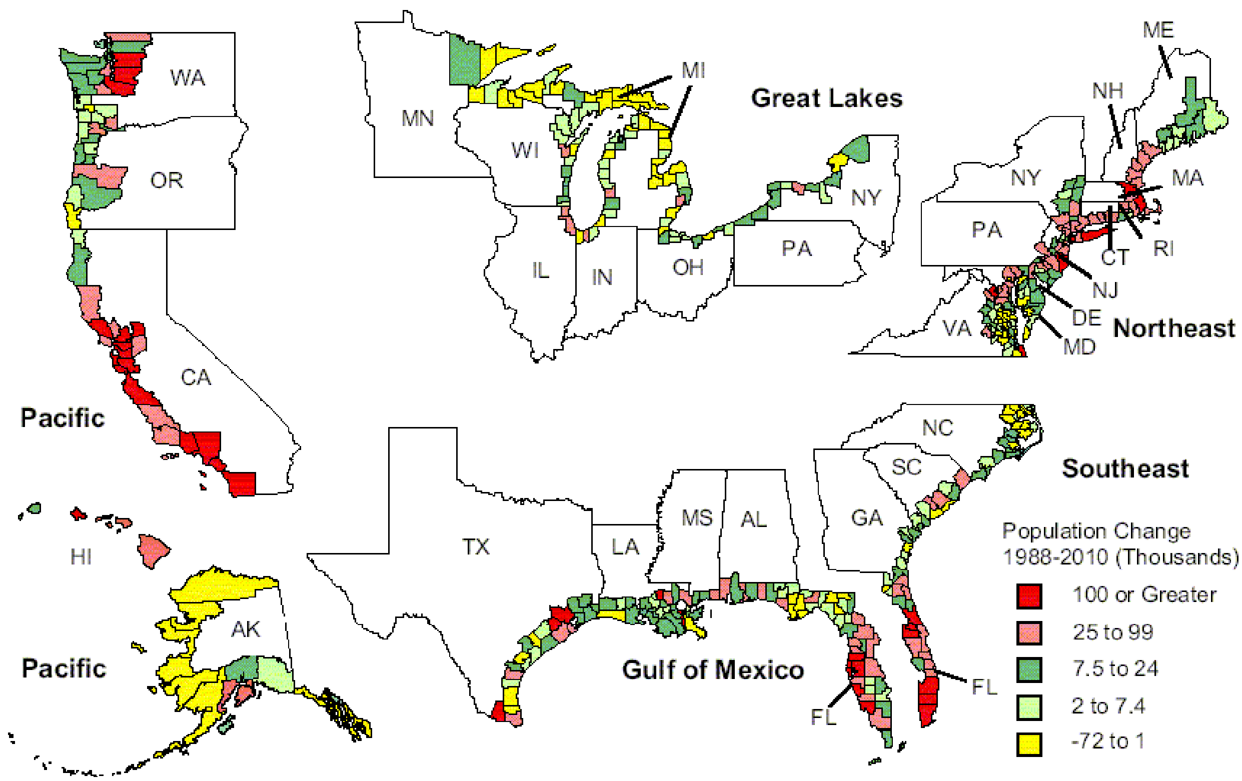

Figure 4-4. Population Change in Coastal Counties, 1988-2010 (NOAA 1990)

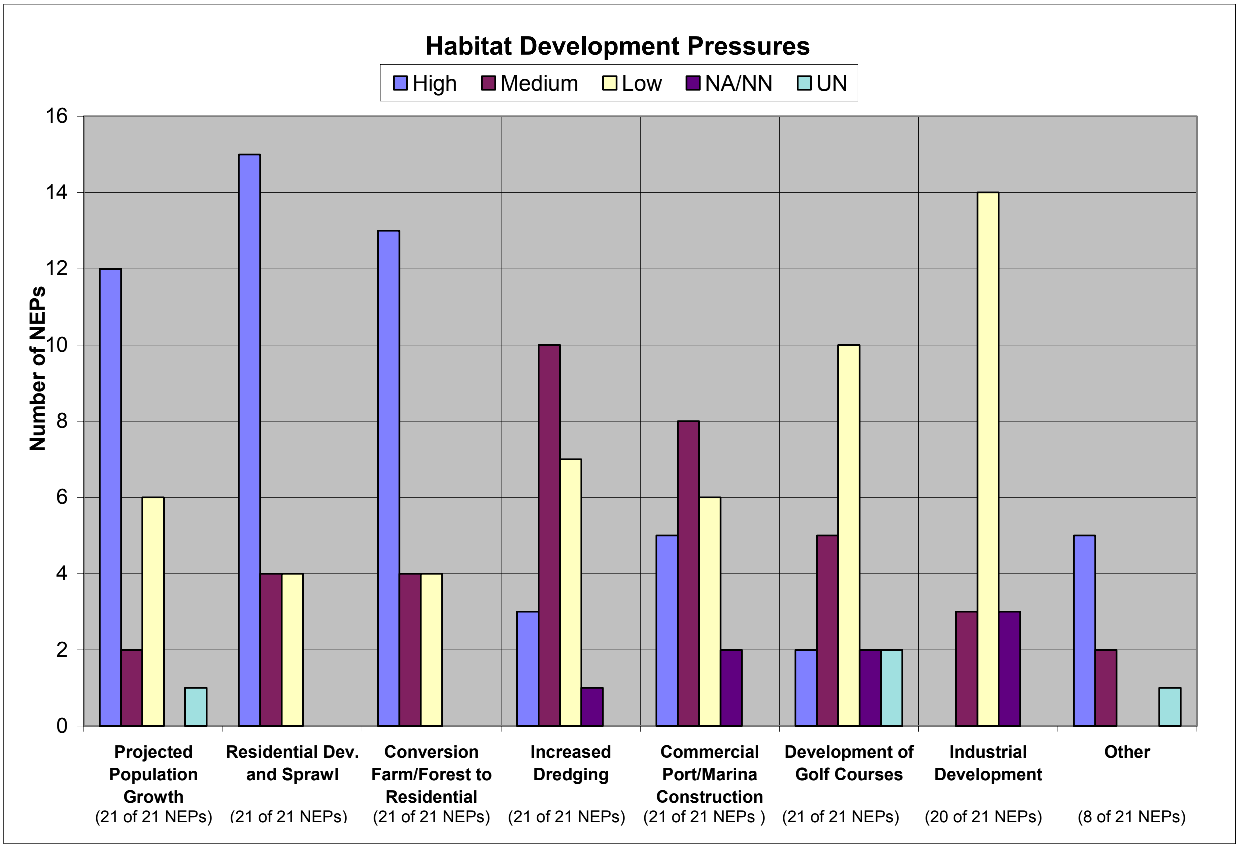

Figure 4-5. Specific Factors Leading to Loss of Habitat through Development

4.2.1.2 Nutrient Loading

Thirteen of the 21 NEPs indicated that nutrient loading was of high importance in habitat degradation/loss, while two NEPs ranked it as moderate and 6 NEPs noted it as low or not important. Sixteen of the 21 NEPs ranked reduction of SAV as high to moderate importance compared to habitat loss. The majority of the NEPs were unable to quantify the actual acreage of SAV lost due to nutrient loading. Four NEPs estimated that over 1000 acres of SAV have been lost (see Figure 4-6).

Nutrient enrichment and coastal eutrophication is a common problem that is impacting a majority of the NEPs. Many coastal areas receive excessive amounts of nitrogen and phosphorus from point and nonpoint sources, leading to high growth of algae and vegetation. Municipal wastewater treatment plants, urban and suburban stormwater runoff, septic systems, and agricultural land use appear to be the primary reasons for estuarine habitat loss through nutrient overloading (Figure 4-7). Equal numbers of respondents noted that nutrient loading from groundwater inputs and atmospheric deposition were either high to moderate concerns or low to not applicable. Although marina construction was found to have low importance in habitat loss, marina and boat discharges are moderately important to nutrient loading, according to the NEPs. Industrial wastewater discharges and unidentified nonpoint sources are of low importance. Four NEPs reported that illicit sewer connections were primary reasons for nutrient overloading, however, the majority of the NEPs found this factor to be not applicable.

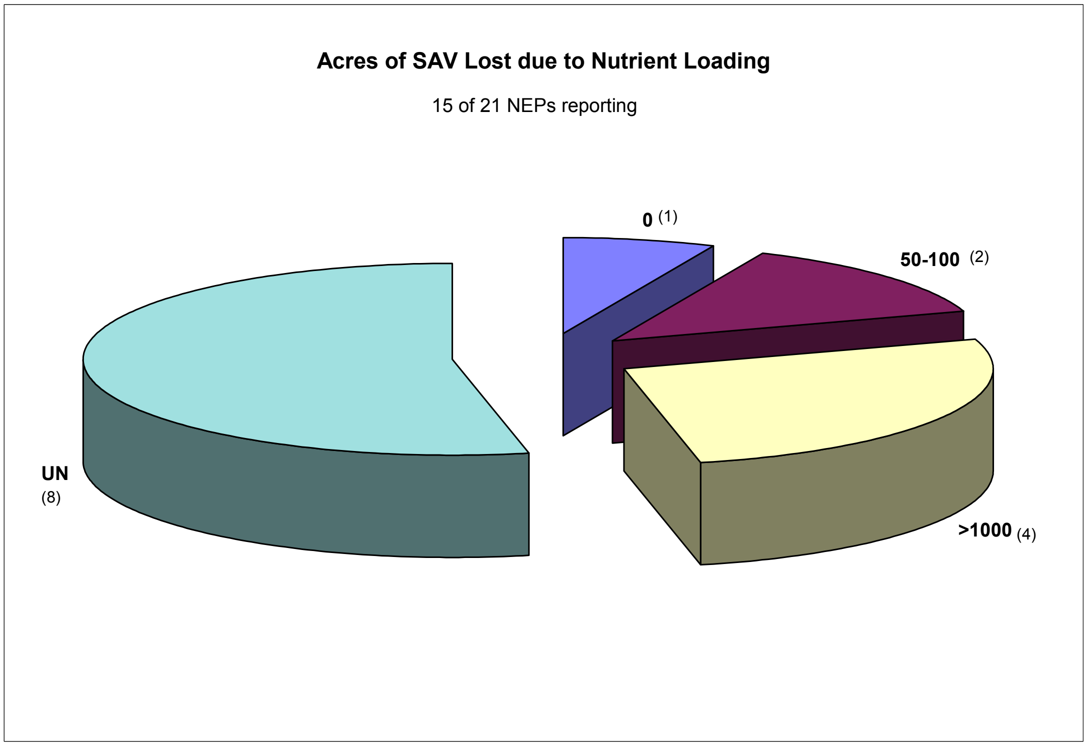

Figure 4-6. Acres of SAV Lost due to Nutrient Loading

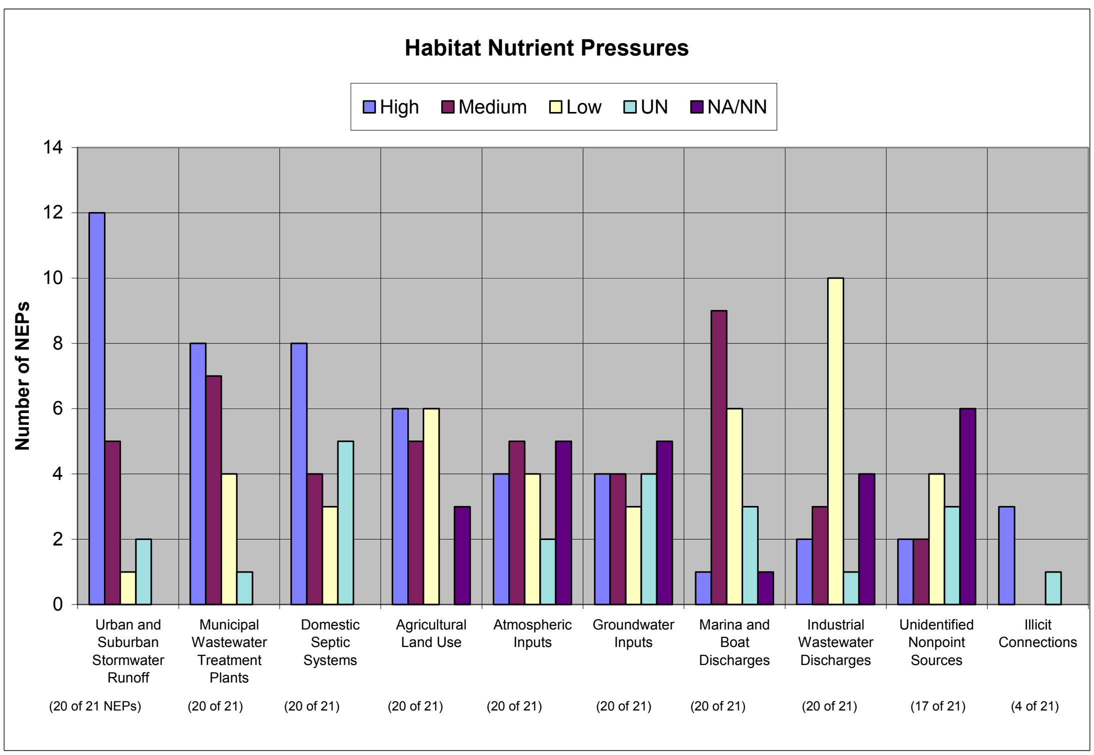

Figure 4-7. Specific Factors Leading to Loss of Habitat through Nutrient Loading

4.2.1.3 Sediment Loading

Sixteen of 20 NEPs reported that introduction and removal of sediment was of high to moderate importance with regard to loss of habitat. Sediment management practices can physically alter coastal wetlands, which can lead to loss of estuarine habitat and degradation of habitat conditions. Factors that influence sediment loading include stormwater runoff, mining, forestry, erosion, agriculture, filling activities for mosquito abatement, dredging activities, and construction/development activities. Figure 4-8 presents the NEP responses related to sediment loading pressures resulting in habitat loss. Erosion, agricultural practices, urban stormwater runoff, and dredging activities were noted as being of high to moderate importance due to loss/gain of sediment. Mining, forestry, and filling activities for mosquito abatement are low to not applicable at a majority of the NEPs. Four NEPs noted that construction/development activities were of high importance while the remaining NEPs qualified this factor as not applicable. One of the end products of sediment loading is loss of SAV. Figure 4-9 indicates that the actual acreage of SAV lost due to sediment is unknown for a majority of NEPs. Three NEPs quantify the loss at greater than 1000 acres.

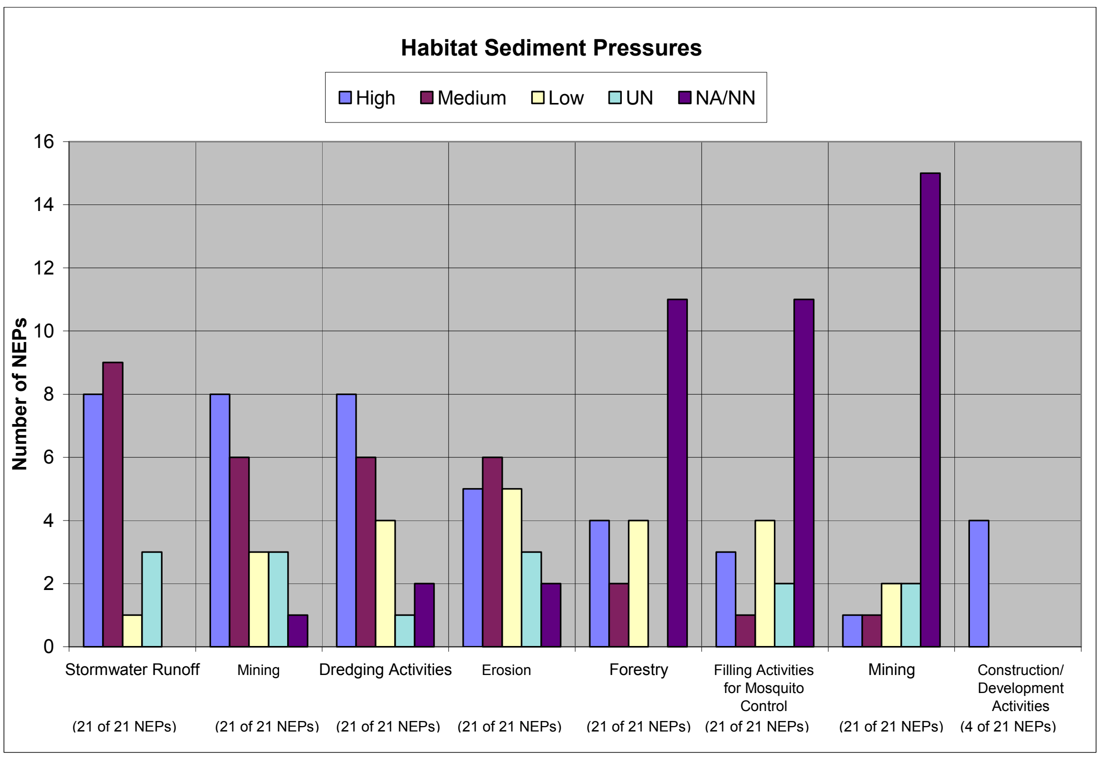

Figure 4-8. Specific Factor Leading to Loss of Habitat through Sediment Loading

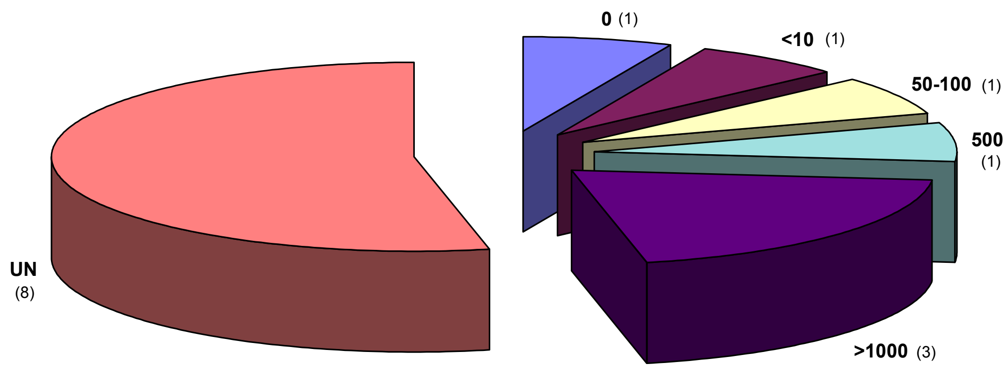

Figure 4-9. Acres of SAV Lost Due to Sediment Loading

4.2.1.4 Invasive Species

Twelve of 21 NEPs found the introduction of invasive species to be of high importance in habitat degradation and loss. The intentional or accidental introduction of invasive species can lead to predation and competition that contributes to the eradication of some native populations and drastic changes to the food web. It can also alter: (1) the water table; (2) modify the nutrient cycle or soil fertility; (3) increase erosion; (4) interfere with navigation, agricultural irrigation, sport and commercial fishing, recreational boating and beach use; and (5) increase possible pathogens (USEPA 2003). Introduction of invasive species has impacted 1000 acres at 5 NEPs and 500 to 1000 acres at 4 NEPs. Another 1000 acres are being threatened by invasive species at 8 NEPs. It is anticipated that the eradication of invasive species may save on average 100 to 500 acres of habitat at 3 NEPs; the majority of the NEPs noted that the actual acreage of habitat recovered from these efforts is unknown. Invasive species appear to impact all habitat types equally (i.e., salt water, estuarine, salt marsh, and freshwater). Plants make up the largest group of invasive species within each NEP region. Twenty-six different plant species were reported as occurring in at least one NEP. The Southeast and Pacific NEPs each have 12 species of invasive plants. The most common invasive plant is *Phragmites*, which occurs in 7 NEPs from the Northeast, Southeast, and Pacific regions. Of all the invasive plants, 9 species occur in more than one NEP region (Figure 4-10).

Five species of invasive mollusks (Figure 4-11) occur in 6 NEPs, and 4 species of crustaceans occur in 8 NEPs. The most common crustacean is the green crab (C*arcinus sp.*), which occurs in 2 of the Northeast NEPs, one of the Southeast NEPs, and 2 of the Pacific NEPs (Figure 4-12). The Southeast NEPs have the largest number of invasive species; 42 species among 3 NEPs.

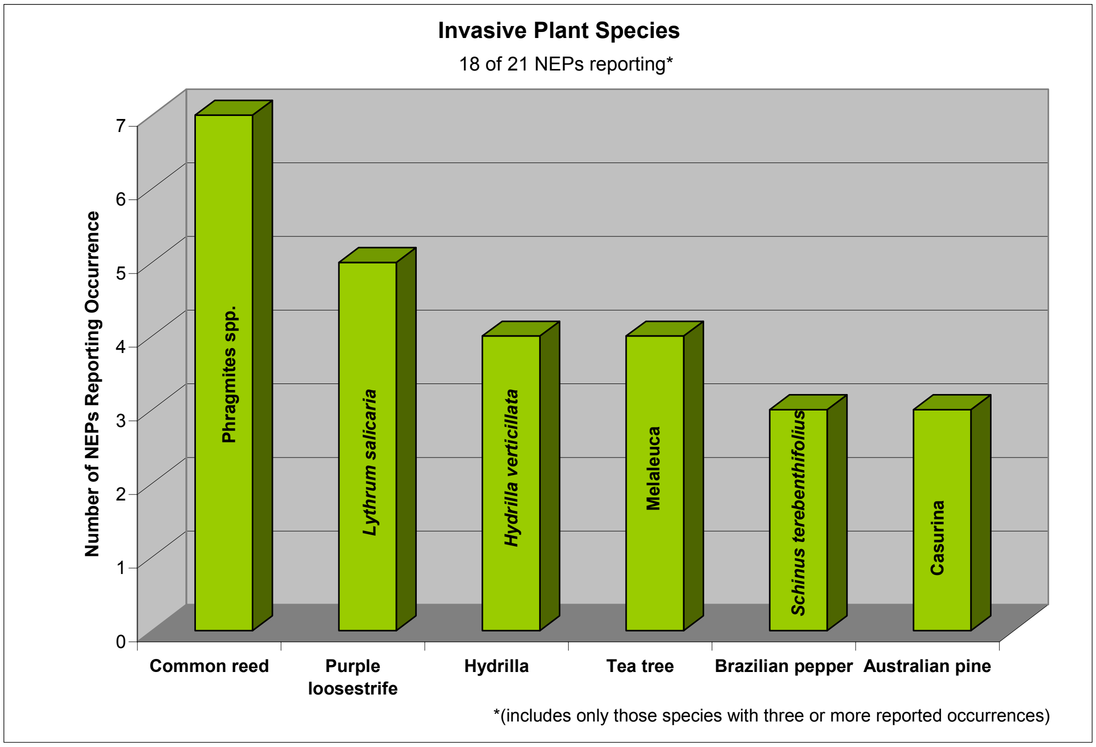

Figure 4-10. Most Common Invasive Plant Species

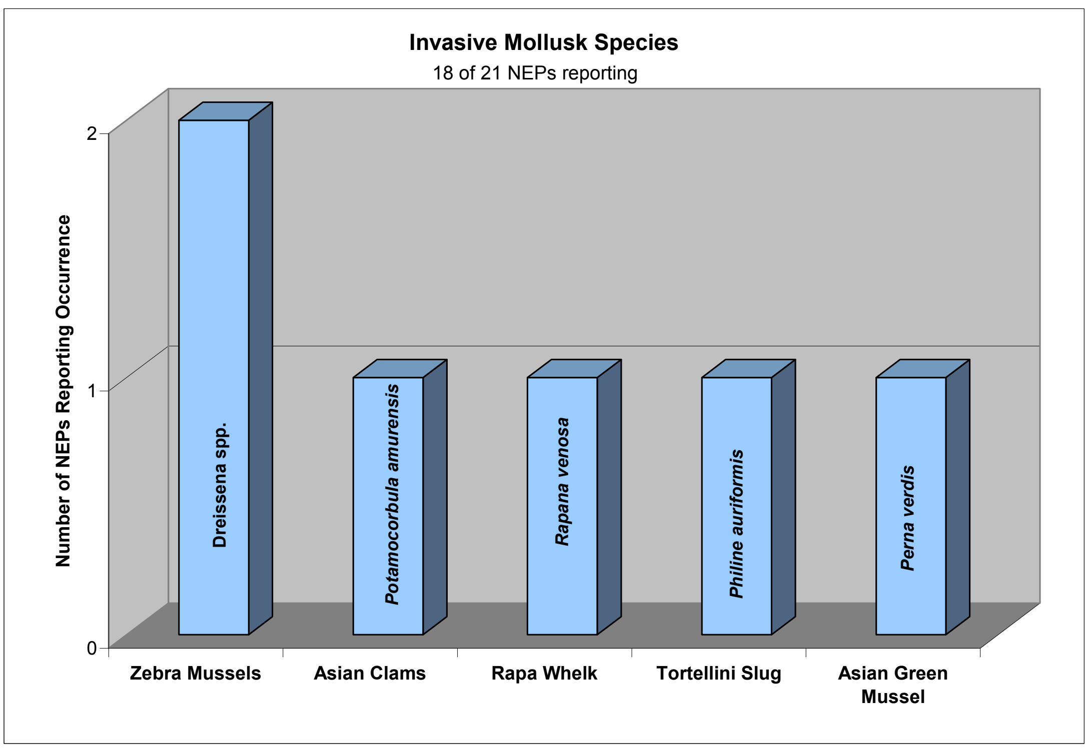

Figure 4-11. Most Common Invasive Mollusk Species

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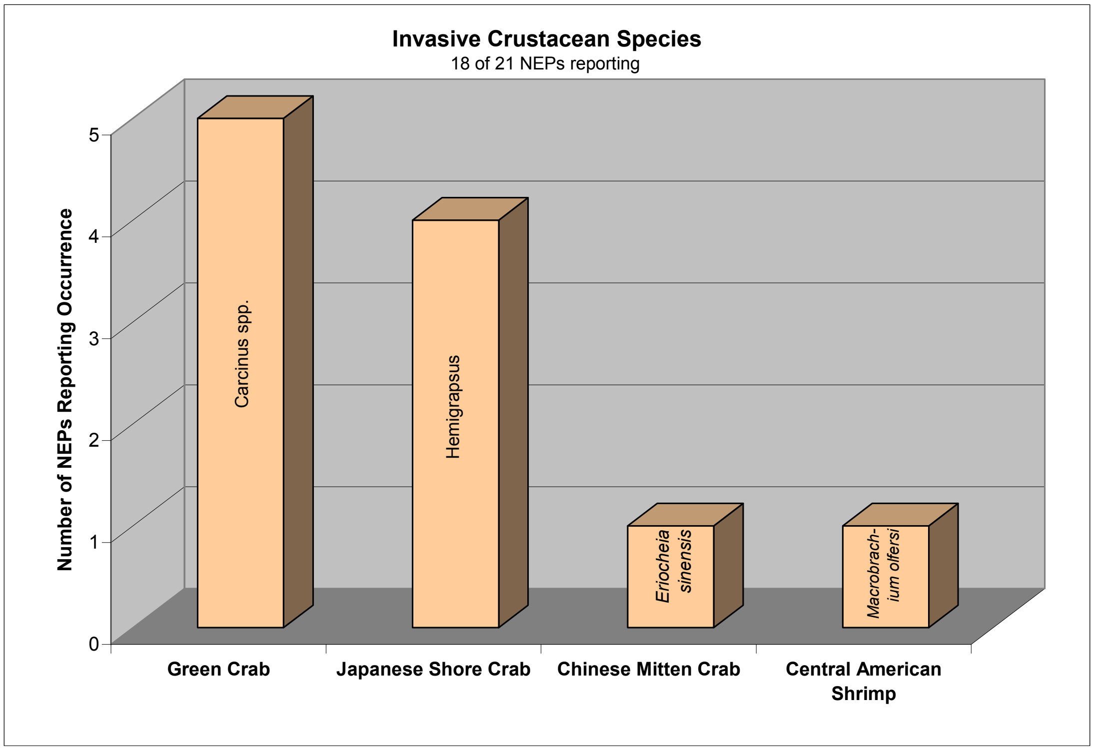

Figure 4-12. Most Common Invasive Crustacean Species

Invasive species enter new ecosystems through a large variety of pathways. Figure 4-13 presents the most common pathways by which invasive species are introduced into NEP estuaries. Transport activities introduce invasive species through the discharge of ballast water or through the use of commercial/recreational vehicles or in cargo shipments. Use of non-native species for aquaculture, landscaping, or as pets can also lead to the introduction of invasive species. A third category includes illegal introduction by the release of domestic and game species.

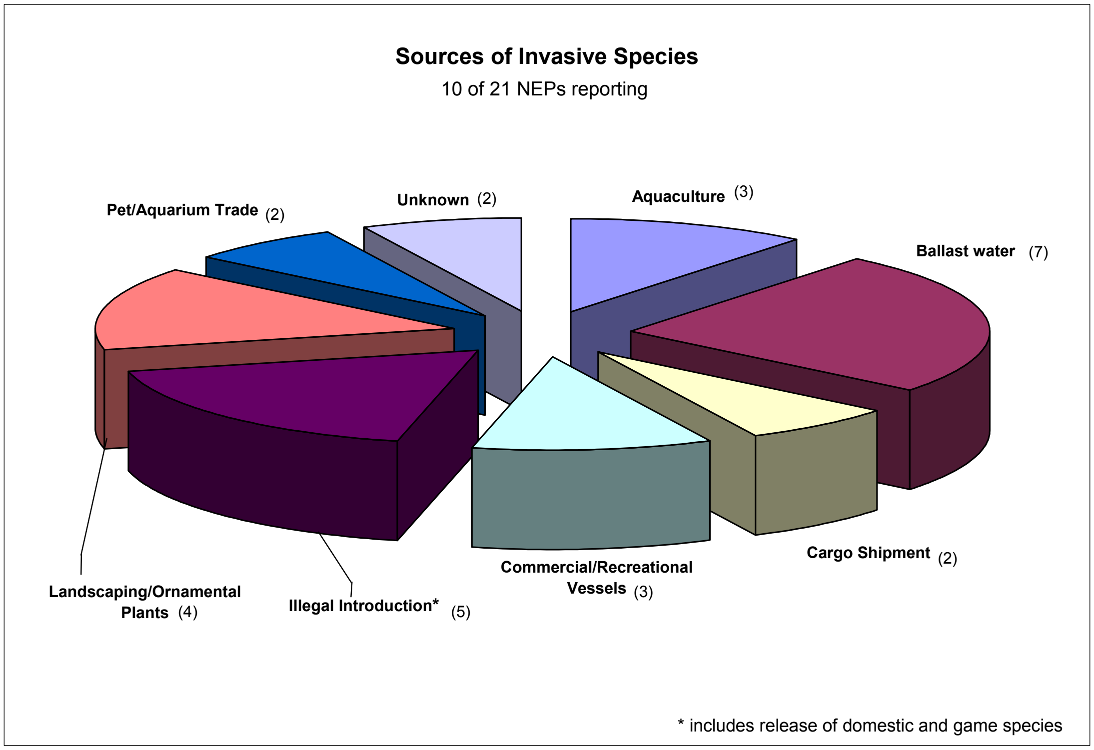

Figure 4-13. Pathways for Invasive Species Introduction

4.2.2 State of Estuarine Habitat

Habitat mapping is used to measure the extent of habitat in an estuary. Sixteen NEPs reported that major progress has been achieved in mapping available habitat since 1997. Only one NEP site noted that it had completed this effort (see Figure 4-14). Five NEPs have 61 to 80 percent of the habitat mapped while another 5 NEPs have mapped over 81 percent of the habitat. Approximately 7 NEPs have less than 60 percent of the habitat mapped. As shown in Figure 4-15, only about half of the NEPs have created land use and land cover maps from these surveys. Five NEPs were unaware if these maps were created. In conjunction with habitat mapping effort, the NEPs were also asked whether progress has been made since 1997 to develop a database and GIS platform to warehouse the monitoring data. The majority of NEPs (13 of 21) reported major progress in developing a GIS platform while 7 NEPs noted little or no progress being made in this effort. Of the NEPs that have made progress in developing GIS systems, 4 NEPs have developed over 20 GIS data layers or databases detailing ecologically significant areas or areas that contain rare species. A total of 10 NEPs have some form of database that identifies ecological relevant or sensitive areas.

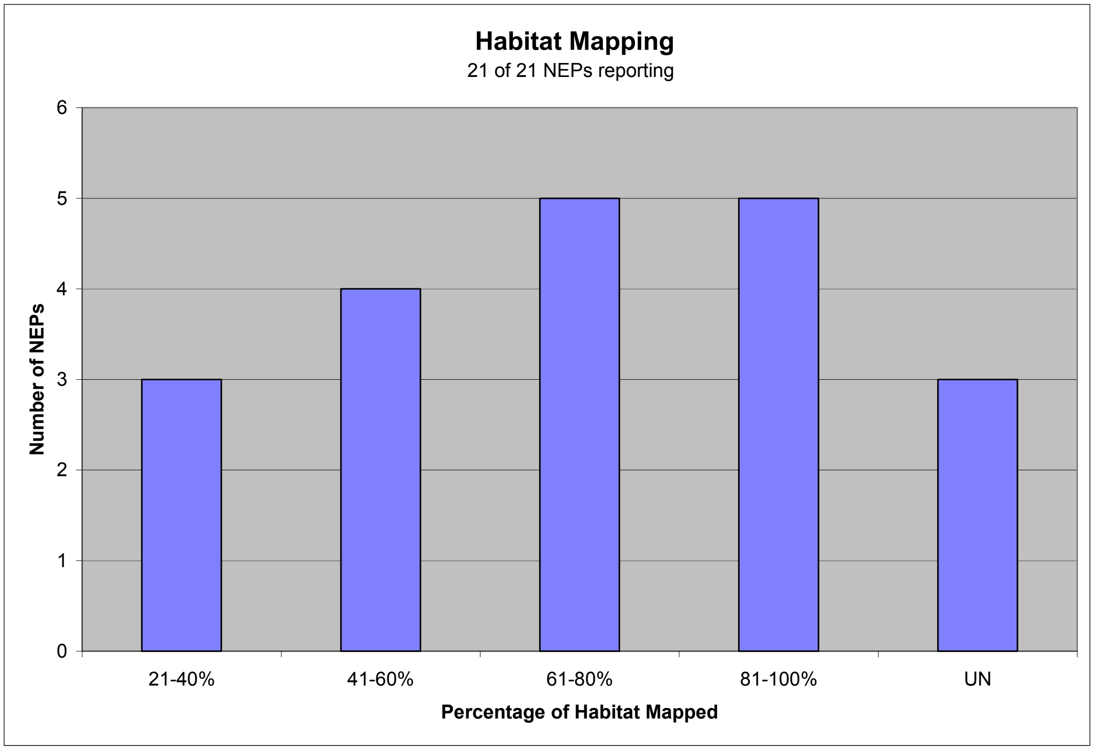

Figure 4-14. Habitat Mapping Efforts

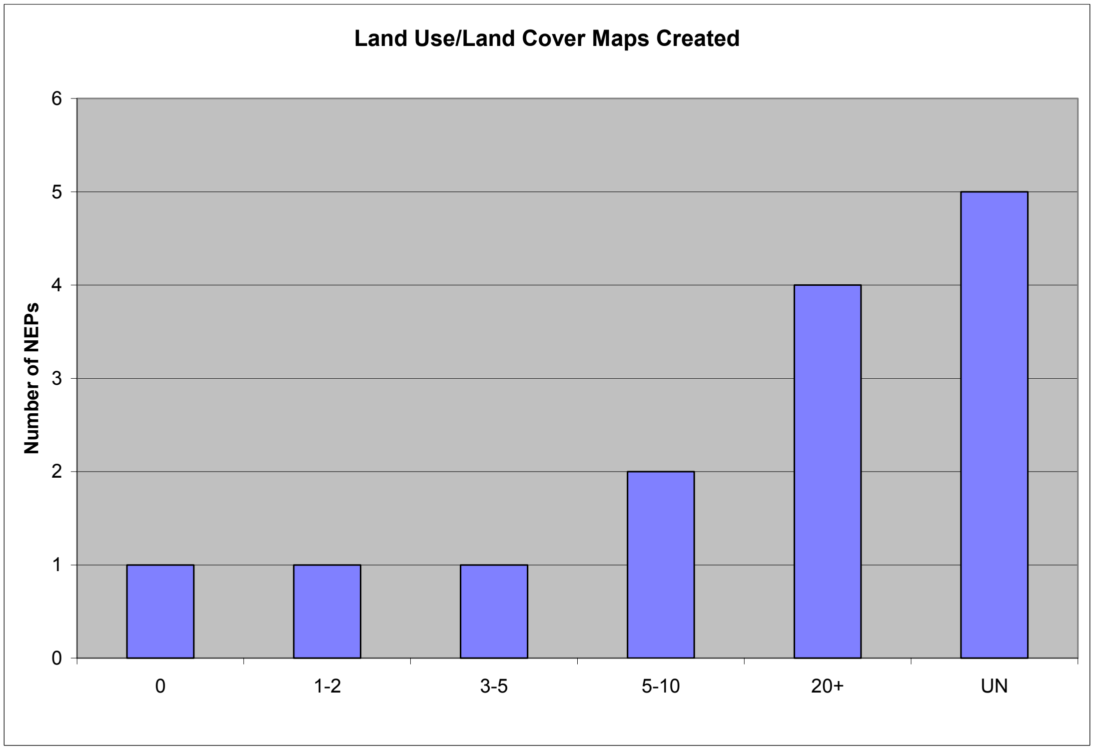

Figure 4-15. Land Use/Land Cover Maps Created

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4.2.3 Societal Responses to Habitat Degradation/Loss

The actual acreage of habitat restored or protected through the successful implementation of restoration, mitigation, and banking program is shown in Figure 4-16. On average, approximately 50 to 100 acres were restored under these programs, and over 1000 acres were restored or protected at 4 NEPs. Unfortunately, the restoration programs have not lead to dramatic changes in incorporating habitat restoration initiatives into land use planning and zoning regulations to limit development along the coast. Based on responses from the NEPs, it appears that little progress has been made in changing zoning regulations. Only 6 NEPs noted major to intermediate progress in incorporating habitat restoration programs into land use planning and zoning regulations. Those communities that have successfully adopted land use planning regulations, have on average restored or "not lost" approximately 100-500 acres. One NEP was able to restore 1000 acres due to community land use planning. A similar pattern is shown for communities attempting to adopt a "no net loss" restoration goal. Five NEPs have no community action in adopting restoration goals. Three NEPs have 100 percent of community groups involved in adopting restoration goals while 3 other NEPs have approximately 90 percent community involvement. Three NEPs have less than 50 percent of community groups involved in adopting restoration goals.

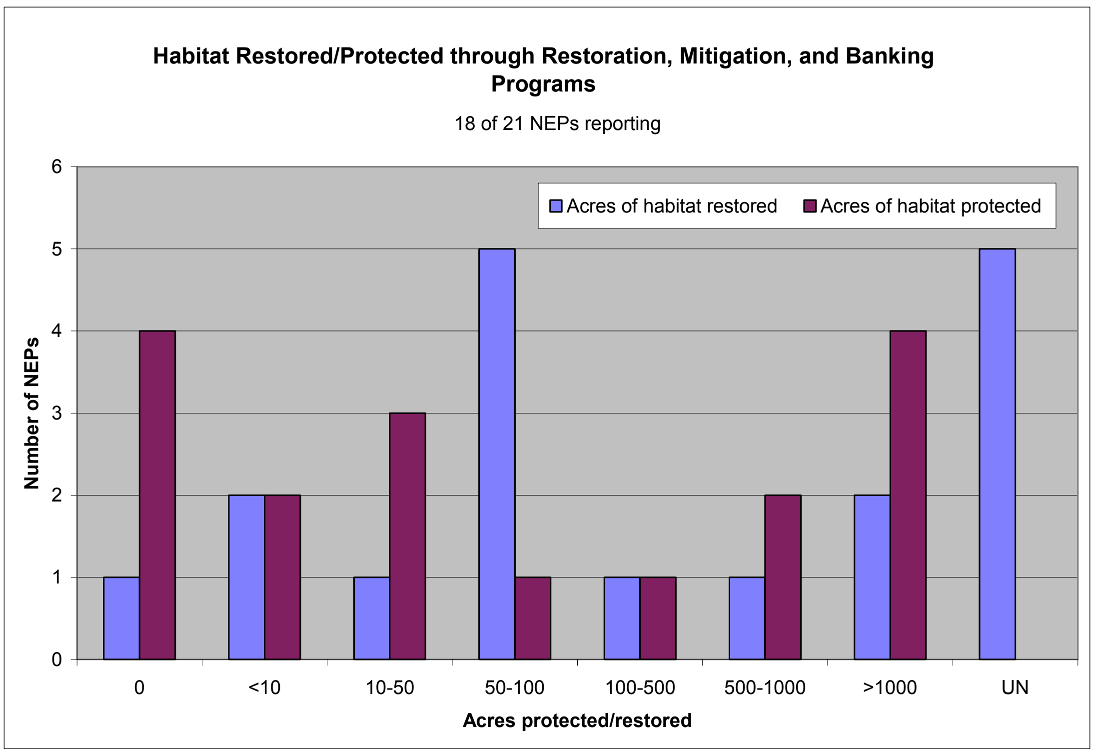

Figure 4-16. Acres Protected/Restored Under Restoration, Mitigation, and Banking Programs

The National Coastal Condition Report documented that the loss of wetland habitat in the U.S. was significant and, as a “state” indicator, had received a poor rating. It was estimated that nearly 50 percent of the existing wetlands of the conterminous U.S. was lost from 1780 to the 1980s. The West Coast had the largest acreage loss of habitat at 68 percent, although it had the smallest actual number of acres lost. The Great Lakes and Gulf of Mexico coast are also high at 50 percent, and the southeastern and Gulf of

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Mexico continued to lose habitat at a rate of approximately 1 percent per year. These findings are supported by responses to the Information Request, which indicate that the Gulf and Caribbean region had the lowest habitat acreage restored or protected (<1000 acres) (Figure 4-17). The Pacific region had the highest reported habitat restored (>60,000 acres) and protected (>50,000 acres) as compared to all other regions. The Northeast region had the second highest restored acreage at over 40,000 acres while the Southeast region had less than 40,000 acres protected.

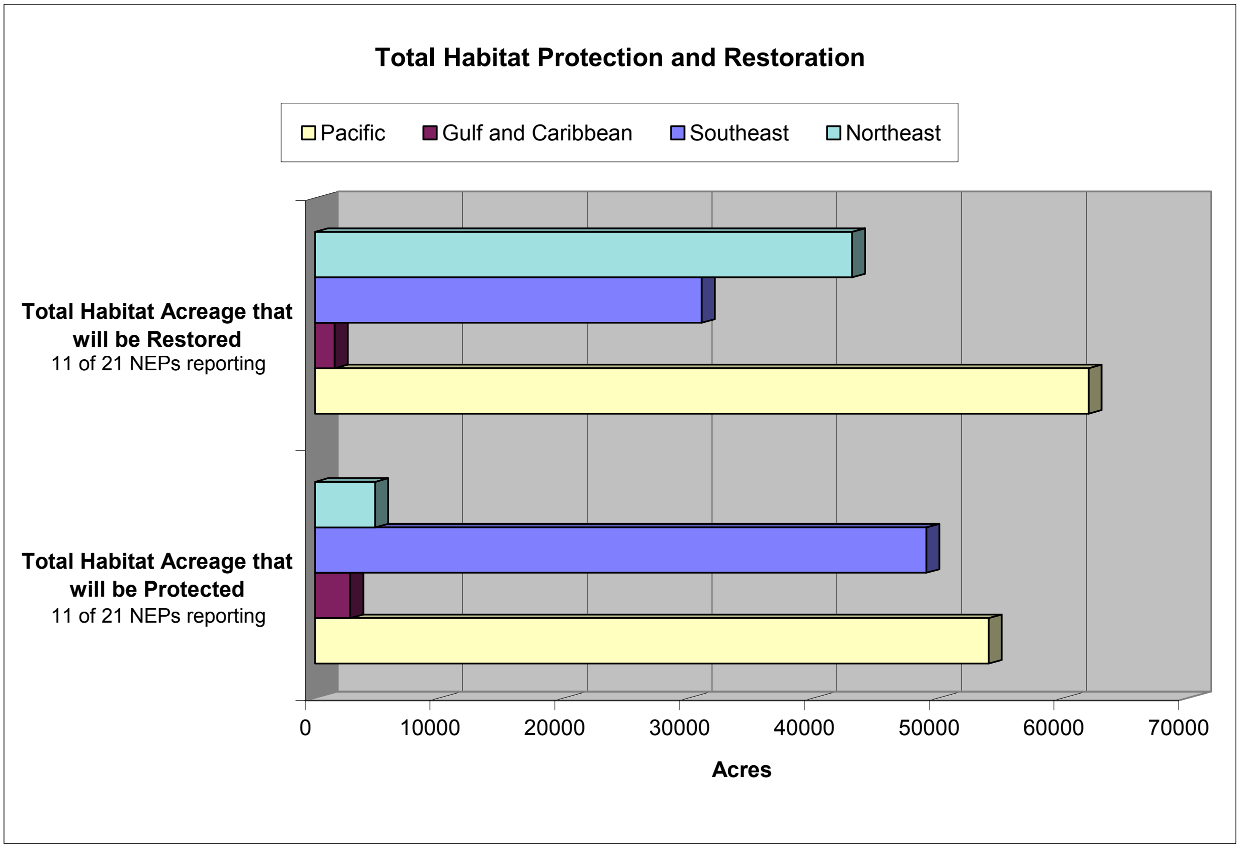

Figure 4-17. Total Habitat Protected and Restored

A similar pattern was shown in 2001 with the highest habitat acreage restored and protected was in the Pacific region (Figure 4-18). The Northeast region showed the lowest habitat acreage restored or protected, at less than 100 acres in 2001. The Gulf and Caribbean region reported over 4000 acres restored while the Southeast region protected over 3000 acres. The evident degradation and loss of critical coastal habitat is resulting in higher numbers of species being at risk of extinction. As shown in Figure 4-19, areas with the highest number of wetland and aquatic species at risk are located along the Pacific, Southeast, and Northeast regions.

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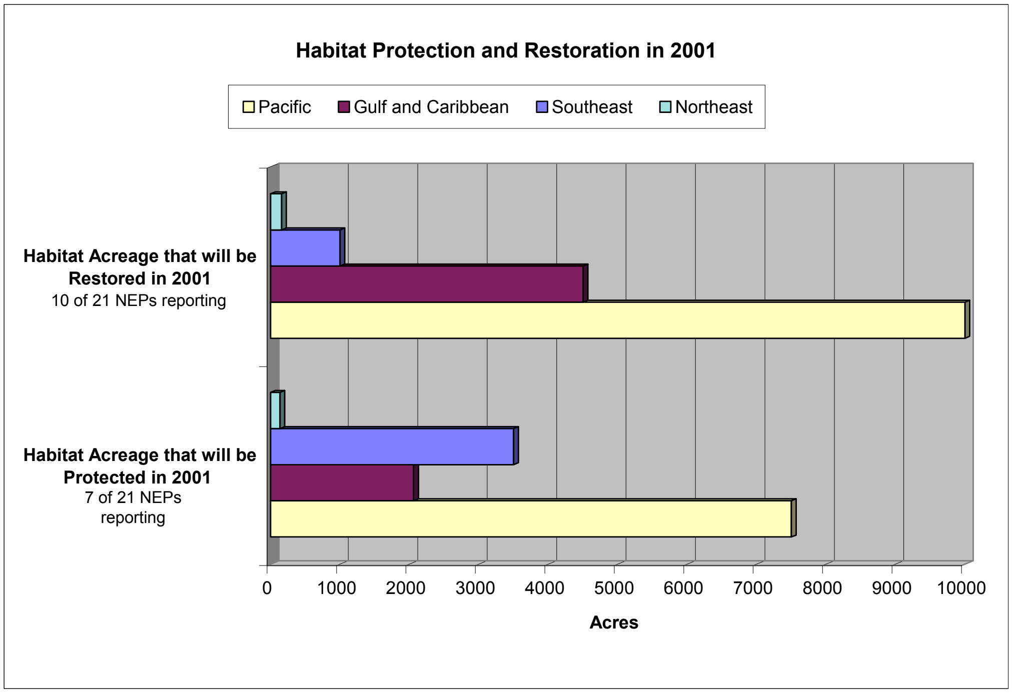

Figure 4-18. Total Habitat Protected and Restored in 2001

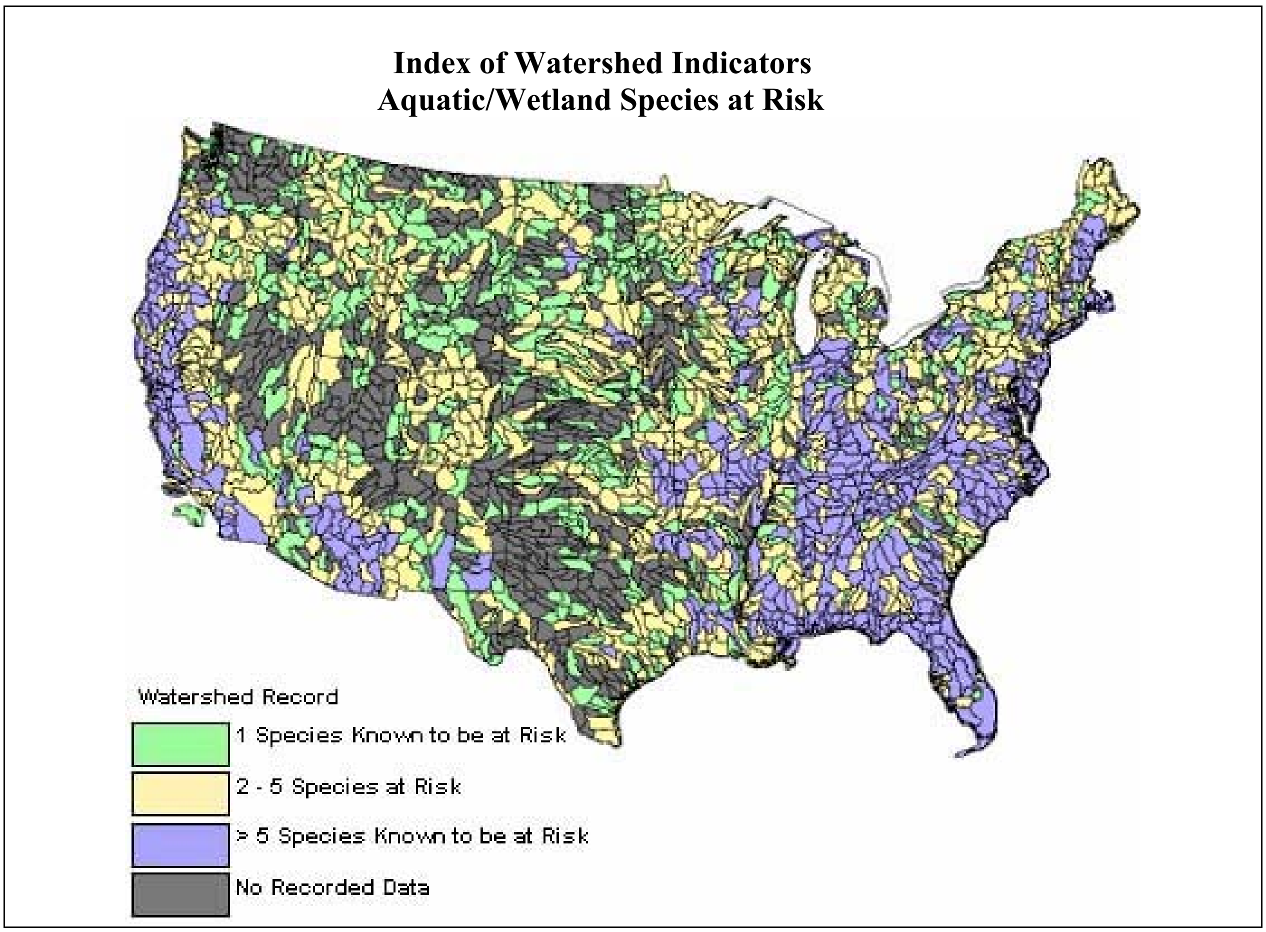

Figure 4-19. Number of Aquatic and Wetland Species at Risk

4.2.3.1 Conservation/Restoration

One of the major societal responses to habitat loss has been conservation and restoration activities by government, university, and citizen groups. The NOAA *State of the Coast Report* states that "at the national level, no fewer than 14 Federal programs within 5 cabinet-level departments are working to restore coastal habitats, while at least 11 Federal laws authorize and fund restoration activities" (NOAA 1998). Many conservation and restoration efforts conducted by NEPs have led to major progress in reducing habitat loss. Approximately 13 NEPs noted major changes when mitigation, restoration, and wetland banking programs were implemented. Five NEPs reported little progress, while only one NEP had no success. Nine NEPs have initiated over 10 restoration programs for damaged habitat (Figure 4-20). Mitigation programs were initiated at 10 NEPs, with 4 NEPs implementing over 10 programs. The median number of mitigation programs at any NEP was one. Few NEPs have implemented wetland banking programs. Approximately 6 of 16 NEPs have at least one wetland restoration program initiated.

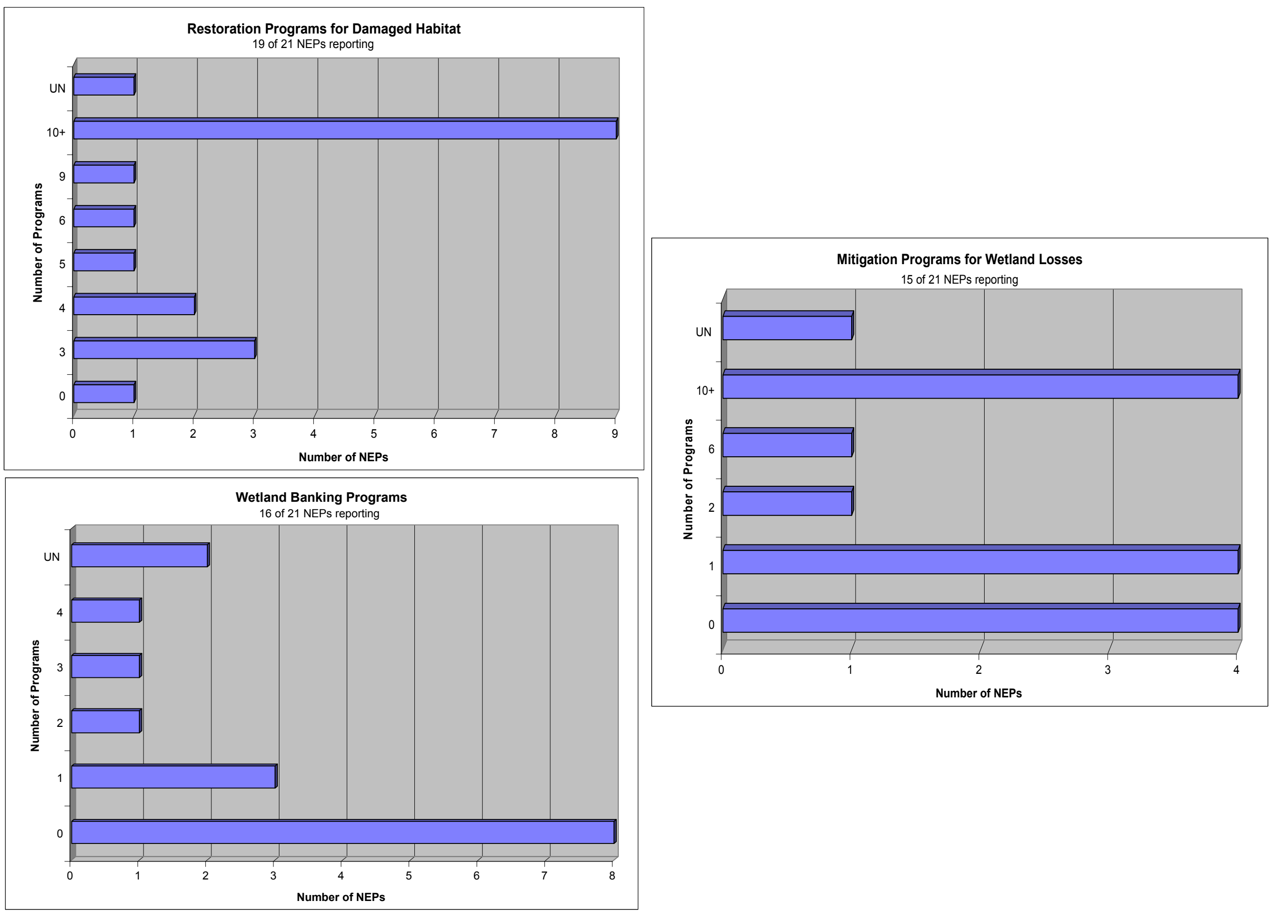

Figure 4-20. Number of Restoration, Mitigation, and Wetland Banking Programs

A large part of the success of these programs is attributed to having community support. Figure 4-21 presents the number of communities involved in habitat mitigation, restoration, or banking programs. Twelve NEPs have community involvement, with 4 NEPs having over 10 community groups supporting these programs.

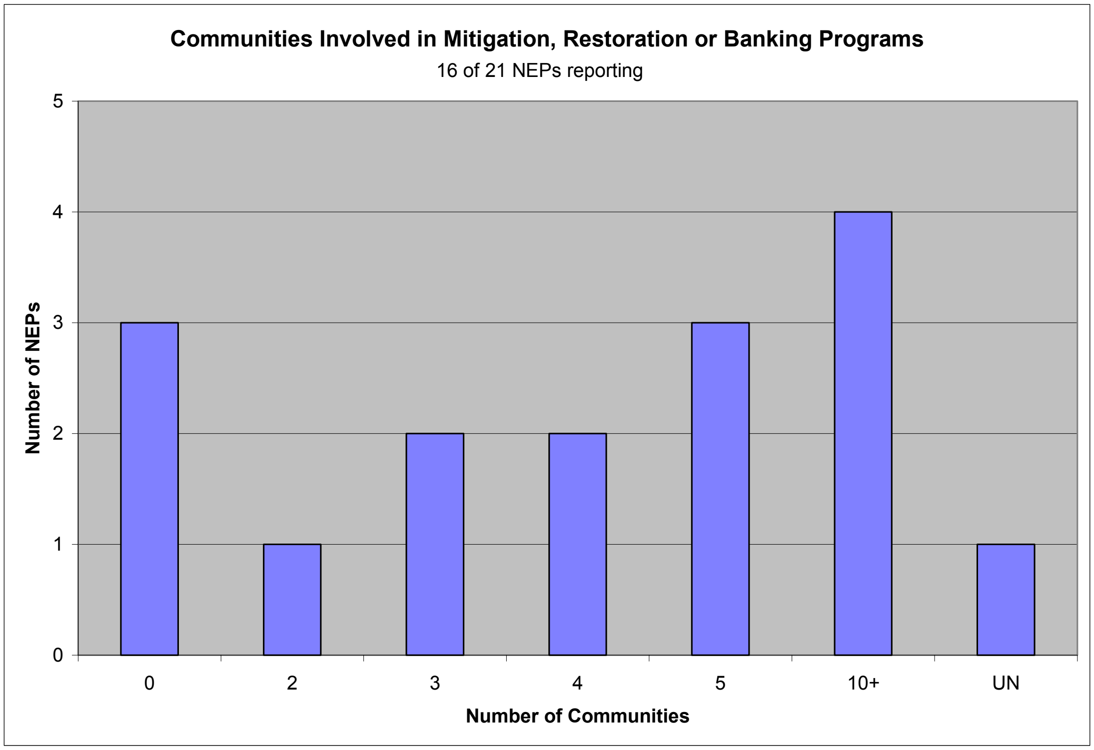

Figure 4-21. Number of Restoration, Mitigation, and Wetland Banking Programs

Both nutrient and sediment reduction programs have been implemented in several NEPs, in order to reduce the loss of SAV. Although the NEPs reported that the loss of SAV as high importance, less than half of the NEPs reported acres of SAV gained due to implementation of nutrient/sediment reduction programs (Figure 4-22). Two NEPs stated that they gained over 1000 acres of SAV through nutrient reduction programs, while sediment loading reduction programs showed minimal progress toward limiting SAV acreage loss. Acreage of SAV impacted due to nutrient and sediment loading ranges from 1000 acres (2 NEPs) to no loss (1 NEP).

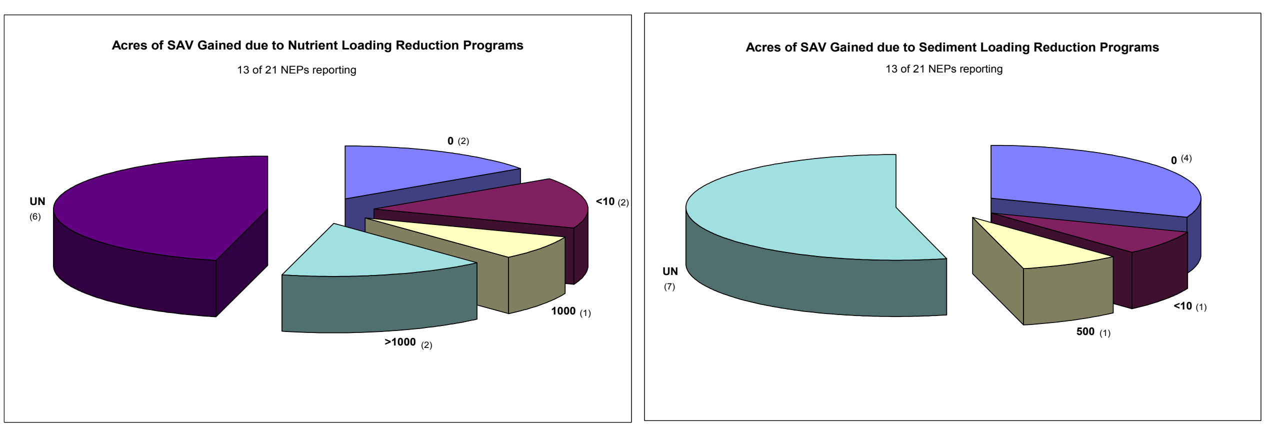

Figure 4-22. Acres of SAV Gained Through Nutrient and Sediment Loading Reduction Programs

4.2.3.2 Public Involvement

The effects of stressors and management actions on an estuarine ecosystem can be tracked through monitoring. Monitoring is crucial to documenting status and trends, determining associations between stressors and responses, and assessing the effectiveness of management actions. This monitoring includes efforts by citizen and volunteer monitoring groups. The majority of the NEPs have at least one citizen monitoring group. Approximately 6 NEPs have 10 or more volunteer programs being implemented (Figure 4-23). An indicator of the success of these programs may be measured by the number of volunteers involved in the programs. Figure 4-24 shows that 5 NEPs have over 1000 volunteers while the average number of volunteers per NEP appears to range from 100 to 500 volunteers.

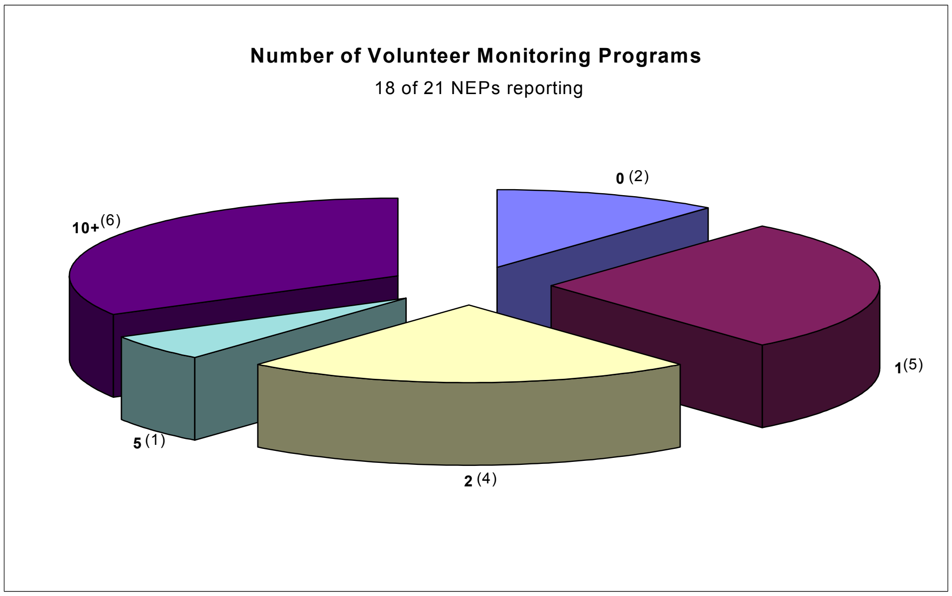

Figure 4-23. Number of Volunteer Monitoring Programs

4.2.3.3 Education

Citizen education efforts and demonstration projects can be a societal response to help control stressors. Several indicators are used to measure education programs, including number of citizen demonstration projects and implementation of public education and outreach programs. Figure 4-25 shows that 9 NEPs have over 10 habitat demonstration projects. Only 3 NEPs have no known community projects while the majority of NEPs had at least 2 or more habitat demonstration projects.

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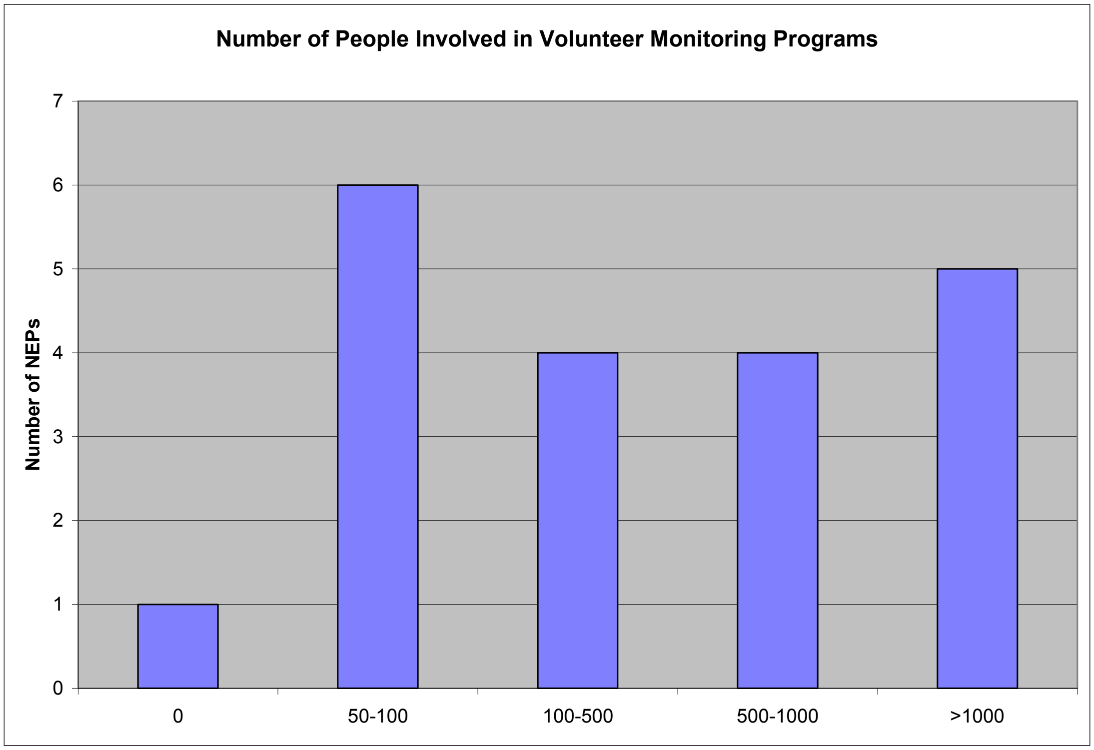

Figure 4-24. Number of People Involved in Volunteer Monitoring Programs

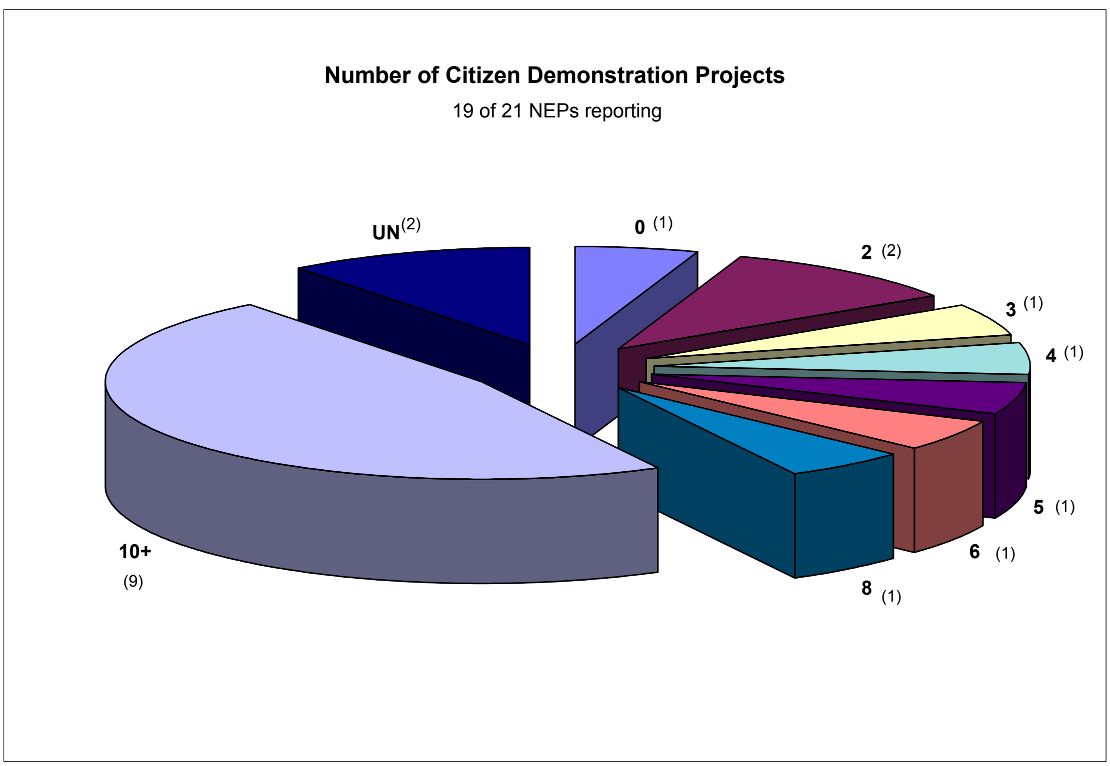

Figure 4-25. Number of Habitat Demonstration Projects

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There is a marked increase in public education and outreach programs involving NEP sites. Sixteen NEPs reported that major progress has been made in implementing public education and outreach programs. Only 3 NEPs showed little or no progress.

4.2.3.4 Effects of Management Actions

Figure 4-26 presents a summary of the types of management actions that may be implemented to control development pressures. The management actions that appear to have a high to medium effect on habitat degradation/loss are zoning regulation changes (increased lot sizes and riparian buffers), land use changes (changes that reduce runoff and inputs of contaminants, nutrients, or sediments in the coastal zone), and best management practices at new residential developments and/or golf courses. The NEPs reported that coastal development changes (relocation or reduction in planned coastal developments) and marina renovations to reduce habitat impacts had a medium to low effect on habitat degradation/loss.

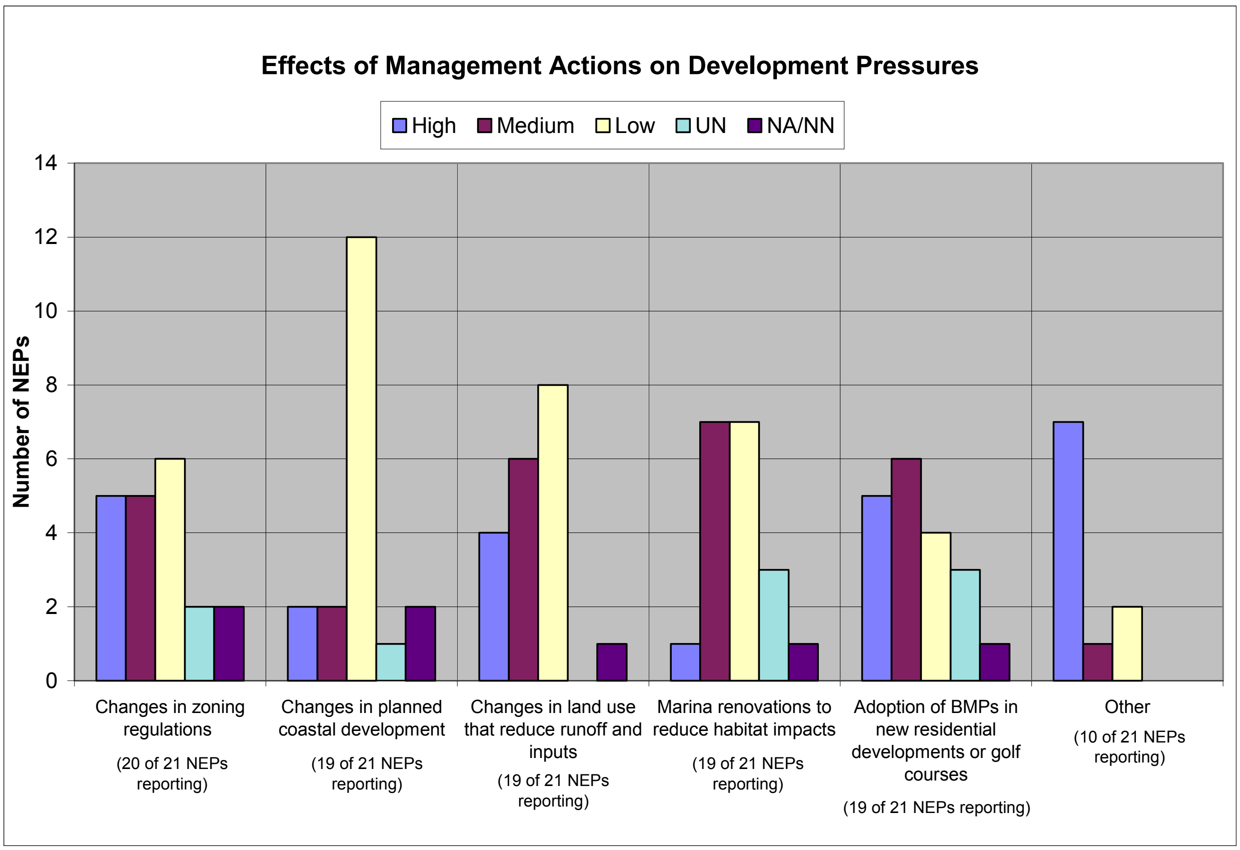

Figure 4-26. Effects of Management Actions on Development Pressures

Hydrologic modifications including construction or removal of dams, weirs, and seawalls, implementation of dredging operations and plans, and construction of freshwater inflow were evaluated to determine if these modifications have an effect on habitat degradation/loss. Hydrologic modifications that were reported as having a high to medium effect were associated with flow impedances (construction or removal of dams or other impedance to flow) and dredging operations (regular maintenance dredging operations or dredging of new channels) (Figure 4-27). Four NEPs ranked increased coastal construction of weirs, boardwalks, and seawalls as having high effect, while 8 NEPs cite freshwater inflow as having a high effect. Adoption of dredging plans (i.e., plans that incorporate hydrologic condition for habitat restoration) and increased coastal construction, had a medium to low effect, while decreased coastal construction of weirs, boardwalks, and seawalls was not applicable at a majority of the NEPs.

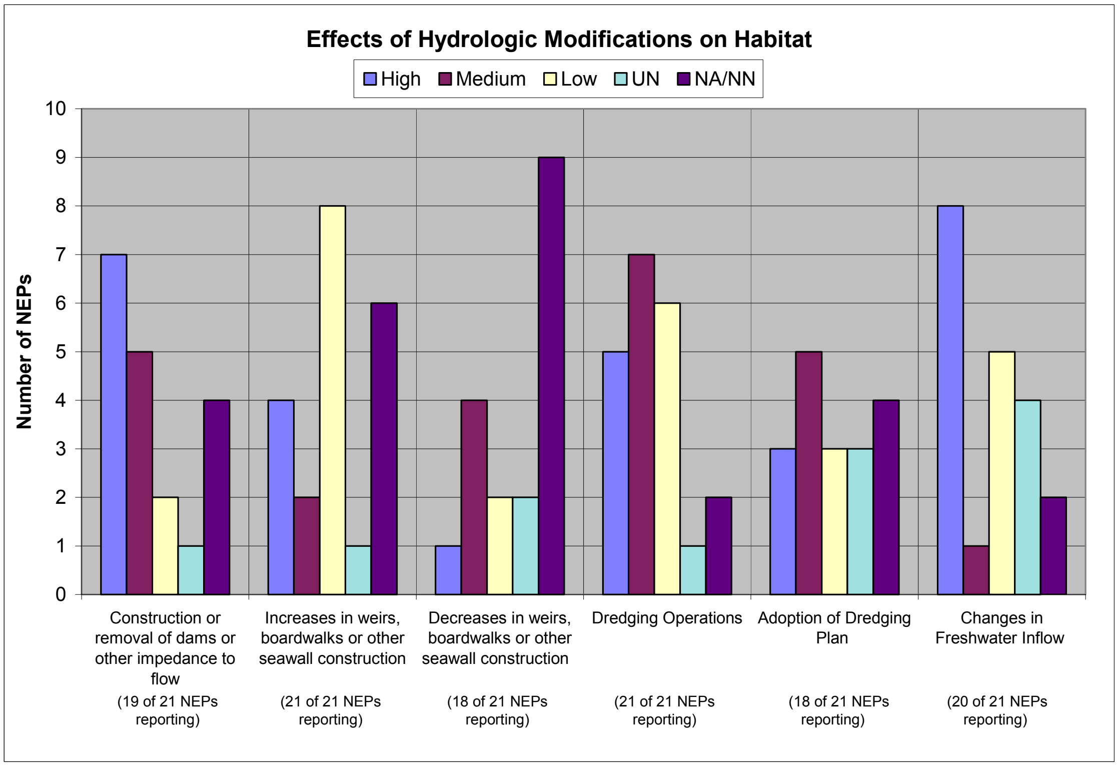

Figure 4-27. Effects of Hydrologic Modifications on Habitat Management

Management actions on water quality may impact the amount of effluent and hence, nutrients entering a habitat system. Actions such as connections of homes to municipal sewer systems, use of alternative septic systems or additional associated education, controlling nitrogen discharge from industrial sources, and installing improved wastewater treatment technologies, can all play a role in limiting nutrient loading. Figure 4-28 presents the reported effects of water quality management actions.

4.2.4 Summary of Habitat Degradation/Loss Indicators Used by NEPs

Although each NEP is unique, there are several similar indicators being used by a majority of NEPs for the management of habitat degradation/loss. Figure 4-29 illustrates the most common indicators that are currently being utilized. These indicators are generally specific to the issues impacting each NEP, but may include hydrology, invasive species, water and sediment quality, shellfishing area condition, wildlife populations, and area of habitat. Area of habitat appears to be the most common indicator that is being measured by a majority of the NEPs (17 of 18) that responded to the Information Request. The second most commonly measured indicators are wildlife populations (5 of 18) and shellfishing area condition (5 of 18).

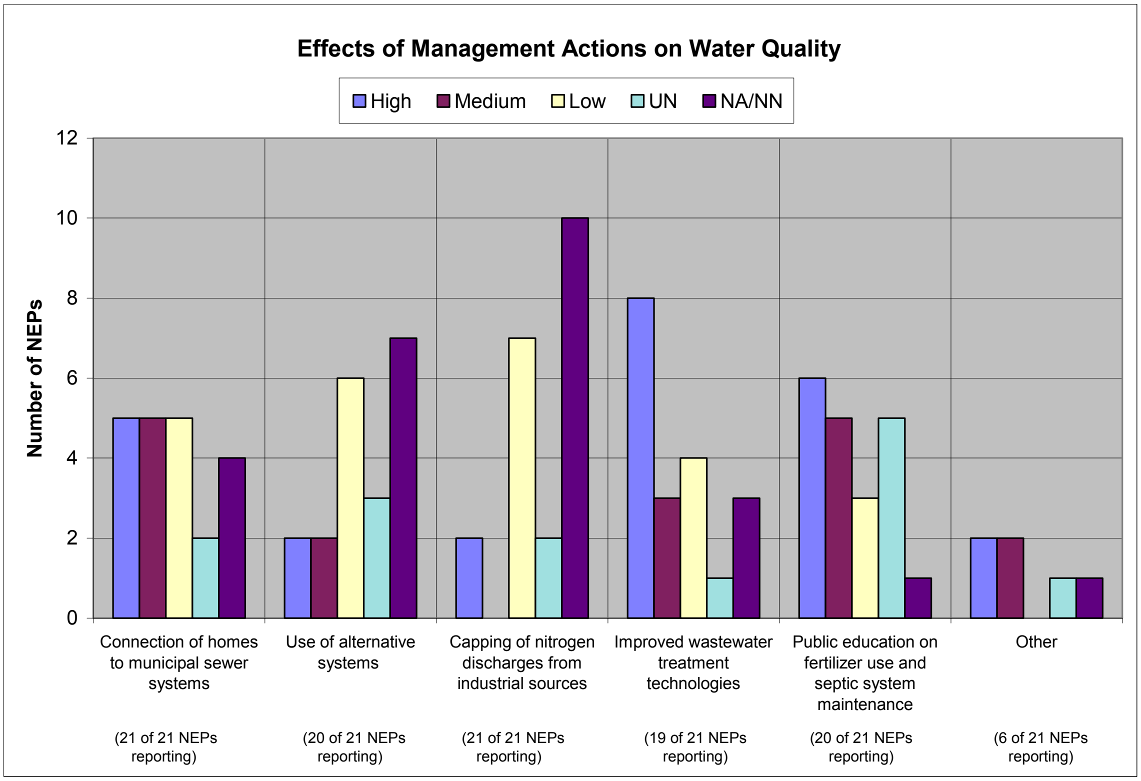

Figure 4-28. Effects of Management Actions on Water Quality

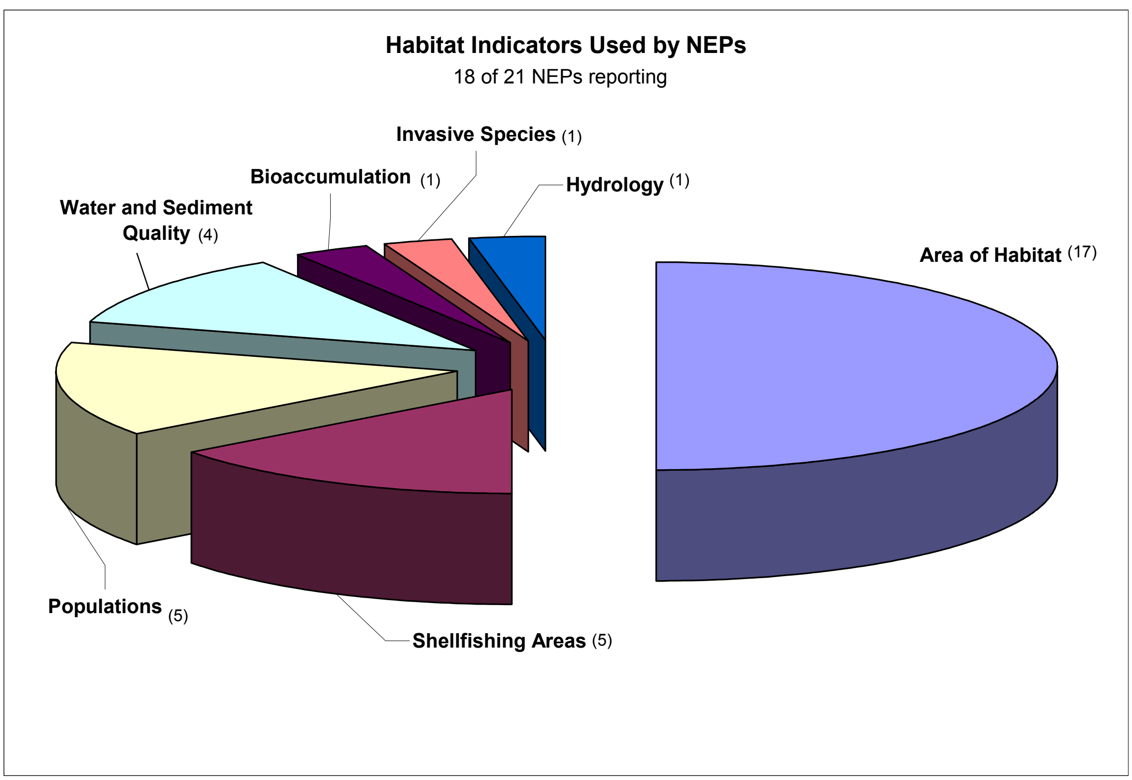

Figure 4-29. Habitat Indicators Used by NEP

4.3 Nutrient Overloading

4.3.1 Pressures Causing Nutrient Overloading

Excess nutrients in estuarine ecosystems stimulate algae growth, which can deplete dissolved oxygen concentrations and prevent sunlight from underwater penetration. Species dependent on oxygen such as fish and shellfish can die or migrate to more suitable habitats. SAV such as seagrass can die off due to lack of light. Sources of nutrient overloading include both point and nonpoint sources, and each of the NEPs were asked to weigh the relative importance (i.e., "top priority issue", "moderate importance", "low importance", "unknown, but an issue", and "not a factor") of sources contributing to nutrient overloading within their system. Overall, point sources were ranked slightly higher in importance as compared to non-point sources (Figure 4-30).

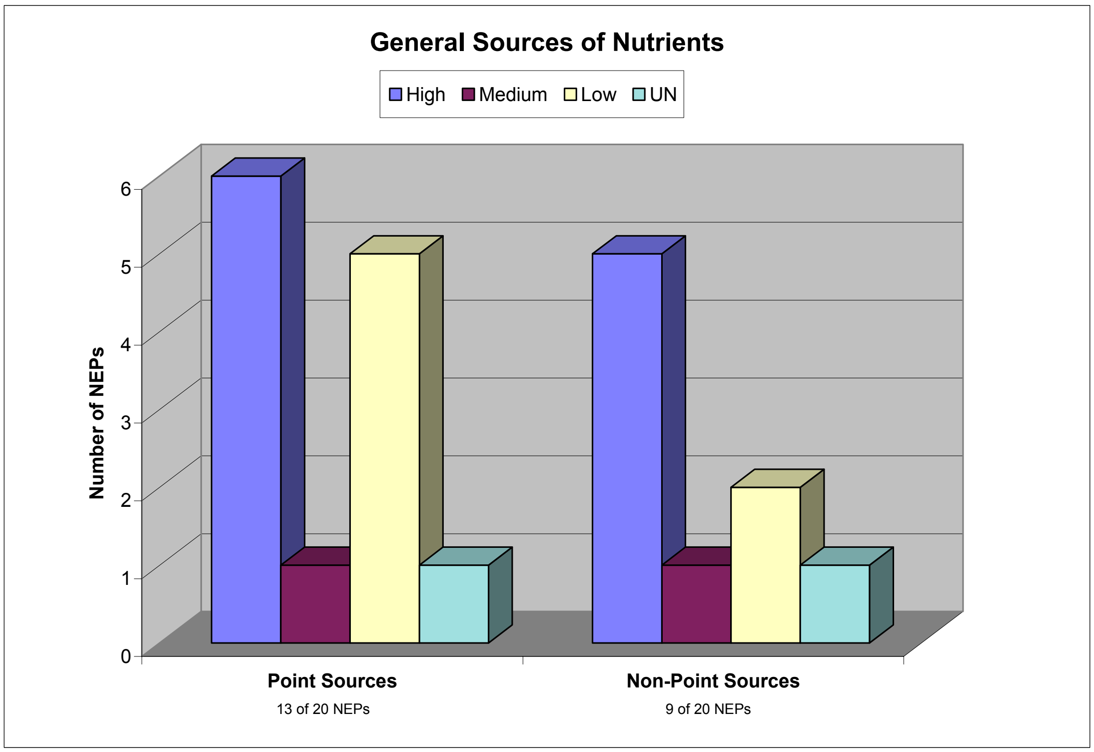

Figure 4-30. General Sources of Nutrient Overloading

Point sources include discharges from wastewater treatment plants, rivers, industrial sources, and dam spills. Among point sources, wastewater treatment plants and rivers were reported as having the highest importance as nutrient sources to NEP estuaries (Figure 4-31). Industrial and dam spills have low importance as point sources for nutrient loading.

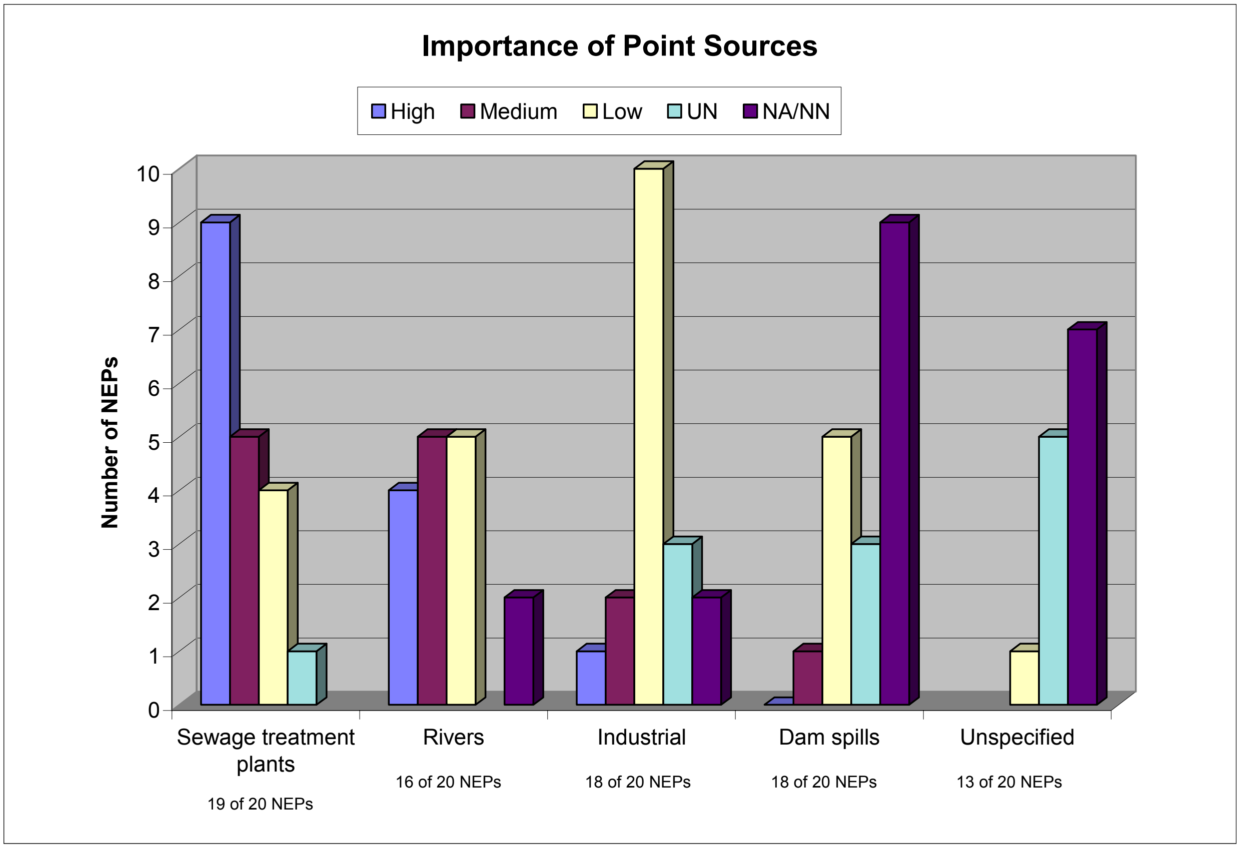

Figure 4-31. Importance of Point Sources

The nonpoint sources of highest importance to NEPs included urban and suburban runoff, agricultural runoff, septic systems, and atmospheric deposition. Sediment nutrient flux, groundwater, silvicultural runoff, manure disposal practices, and benthic input were considered low to not important as nonpoint nutrient sources.

4.3.2 State of Estuarine Eutrophication

Eutrophication is caused by the excess amounts of nitrogen and phosphorus that is introduced into an estuary system. The NOAA *State of the Coast Report* states that "high expressions of eutrophic conditions are exhibited in 44 estuaries of the coterminous United States, representing approximately 40 percent of the national estuarine surface area" (NOAA 1998). An additional 40 estuaries exhibit moderate conditions. When considered together, the estuaries with moderate to high eutrophic conditions represent approximately 65 percent of the Nation's estuarine surface area. High conditions, determined by assessing the extent of primary and secondary symptoms of eutrophication, occur in estuaries along all coasts, but are most prevalent in estuaries along the Gulf of Mexico and Middle Atlantic coasts. A high level of human influence is associated with 36 of the 44 estuaries with high eutrophic conditions. While high levels of primary symptoms, such as elevated levels of chlorophyll-*a*, are strong indicators of the onset of eutrophication, secondary symptoms such as depleted dissolved oxygen (DO), indicate more serious or highly developed eutrophication. Moderate to high expressions of at least one of the secondary symptoms are exhibited in 82 estuaries, representing 67 percent of the estuarine surface area studied.

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Eutrophic conditions are exhibited in many NEP estuaries. Hypoxia, or low DO, is one of the most significant conditions resulting from excess nutrient loading. If oxygen levels become too low, estuaries are unable to sustain healthy populations of living resources. States set standards for DO to assess the health of its waters and consequently, most states in which reporting NEPs are located, have DO standards set at 5 mg/L or higher (Figure 4-32). DO levels less than this standard are likely to cause poor water quality for living resources.

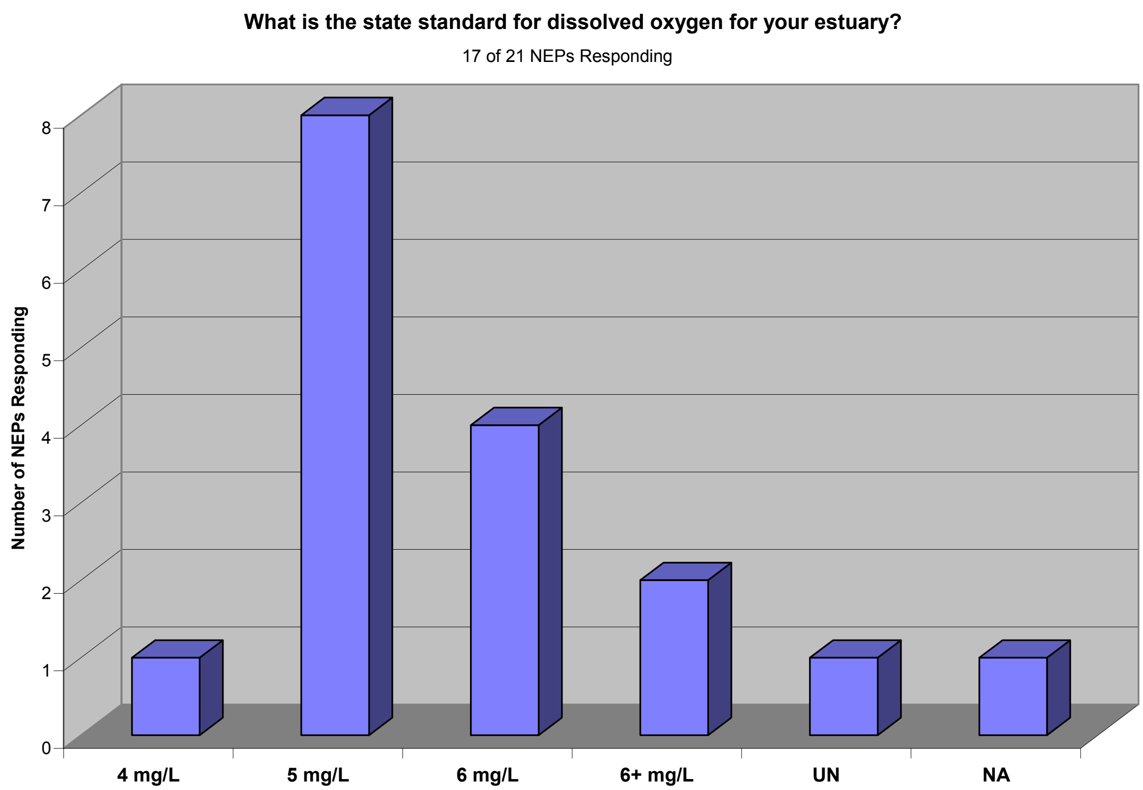

Figure 4-32. Benchmark for Acceptable Dissolved Oxygen Concentrations in Estuaries

Since 1997, DO concentrations in 10 of the reporting NEPs have fallen below the State's DO standards more than 20 times. As shown on Figure 4-33, 4 NEPs had less than 20 occurrences in which the DO concentrations were below the standard. Furthermore, a majority of the reporting NEPs (63 percent) have between 10 and 40 percent of their estuaries area affected by hypoxia (Figure 4-34). Another 21 percent have more than 41 percent of their estuaries' area affected by hypoxia. However, it should be noted that periodic low levels of oxygen are part of the natural ecology at some estuaries (USEPA 2001).

Other effects of nutrient overloading include the stimulation of growth of dinoflagellates and algae. Some dinoflagellates produce toxins, which can poison humans (via raw shellfish consumption and recreational exposure) and cause massive fish kills. Foul smells and generally poor aesthetic values may result from increased algae. NEPs reported the importance of each of these impacts in their estuaries (Figure 4-35). Low dissolved oxygen and red/brown tide were the 2 highest ranked effects. Other highly ranked effects that were mentioned included shellfish diseases (PSP, MSX, Dermo), *Pfiesteria*, and pathogens.

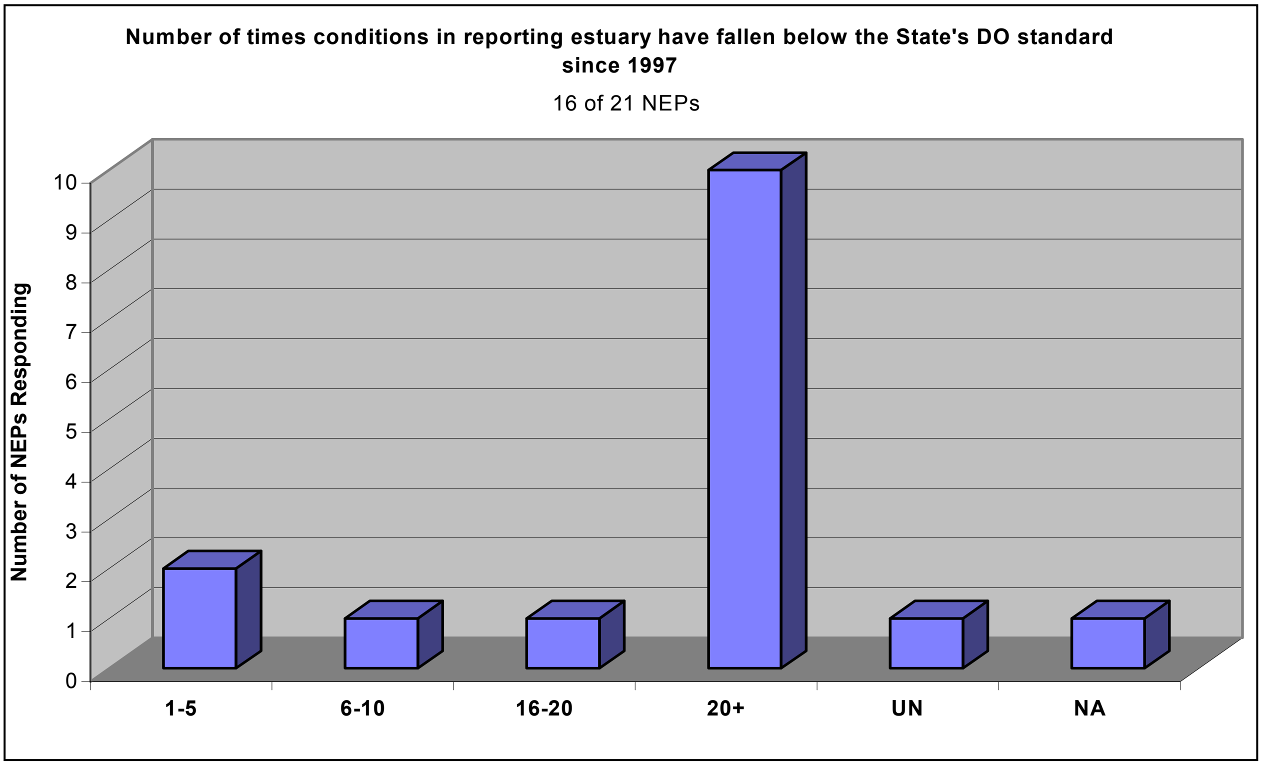

Figure 4-33. Number of Times Dissolved Oxygen Levels Fell Below the State Standard

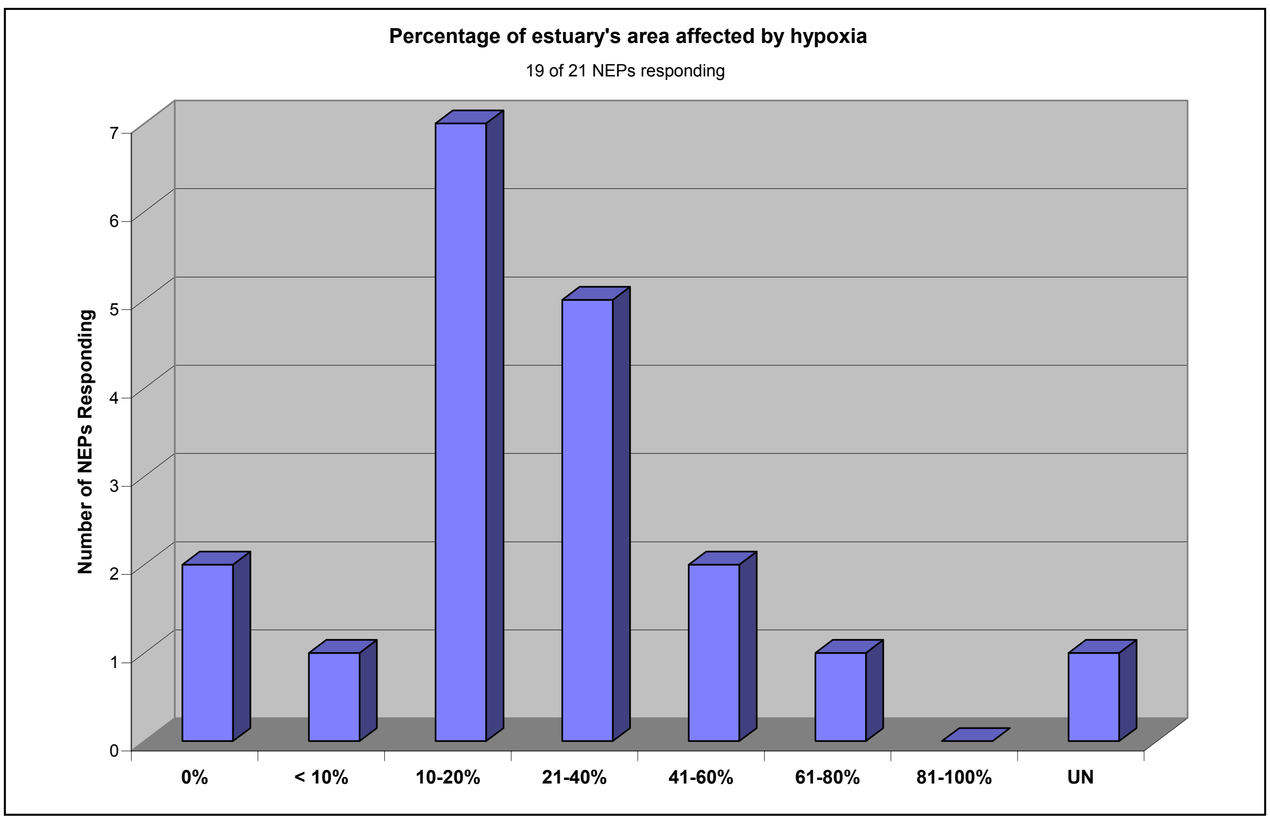

Figure 4-34. Percentage of Estuary's Area Affected by Hypoxia

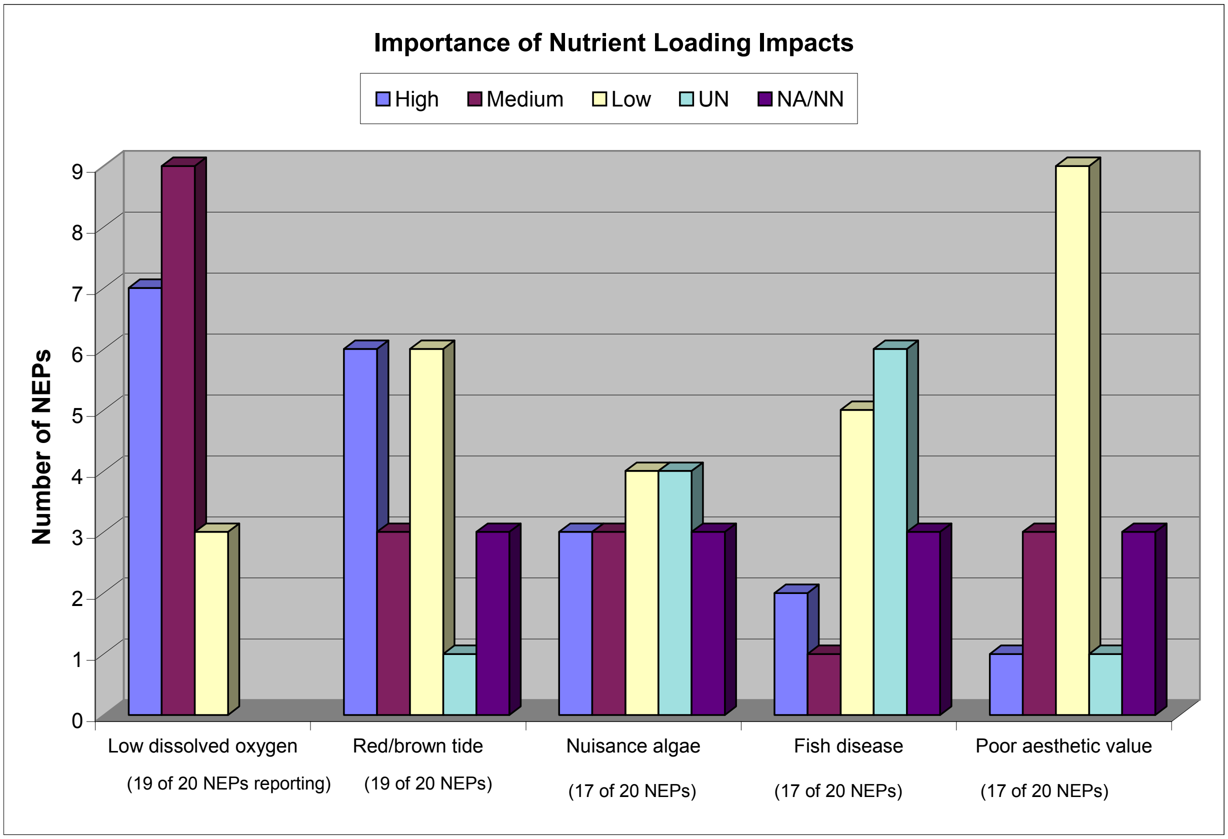

Figure 4-35. Importance of Nutrient Loading Impacts

4.3.3 Societal Responses to Nutrient Overloading

4.3.3.1 Nutrient Source Management

NEPs were asked to report on efforts and initiatives related to wastewater treatment since 1997. Half of the reporting NEPs indicated having major progress since 1997, and an overwhelming majority reported at least some level of progress. Specific management actions that have been implemented by NEPs included replacing septic tanks with central sewer systems, upgrading municipal wastewater treatment plants, and using alternative onsite wastewater systems. As illustrated in Figure 4-36, approximately half of the NEPs reported major progress in replacing septic tanks and upgrading wastewater treatment plants, which are considered the primary point source for nutrient overloading. Six NEPs had success of replacing 10 to 20 percent of septic tanks with central sewer systems. Only one NEP had over 80 percent of septic tank users switched to a central sewer system. On average, municipal wastewater treatment plants near NEPs upgraded about 50 percent of its technology. Four NEPs reported over 80 percent of the municipal wastewater treatment plants were upgraded while another 4 NEPs reported no upgrades were implemented by their local plants. Community involvement appears to factor in promoting the replacement of septic tanks and upgrading wastewater treatment plants. In 8 NEPs, there were over 6 communities that supported these initiatives. The majority of these communities have no adopted "no net increase" policies for limiting nitrogen discharges. Only 2 NEPs had over 10 community groups that were involved in setting nitrogen levels.

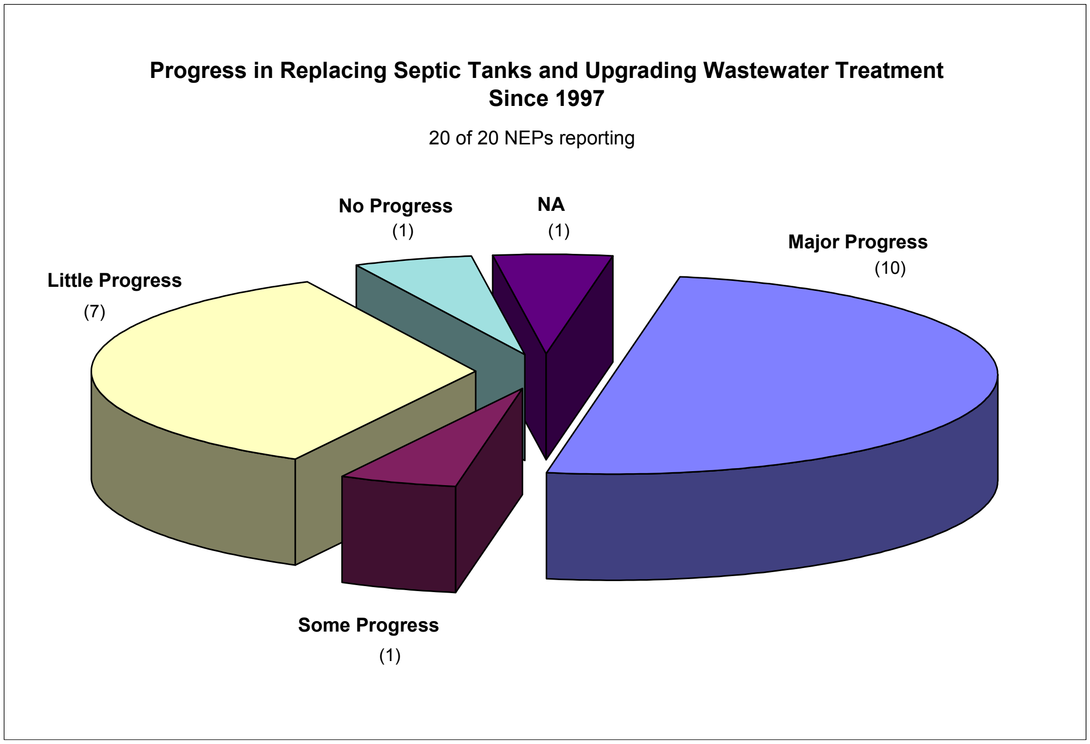

Figure 4-36. Progress in Replacing Septic Tanks and Upgrading Wastewater Treatment Plants

Figure 4-37 presents the number of alternative onsite wastewater systems in use by NEP estuaries. Six NEPs noted that there are over 10 alternative onsite wastewater systems while 4 NEPs reported no such systems in use.

Another source management option is to regulate the quantity of nutrients discharged through the development of Total Maximum Daily Loads (TMDL). The majority of the NEPs reported that little or no progress has been made in developing nutrient specific TMDLs; however, major progress has been made at 6 of 18 responding NEPs. The majority of TMDL development is not being driven by community involvement (Figure 4-38). Only 3 NEPs had 6 or more community groups actively developing TMDLs while 7 NEPs had no community involvement in TMDL development.

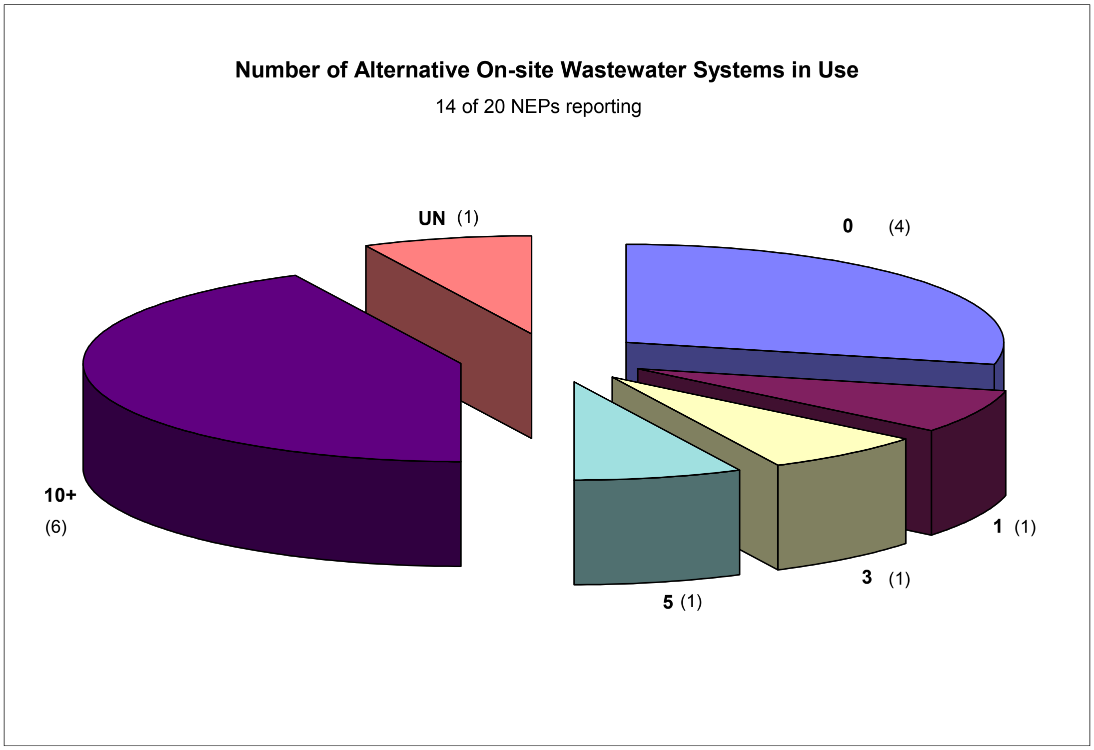

Figure 4-37. Number of Alternative On-site Wastewater Systems in Use

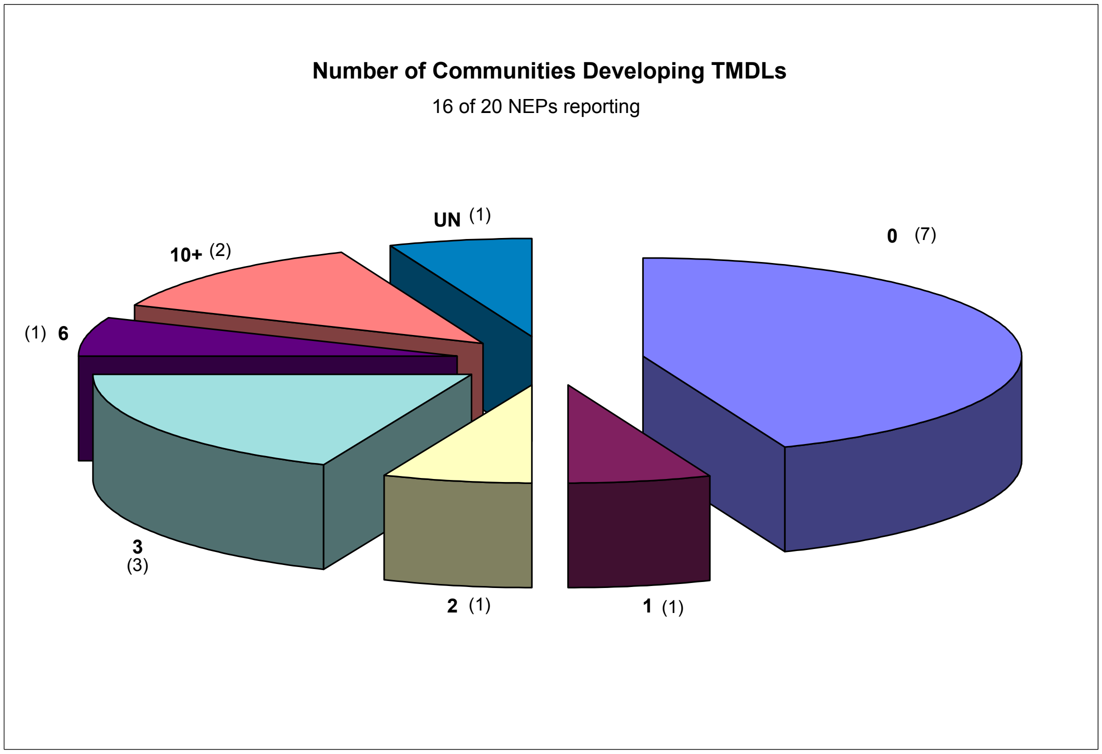

Figure 4-38. Number of Communities Developing TMDLs

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4.3.3.2 Public Education/Involvement Programs

Public involvement and outreach programs appear to be an important factor in controlling nonpoint source releases of nutrients to estuaries. Twelve NEPs reported having at least one community group involved in programs that have led to major progress in controlling nonpoint source pollution (Figure 4-39). Six NEPs indicate that some or little progress has been made through public education.

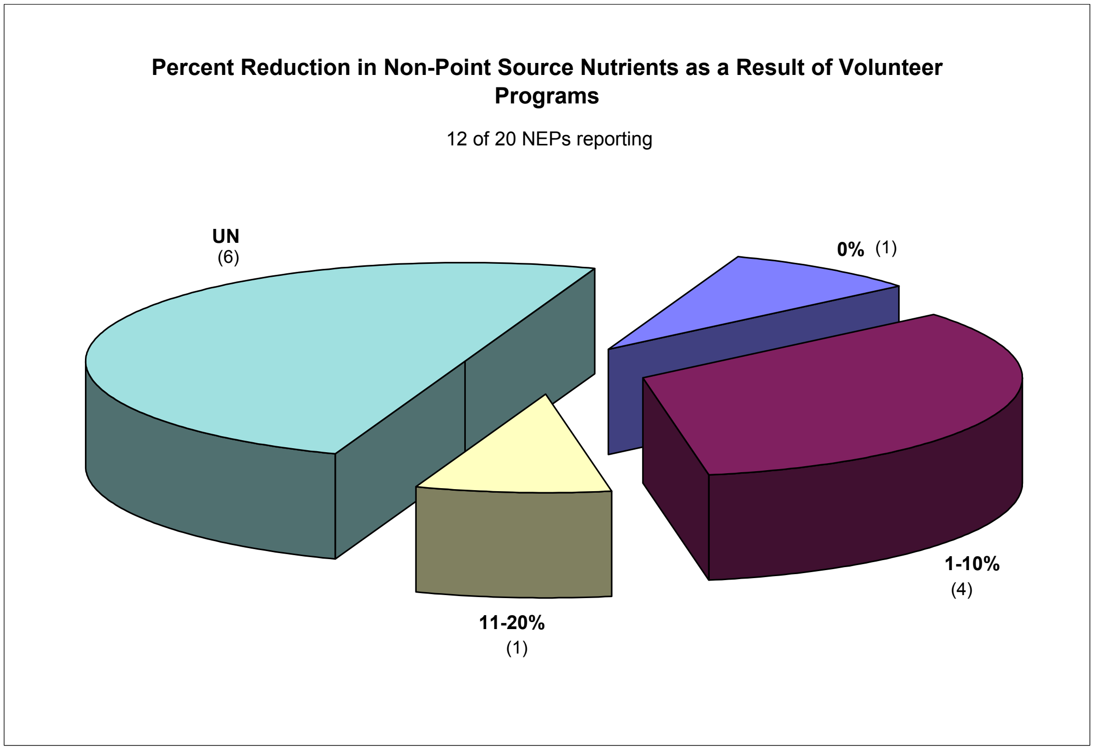
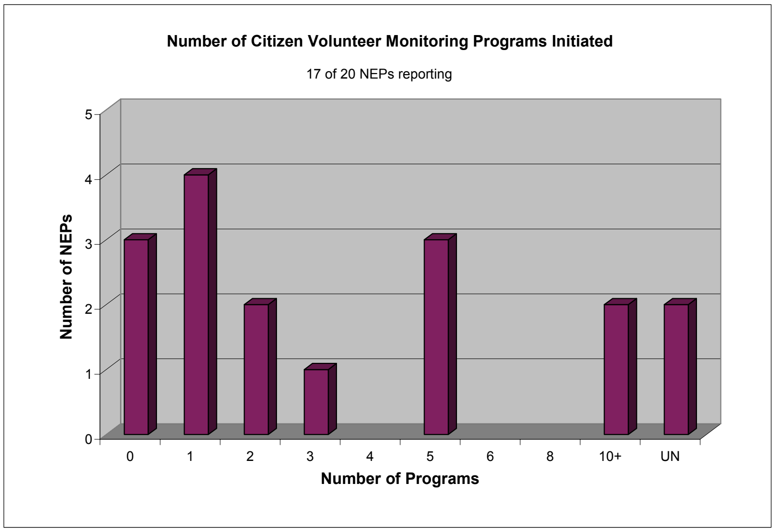
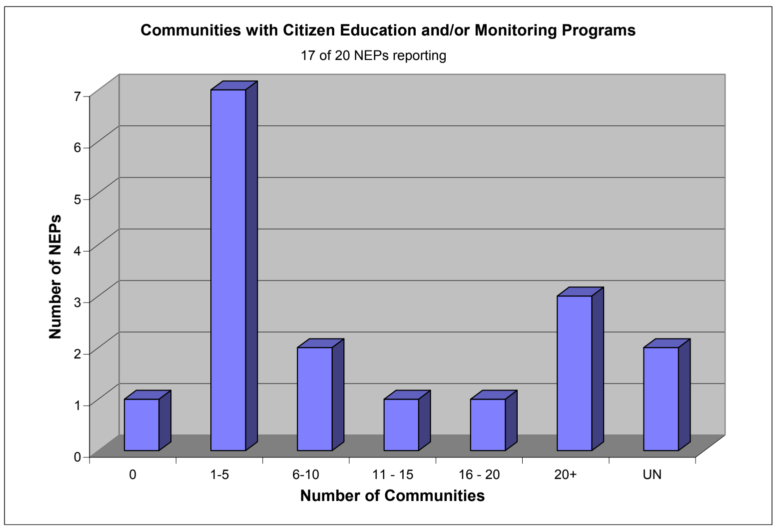


Figure 4-39. Number of Communities with Education and/or Involvement Programs

Figure 4-40 indicates the number of communities that have citizen education and/or volunteer monitoring programs. Two NEPs reported having over 20 community groups involved in either education or monitoring programs. On average, NEPs generally are limited to 1 to 5 community groups that supported such programs. The number of volunteers involved in these programs may be used as an indication of the success of these programs in fostering community involvement. The majority of the reporting NEPs have over 100 citizen volunteers involved in these programs. It is estimated that 1 to 10 percent of the reduction of nonpoint source nutrient pollution at 4 NEPs is a direct results of these volunteer programs. However for a majority of NEPs, the actual percent reduction is unknown.





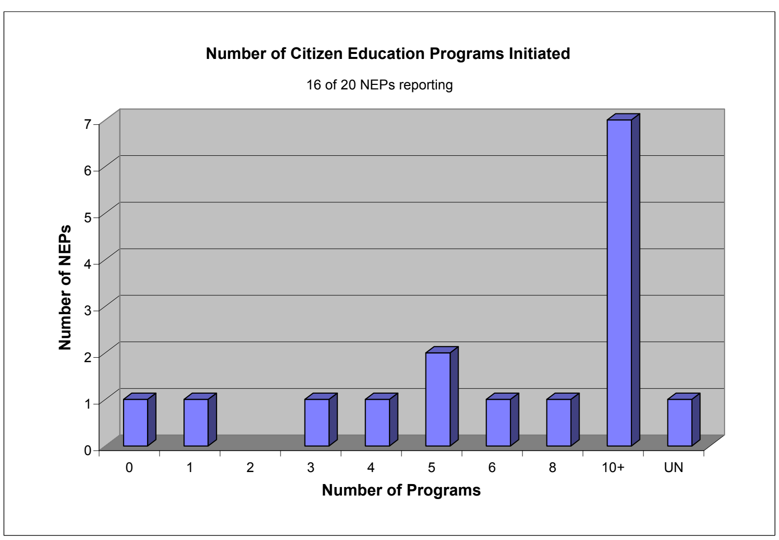


Figure 4-40. Number of Communities with Education and/or Monitoring Programs

4.3.3.3 Effects of Management Actions

The Information Request questioned if specific management actions to improve water quality, including connections to municipal wastewater treatment systems, implementation of stormwater management, upgrade to stormwater treatment, capping discharges from point sources, installation of pumpout stations at marinas, and improvement of wastewater treatment, had a high to low effect on nutrient loading. Figure 4-41 presents a summary of the scores given by NEPs regarding these specific management actions on water quality. The management actions that appear to have the highest effect on nutrient overloading are upgrades to existing stormwater treatment facilities and improved wastewater treatment technology. The NEPs reported that increased connections to municipal wastewater treatment systems, limiting point source discharges, and installing marine pumpout stations had a low effect on controlling nutrient overloading. An equal number of NEPs reported that implementing stormwater management had a high to medium effect as a low to no effect.

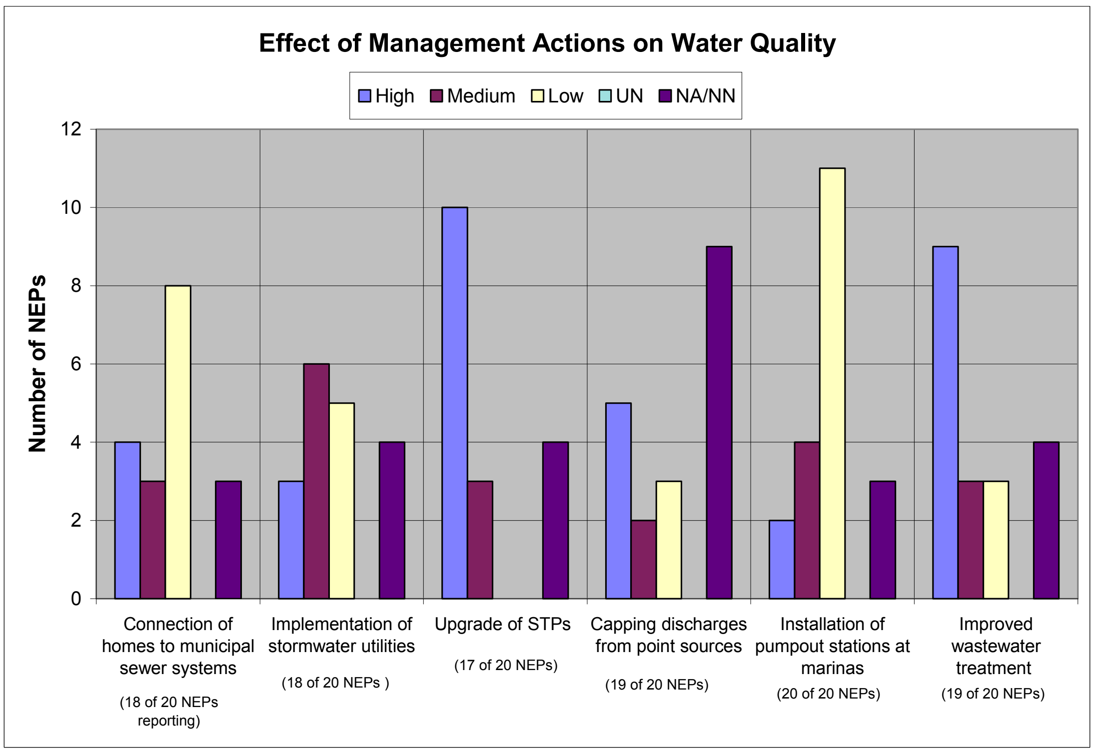


Figure 4-41. Effects of Management Actions on Water Quality

Nonpoint source management actions including implementation of baseline monitoring programs, updating zoning laws on riparian area protection and runoff reduction, and public education on septic systems and fertilizer use were evaluated to determine their potential effects at reducing nutrient loading. The majority of the NEPs reported a high to medium effect on nutrient loading from implementation of baseline monitoring programs. Updated zoning laws on riparian area protection and runoff reduction had an equal number of NEPs reporting both a high to medium effect and a low to no effect. Public education associated with septic systems and fertilizer use had a low to no effect at reducing nutrient overloading.

4.3.4 Summary of Nutrient Indicators Used by NEPs

There are a few common indicators of nutrient overloading being used at reporting NEPs (Figure 4-42): dissolved inorganic nutrients (11 of 15), chlorophyll-*a* (9 or 15), DO (8 or 15). Other potential indicators– plankton populations, biological oxygen demand, secchi depth, light penetration, wastewater treatment discharge, benthic and eelgrass habitat, and juvenile fish assessments – were used by many fewer NEPs.

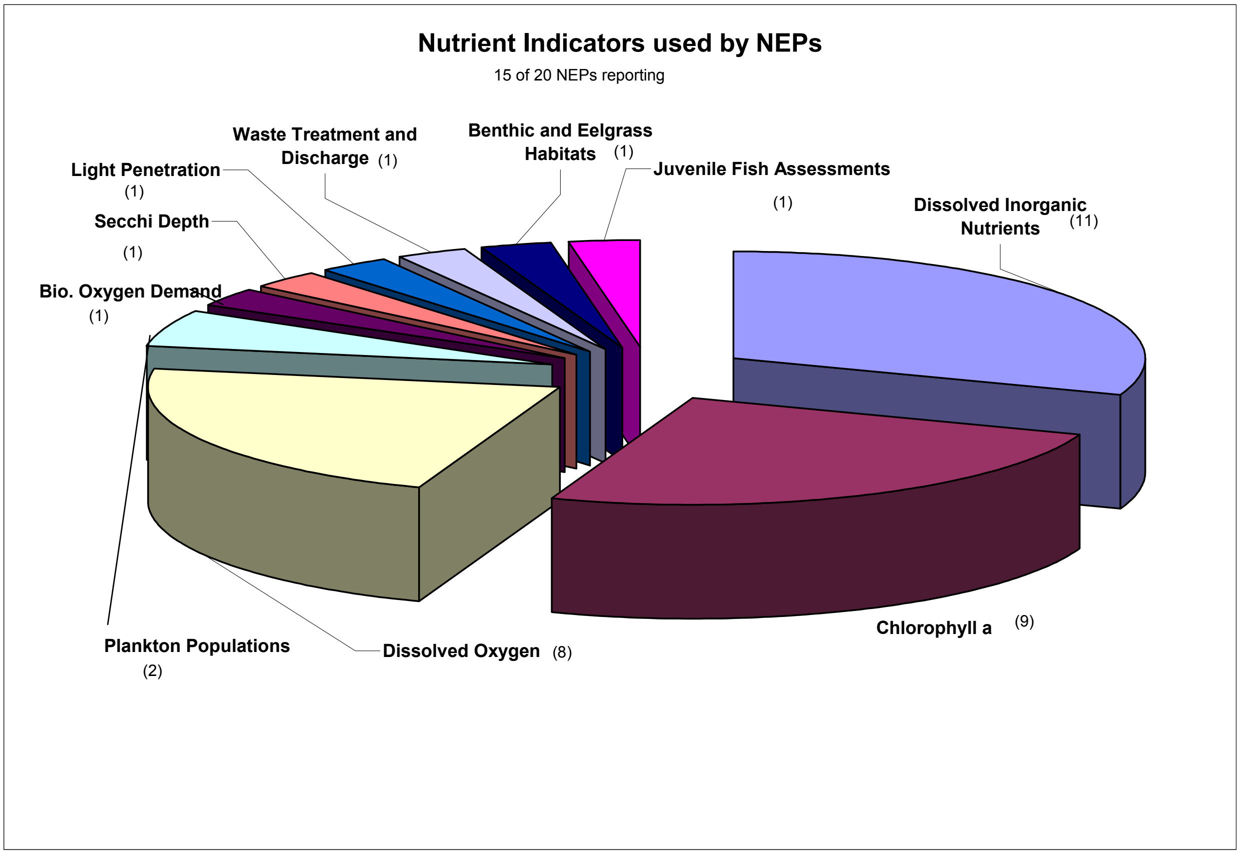


Figure 4-42. Nutrient Loading Indicators Used by NEP

5. SUMMARY AND RECOMMENDATIONS

The Information Request was designed to attain an overview of progress (i.e., implementation of restoration actions and changes in ecological condition) on the management of habitat degradation/loss and nutrient overloading in the NEP. The overall conclusion from this Information Request is that, for the two issues under consideration, no suite of definitive indicators can be readily extracted from current individual NEP monitoring/indicator efforts to adequately report implementation progress and changes in ecological condition in the NEP. There are numerous comprehensive monitoring programs, and existing and potential associated indicators, at the individual NEP level, but great variability among the programs makes aggregation across even a majority of programs difficult. What has been gained from the Information Request is a useful set of summary statistics on NEP initiatives and programs related to habitat degradation/loss and nutrient overloading.

The following discussion and recommendations, organized according to the PSR framework, present an evaluation of good candidate and potential indicators based on the Information Request results and, to the extent allowed by the scope of this report, existing national estuarine monitoring and indicator programs related to habitat degradation/loss and nutrient overloading. This evaluation, however, is principally limited to the information gathered through the Information Request results from 21 of 28 NEPs. As such, the data gathered during this project can form a basis for moving forward in the indicator development process for the NEP. This process should begin with developing a set of assessment questions and identifying the target audience for indicator reporting. Once these issues are resolved, national level guidance could assist the development of appropriate local (NEP-specific), regional, and national environmental indicators that report NEP progress.

5.1 Habitat Degradation/Loss Indicators

5.1.1 Summary of Habitat Degradation/Loss Pressures

Habitat loss appears to be a common problem impacting a majority of the NEP estuaries. As noted in the National Coastal Condition Report, coastal wetland conditions along the Western, Gulf, and Great Lakes regions were considered poor quality while the Northeast and Southeast regions had fair habitat recovery and all regions experienced loss of wetland acreage. As described in Section 4.2.1, the most common habitat pressures are development, nutrient overloading, invasive species, and sediment loading, however, each of these pressures varies in importance depending on the estuary. Increased nutrient loading was found to be primarily attributed to urban and suburban stormwater runoff, municipal wastewater treatment plants, septic systems, and agricultural land uses. Sediment loading from erosion, agriculture, urban stormwater runoff, and dredging activities were also common pressures resulting in habitat loss. Although invasive species was not generally considered of high importance by the reporting NEPs, 5 NEPs estimated that over 1000 acres of habitat was lost due to invasive species, while 4 sites lost approximately 500 to 1000 acres of habitat.

5.1.2 Summary of Habitat State

Major progress has been made in habitat mapping by 16 of the reporting NEPs. Ten NEPs reported having over 61 percent of their habitat mapped, and one NEP has completed this effort in its entirety. About half of the NEPs have created land use and land cover maps based on these surveys. In addition to the habitat mapping effort, the majority of the NEPs (13 of 21) reported major progress in developing a GIS platform, while 7 NEPs noted little or no progress being made in this effort. Four NEPs have developed over 20 GIS data layers or databases detailing ecologically significant areas or areas containing rare species.

5.1.3 Summary of Habitat Degradation/Loss Responses

In response to the habitat degradation/loss, conservation and restoration activities have been implemented by government, universities, and the community in most NEPs. Approximately 13 of the reporting NEPs, noted major improvements once mitigation, restoration, and wetland banking programs were implemented. A major contributing factor to the success of these programs is community involvement. Twelve NEPs have community involvement programs, with 4 NEPs having over 10 community groups supporting these programs. Approximately 6 NEPs have 10 or more volunteer programs being implemented with upwards of over 1000 volunteers. The majority of the NEPs noted that major progress has been made in implementing public education and outreach programs.

Implementation of specific programs has restored or protected on average approximately 50 to 100 acres. Four NEPs have over 1000 acres of habitat protected. Unfortunately, restoration programs have not led to changes in land use planning or zoning regulations to limit development along the coast. Those few communities that have been successful in changing zoning have, on average, restored or had "no net loss" of approximately 100 to 500 acres.

Management actions to improve water quality appear to have an added benefit in reducing habitat loss. Actions to change zoning regulations, land use changes, reduce runoff, and install best management practices appear to have the highest impact on habitat restoration. Supplemental changes such as connecting homes to central sewer treatment systems, the use of alternative onsite wastewater systems, septic system education, controlling nitrogen discharge from industrial sources, and installing improved wastewater technologies were also identified as priority factors that may reduce nutrient loading.

5.1.4 Recommendation for Habitat Degradation/Loss Indicators

Figure 5-1 presents indicators used by NEP to manage habitat degradation/loss, as determined by the Information Request. The most common indicator used by a large majority (17 of 18) of reporting NEPs is the area of habitat (or habitat extent, i.e., total acres of habitat within the estuary). This indicator is also utilized, in various forms, by a number of Federal monitoring/indicator programs, and could serve as an excellent national environmental indicator for the NEP. This indicator has the advantage, as it is monitored over time, to measure change in habitat extent, possibly capturing the response of pressures and the results of management actions.

As currently demonstrated by the NEP, which requires that individual NEPs annually calculate and report habitat acreage restored and protected for Government Performance and Results Act (GPRA) reporting (see http://www.epa.gov/owow/estuaries/pivot/habitat/hab_fr.htm), habitat acreage restored /protected is an excellent national environmental indicator for the NEP. One criticism of this indicator is that it does not directly address the functionality or condition of the restored habitat.

A summary of recommended indicators, according to the PSR framework, is provided below. Note that these recommendations account for the full spectrum of estuarine restoration activities undertaken by the NEP: planning, funding, constructing restoration projects, and then monitoring resultant changes in human behavior, changes in ambient ecological conditions, and changes in ecosystem services.

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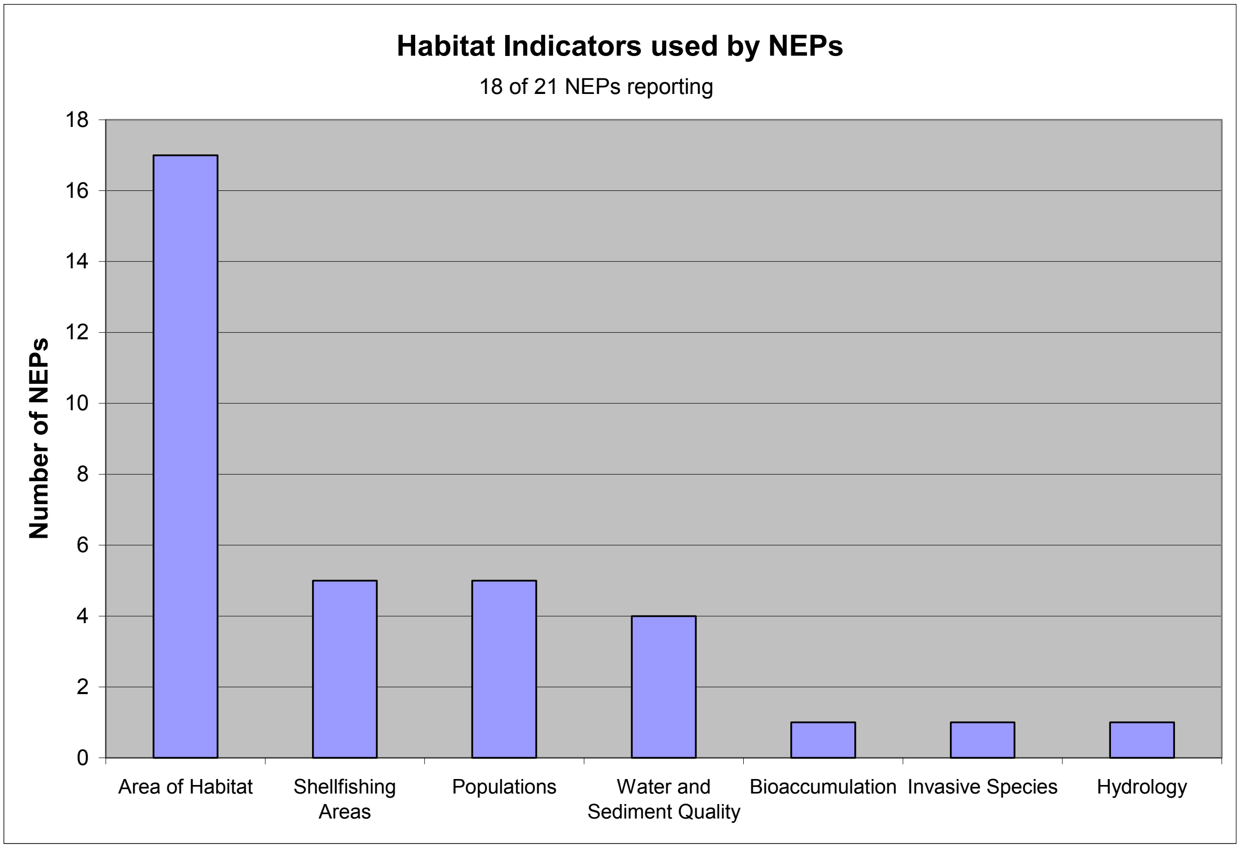

Figure 5-1. Habitat Indicators Used by NEPs

Additional pressure indicators for habitat degradation/loss:

- The number of habitat acres converted to development – report the conversion of habitat to residential (15 out of 21 reporting as very significant, 4 moderately) and agricultural uses (13 reporting as very significant, 4 moderately);
- Acres if SAV habitat lost/gained (13 out of 20 NEPs reporting that nutrients are a very significant factor in the loss of SAV); and
- Acres of habitat lost and acres of habitat degraded by introduced invasive species (12 out of 20 NEPs reporting as very significant).

Additional state of estuarine habitat indicators:

- Ultimately define a measure of habitat functionality.

Additional response indicators for habitat degradation/loss:

- Number and location of zoning/land use change actions;
- Number of mitigation/banking programs initiated and successful actions undertaken;
- Number of volunteers involved in monitoring or public involvement programs; and
- Number of public education/outreach programs implemented and number people reached.

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5.2 Nutrient Overloading Indicators

5.2.1 Summary of Nutrient Overloading Pressures

The National Estuarine Eutrophication Assessment (Bricker et al. 1999) states that 65 percent of U.S. estuaries by surface area, exhibit moderate to high expressions of eutrophic conditions. High conditions occur in estuaries along all coasts, but are most pervasive in estuaries along the Gulf of Mexico and Middle Atlantic coasts. Moreover, eutrophic conditions are anticipated to worsen in 70 percent of estuaries by 2020 (EPA 2001). A high level of human influence is directly associated with a majority (36) of the 44 estuaries that are exhibiting eutrophic conditions. It appears that both point and nonpoint sources are likely contributing to nutrient loading in estuaries. The most common point sources of excessive nutrients are discharges from wastewater treatment plants and rivers while nonpoint sources include septic tank systems, urban and suburban runoff, atmospheric deposition, and agricultural runoff (see Section 4.3.1). Nutrient loading pressures and associated eutrophic potential of estuaries is highly location-specific.

5.2.2 Summary of the State of Nutrient Water Quality

Eutrophic conditions are exhibited in many of the NEP estuaries. The NOAA State of the Coast Report states that approximately 65 percent of the nation's estuarine surface area has moderate to high eutrophic condition (NOAA 1998). As demonstrated in the NOAA National Estuarine Eutrophication Assessment, the assessment of eutrophic condition and potential is an extremely complex process. To date, this NOAA work is the best available national environmental indicator on the state of nutrient water quality in the NEP.

5.2.3 Summary of Nutrient Overloading Responses

Major progress has been made in implementing management actions to reduce nutrient loading from wastewater treatment plants. About half of the NEPs have started replacing septic tanks with connections to central sewer systems, upgrading municipal wastewater treatment plants, and using alternative onsite wastewater systems. Six NEPs have successfully replaced 10 to 20 percent of septic tanks with central wastewater systems. Four NEPs reported that 80 percent of the municipal treatment plants were upgraded while another 4 NEPs reported no upgrades were implemented by their local municipality. Community involvement appears to have some influence in promoting the replacement of septic tanks and upgrading the treatment plants. It is premature to determine the responses that will result from having to meet TMDL standards; however, minor progress has been made in promulgating TMDL guidelines. Public involvement was found to be an important factor in controlling nonpoint source releases to estuaries. Twelve NEPs reported having at least one community group involved in these programs that has lead to major progress in controlling nonpoint pollution. Two NEPs have over 20 community groups involved in either education or monitoring programs. In some cases, over 100 volunteers are involved in these programs. Management actions that appear to have the highest impact at improving water quality include upgrades to existing stormwater treatment facilities, baseline monitoring, and improved wastewater treatment technology.

5.2.4 Recommendation for Nutrient Indicators

Figure 5-2 presents indicators used by NEP to manage nutrient overloading, as determined by the Information Request. The most common indicators used by NEPs are dissolved inorganic nutrients (11 of 15), chlorophyll-*a* (9 of 15) and DO (8 of 15), however the rate of use of these indicators among reporting NEPs might not be adequate. In the National Estuarine Eutrophication Assessment, NOAA developed a system that evaluates several indicators to interpret the overall eutrophic condition of an estuary. The primary indicators employed included chlorophyll-*a*, macroalgal abundance, and epiphyte abundance; however, secondary indicators such as loss of SAV, presence of harmful algae, and low dissolved oxygen

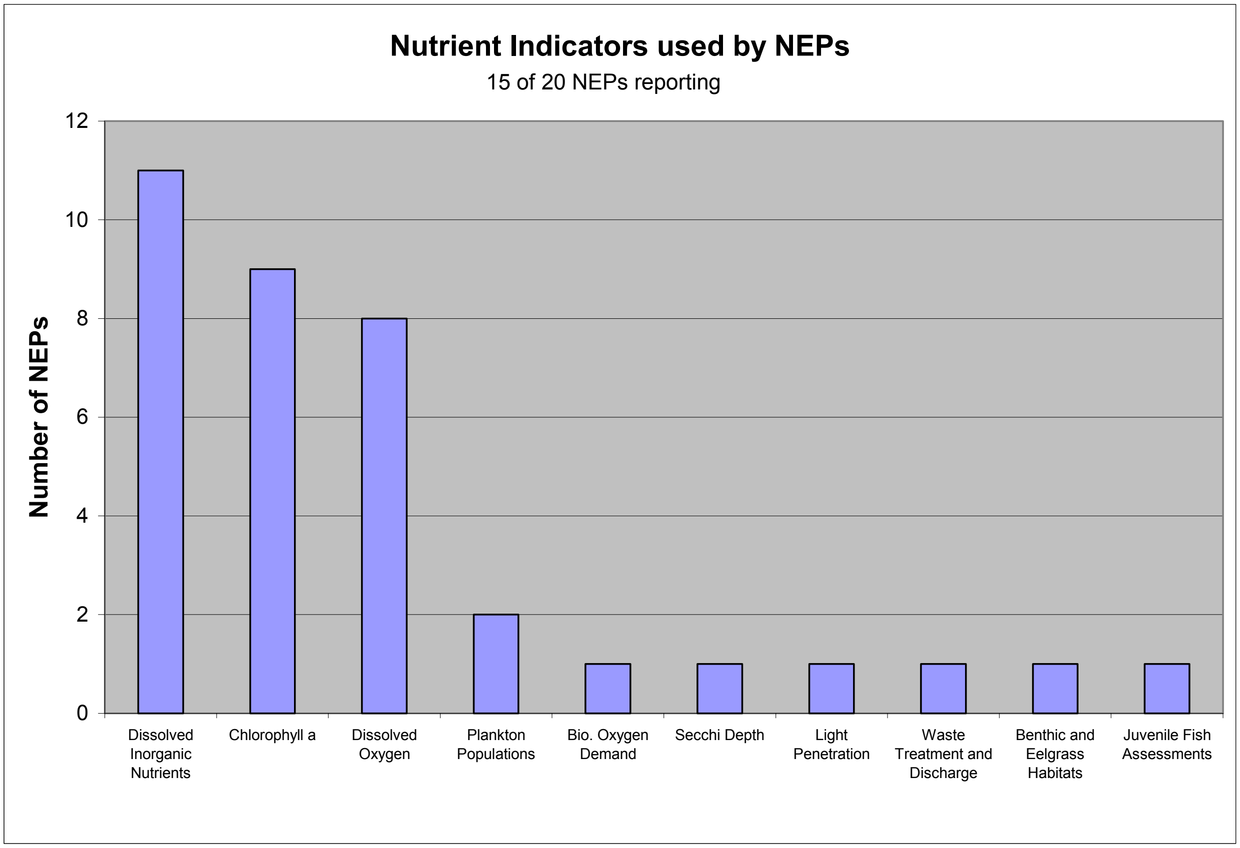

Figure 5-2. Nutrient Indicators Used by NEPs

are also used to support the finding of eutrophic condition. DO is probably not a suitable indicator for determining nutrient overloading since it is difficult to interpret whether the observed effects are the result of natural processes or human pressures.

Unlike the discussion of habitat degradation/loss indicators above, there does not appear to be one single indicator that can be applied to the NEP nationally for the pressures and state of nutrient overloading from data collected by the individual NEPs. Because of the diverse issues causing nutrient loading and the multitude of indicators that are being monitored by the various programs, it is difficult to form a cause and effect linkage in determining ecological response.

Since 1,114 National Coastal Assessment (NCA) sampling sites currently co-occur in the 28 NEPs, and by 2004, all NEPs will have between 23 and 110 NCA sampling sites within their study area boundaries, it is recommended that the state of nutrient overloading be reported using NCA collected data. These data would facilitate both primary and secondary eutrophication reporting (e.g., chlorophyll-*a*, macroalgal abundance, epiphyte abundance, loss of SAV, occurrence of HABs) and DO.

At the same time, EPA should continue to explore indicators related to responses to nutrient overloading. Potential response indicators include:

- The development of nutrient TMDLs;
- The number of septic replacements by either onsite alternative systems or connection to central sewers;

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- The number of BMPs implemented for agricultural and suburban/urban runoff;
- The number of public education/outreach (including citizen demonstrations) actions and the number of people reached; and
- The number of related public involvement volunteers.

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