

Northeast Coastal and Barrier Network
Protocol Summary
(May 2009)

Protocol Title: A Protocol for Monitoring Estuarine Nutrient Enrichment in Coastal Parks of the National Park Service Northeast Region

This protocol has been implemented in the following parks:

- Cape Cod NS, Gateway NRA
- Fire Island NS
- Sagamore Hill NHS
- Assateague Island NS
- George Washington Birthplace NM
- Thomas Thomas Stone NHS
- Colonial NHP

Justification and Issues addressed:

Approximately one quarter of the NPS land area within the NPS Northeast Coastal and Barrier Network is submerged. These estuaries, bays, and lagoons serve as islands of relatively pristine aquatic habitat within the Northeastern urban corridor. The North Atlantic coastal parks are dependent on high-quality aquatic resources to sustain the complex estuarine and nearshore ecosystems they represent. Diverse threats to NPS estuaries exist, including natural disturbances (e.g. storms, sea-level rise), direct impacts of human activities (e.g. fishing, boating, dock construction), indirect effects of watershed development, and disasters. Of these, park managers throughout the network have repeatedly identified threats to coastal water quality as one of their highest priority management issues. Much of the watershed area of NPS coastal ecosystems lies outside protective park boundaries and is subject to intense developmental pressures. Therefore, there is great potential for human disturbances to coastal watersheds to result in increased nutrient loading to park estuaries. Estuaries can generally assimilate some degree of enrichment without major ecological ramifications, but excessive nutrient inputs typically lead to dense blooms of phytoplankton and fast-growing macroalgae, loss of seagrasses, and decreased oxygen availability in sediments and bottom waters. Ultimately, cascading effects include changes in the species composition and abundance of invertebrates, decline in fish and wildlife habitat value, and the collapse of fin- and shellfish stocks. Protecting the ecological integrity of park estuaries depends on implementing a scientifically-based monitoring program that is capable of diagnosing local causes of nutrient enrichment, detecting changes in nutrient loads, and determining if nutrient inputs are near to exceeding thresholds that would result in shifts in ecosystem structure and function.

Specific Monitoring Questions and Objectives:

Objective 1: Determine if nutrient loads to Park estuaries are increasing.

- **Question 1:** *Based on a four-week summertime index period, are there detectable inter-annual trends in the following estuarine water chemistry constituents: dissolved oxygen concentration, turbidity, attenuation of photosynthetically active radiation, temperature, and salinity?*

- **Vital Sign 1:** Estuarine Water Chemistry
- **Vital Sign 2:** Estuarine Water Clarity
- **Question 2:** *Based on a four-week summertime index period, are there detectable inter-annual trends in estuarine suspended chlorophyll concentrations?*
 - **Vital Sign 1:** Estuarine Water Quality
- **Question 3:** *Are there detectable inter-annual trends in the level of organic carbon in estuarine sediments?*
 - **Vital Sign 1:** Estuarine Sediment Organic Carbon

Objective 2: Determine if estuarine resources are changing in response to nutrient inputs.

- **Question 1:** *Is the distribution and abundance of submerged aquatic vegetation beds changing?*
 - **Vital Sign 1:** Seagrass Distribution
- **Question 2:** *Are there detectable inter-annual trends in the following seagrass-bed condition measures: shoot density, percent cover, and aerial biomass?*
 - **Vital Sign 1:** Seagrass Condition

Vital Signs, measurements, justifications and basic approach:

Vital Sign: Estuarine Water Chemistry

- **Measurement:** Dissolved oxygen, Temperature, and Salinity
- **Justification:** Organic matter on the estuarine sediment surface and within the sediments is mineralized by microbial decomposers, a process which consumes oxygen. Consequently, as the pool of sedimentary organic matter increases in response to nutrient enrichment, intense benthic microbial metabolism can result in reduced concentrations of dissolved oxygen in bottom waters and a decrease in the depth of the oxic-anoxic interface within the sediments (Day et al. 1989, Cloern 2001). Ultimately, the shift to anaerobic benthic metabolism will stimulate sulfate reduction and cause an accumulation of hydrogen sulfide in pore waters (Herbert 1999, Cloern 2001). The increases in extent and duration of bottom water anoxia and concentration of toxic sulfide compounds with nutrient enrichment have obvious negative implications for benthic fauna. Dissolved oxygen concentrations below 2.0-5.0 mg/l cause declines in the diversity and abundance of estuarine fauna (NRC 2000). Therefore, use of dissolved oxygen as a monitoring variable provides indirect information on nutrient loads and direct information on threats to estuarine consumers.

Two of the most important physical characteristics of seawater are temperature and salinity. Although temperature and salinity data are not directly applicable to questions regarding estuarine nutrient enrichment, these variables are critical to interpreting the responses of other parameters.

Vital Sign: Estuarine Water Clarity

- **Measurement:** Photosynthetically active radiation light attenuation (PAR) and turbidity.
- **Justification:** The principal environmental control on Submerged Aquatic Vegetation (SAV) productivity and distribution is light availability (e.g. Dennison and Alberte 1982, 1985; Dennison 1987, Duarte 1991), specifically the amount of photosynthetically available radiation (PAR, light between 400-700 nm) transmitted to plant leaves. A primary factor contributing to the attenuation of PAR through the water column is phytoplankton concentration (Dennison et al. 1993, Gallegos 1994, Krause-Jensen and Sand-Jensen 1998). Therefore, in systems showing increases in phytoplankton biomass with nutrient load, PAR attenuation is correlated with nutrient enrichment (Borum 1996).

Vital Sign: Estuarine Water Quality

- **Measurement:** Chlorophyll A
- **Justification:** Nutrient enrichment of coastal waters frequently stimulates phytoplankton production and results in increased phytoplankton biomass (Sand-Jensen and Borum 1991, Duarte 1995, Borum 1996). A strong linear relationship exists between input of dissolved inorganic nitrogen and phytoplankton production (when both are log transformed) in deep, phytoplankton-based marine systems (Nixon et al. 1996). Chlorophyll a, an indicator of phytoplankton biomass, shows a similar relationship in deep-water systems (Nixon 1992). Because of this, many national, regional, state, and local estuarine monitoring and assessment programs include measures of chlorophyll a concentration as an indicator of nutrient loading (e.g. Bricker 1999, Gibson et al. 2000, USEPA 2001b).

Vital Sign: Seagrass Distribution

- **Measurement:** Submerged Aquatic Vegetation (SAV) bed size, structure and location. Within SAV-bed, percent cover, shoot density and biomass.
- **Justification:** The correlation between increased nutrient loading and declines in SAV distribution has been documented for estuaries worldwide (reviewed by Sand-Jensen and Borum 1991, Duarte 1995, Harlin 1995). Experimental studies have confirmed the causal relationships linking nutrient input, increased algal production, and decreased macrophyte growth and survival (Neckles et al. 1993, Short et al. 1995, Taylor et al. 1995, Sturgis and Murray 1997). The primary mechanism for loss of SAV in response to increased nutrient load is attenuation of light by fast-growing phytoplankton, epiphytic microalgae, and free-floating macroalgae, resulting in reduced availability of light at macrophyte leaf surfaces (Sand-Jensen 1977, Bulthuis and Woelkerling 1983, Twilley et al. 1985, Sand-Jensen and Borum 1991). Changes in seagrass distribution gives information on the long-term effects of estuarine eutrophication.

Vital Sign: Seagrass Condition

- **Measurement:** Within SAV-bed, percent cover, shoot density and biomass.

- **Justification:** The correlation between increased nutrient loading and declines in SAV distribution has been documented for estuaries worldwide (reviewed by Sand-Jensen and Borum 1991, Duarte 1995, Harlin 1995). Experimental studies have confirmed the causal relationships linking nutrient input, increased algal production, and decreased macrophyte growth and survival (Neckles et al. 1993, Short et al. 1995, Taylor et al. 1995, Sturgis and Murray 1997). The primary mechanism for loss of SAV in response to increased nutrient load is attenuation of light by fast-growing phytoplankton, epiphytic microalgae, and free-floating macroalgae, resulting in reduced availability of light at macrophyte leaf surfaces (Sand-Jensen 1977, Bulthuis and Woelkerling 1983, Twilley et al. 1985, Sand-Jensen and Borum 1991). Although changes in seagrass distribution track long-term changes, short-term changes in condition will precede loss and therefore should be monitored in order to provide early warning capabilities.

Vital Sign: Estuarine Sediment Organic Carbon

- **Measurement:** Percent organic carbon of surficial sediments.
- **Justification:** Water column and benthic processes are closely coupled in shallow coastal systems, so responses to nutrient enrichment may be observed in the sedimentary environment (Herbert 1999, Cloern 2001). Some of the organic production stimulated by nutrient inputs may be exported to nearshore waters, but this is generally a small fraction of the total primary production. For example, 10-15% of the primary production in Narragansett Bay is exported from the system (Nixon et al. 1995), and some systems with high rates of primary production export less organic matter than they produce (Smith and Hollibaugh 1993). Thus the majority of increased production that is stimulated through nutrient enrichment is metabolized or stored within the system. Much of this autochthonous organic matter sinks to the benthos and contributes to the pool of sediment organic material. Thus, organic carbon in the sediments may increase with nutrient load. Striking evidence is found in sediment cores from Chesapeake Bay, where a doubling of organic carbon content over the past 80 years corresponds to a period of dramatic increases in nutrient load (Cornwell et al. 1996).

Basic Approach for all Vital Signs:

Estuarine nutrient monitoring variables have been limited to those that are well justified scientifically and deemed feasible from both practical and economic perspectives. Two of these variables are sampled on infrequent time scales. These are sediment organic carbon content and benthic faunal species composition. Data collection methods for these variables are well established (US EPA 2001) so feasibility testing was not necessary. EPA guidance was translated into a network-specific protocol that includes sampling stations, sampling frequency, identification of contract laboratories and cost sourcing, and references to standard procedures. Similarly, data on submerged aquatic vegetation is available for some of the parks to acquire from outside sources. Where it is not available, methodological protocols have been provided so that parks (or the network) can build in-house capability or obtain contract service for the data.

Other variables that have been included in the NCBN estuarine nutrient enrichment monitoring protocol are chlorophyll a, dissolved oxygen concentration, attenuation of photosynthetically active radiation, and the required ancillary data of temperature and salinity.

A fully documented protocol has been completed for all of the vital signs. This protocol includes strategies for continuous and discrete sampling approaches, probability-based spatial sampling strategies, methods for incorporating non-Park Service data, and instruction on reporting and interpreting results. This protocol is compatible with the NPS National Marine Water Quality Monitoring Effort and with the EPA National Coastal Assessment.

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NPS Lead:

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Protocol Development Status:

This protocol has been peer reviewed and published in the NPS Natural Resource Report Series. Peer review comments are available. Please contact the NCBN Program Manager, Sara Stevens, NCBN - National Park Service, University of Rhode Island Coastal Institute in Kingston, #105, 1 Greenhouse Road, Kingston, RI 02881.

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