Recommended Biological Observations and Monitoring Parameters for the National Water Quality Monitoring Network

Network Refinement Workgroup: Biology

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Introduction

The National Water Quality Monitoring Council (Council) has produced a design for the National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries (the Network) as called for in the U.S. Ocean Action Plan. The Network is a framework for linking water quality monitoring in coastal bays, estuaries and the Great Lakes with observations in upland areas and offshore waters, and includes freshwater flows and contaminant input from inland and coastal rivers, ground water, and atmospheric deposition. Wetlands and coastal beaches are also included in the design. A description of the Network design is available at http://acwi.gov/monitoring/network/design.

Biological Observations and Monitoring

The spatial domain of the Network includes coastal streams and rivers, bays and estuaries that are located adjacent to heavily industrialized areas, densely populated metropolitan areas, busy harbors with deep navigational channels in naturally shallow estuaries, and protected waterbodies that are managed to assure natural environments and their associated biota. The Network design document (Table 3-1) lists several kinds of biological assessments including chlorophyll *a*, algae, bacteria, macro-invertebrates, and fish but is not specific about the individual measurements and frequency of observations that will be appropriate in different resource compartments, e.g., estuaries, coastal ocean, etc.

Several federal and state government agencies, as well as non-governmental organizations, track coastal ecosystem conditions using a suite of indicators that are designed to simplify complex scientific data. For a general introduction to such indicators, please refer the interagency National Coastal Condition Report (December 2004) and the Heinz Center report "Filling the Gaps" (May 2006). Examples of such indicators include:

- spatial extent of estuaries and coastal bays that experience recurrent hypoxic conditions (oxygen levels below 2 mg/L) or do not meet other specified criteria established by coastal states;
- regional and spatial trends in toxic contaminant levels in sentinel species;
- percentage of shellfish growing areas closed to harvest (includes prohibition and restriction); and
- percentage of coastal beach miles affected by advisories and closures.

Quite often, changes in natural biological assemblages and ecological conditions are evaluated using measures such a biodiversity, indices of biological integrity, and ecosystem health.

The purpose of the Network refinement workgroup for biological measurements is to define a parsimonious set of water-quality measurements that would be most fruitful for assessing the condition and forecasting response of coastal ecosystems to natural and anthropogenic stressors. The environmental compartments that will include biological measurements are estuaries and coastal bays, nearshore and continental shelf waters, the Great Lakes, wetlands, and rivers. The workgroup will also outline sampling frequency and platforms for such measurements that would be appropriate for different sampling schemes that have been outlined in the Network design document, i.e., GRTS, targeted sites, remote sensing, and continuous sampling.

Largely due to conceptual limitations, varied thresholds and criteria, and different computational schemes, the Network will not have a prescribed set of indices or derived parameters for assessing ecological conditions, ecosystem services, or degree of impairment of waterbodies.

Rather, it will provide primary and ancillary data that may be used for developing such assessments or environmental indicators with broad regional or nationwide application.

Several "biological" variables will be covered in other refinement subgroups, for exampled dissolved oxygen, water color and chlorophyll in the "nutrient workgroup" and levels of toxic chemicals in sentinel species in the "contaminant workgroup." Thus, these variables do not need to be considered by the biology working group. There will be an opportunity for workgroups to review the draft reports of all other workgroups to assure that important measurements or observations have not been overlooked.

Charge to the Biological Observations and Monitoring Workgroup

1. Develop lists of biological and ecological variables, in order of priority, for addressing water quality-related environmental issues noted in Table 1.1 of the Network design document.
2. Consult with representatives of the three pilot study areas to gauge regional information needs and refine the listed variables, in terms of the desired spatial and temporal scales of data and observations.
3. Identify variables whose data may be obtained using remotely-sensed, shore-mounted and in-water sensors.
4. Expand Table 3.1 (Network Measurements) in the Network Design Report and provide supporting text.

Composition of the Workgroup

The workgroup consisted of representatives of the National Water Quality Monitoring Council, NOAA, EPA, USGS, the Network Pilot Studies, academic institutions, and technical experts. The following individuals constituted the workgroup:
Ian Hartwell, NOAA (Chair)
Marty Gurtz, USGS
Hal Walker, EPA
John Kraeuter, Rutgers University
Barbara Scudder, USGS
Danielle Kreeger, PDE
Gabrielle Canonico, USGS
Ellen Tarquinio, EPA
John Hummer, Great Lakes
Ed Santoro, DRBC
Mike Connors, SFEI
Jawed Hameedi, NOAA (alternate chair)

Workgroup Deliberations

The Workgroup communicated primarily via teleconference calls and emails, many of which quite extensive and detailed. Preliminary results of the workgroup deliberations were presented at the National Water Quality Monitoring Council meeting in Philadelphia in July 2007, which provided another forum for further discussions and ideas on the recommended biological measures.
The workgroup noted two significant challenges in arriving at a recommended list: (1) there are numerous, indeed hundreds, of indicators and other variables to describe the state, condition or

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trajectory of biological populations, coastal biological communities, and regional ecosystems, and (2) many of the biological diversity measures or ecosystem health indices had incongruent interpretations and different formulations, and, as such, they were both potentially misleading in their interpretation and in communications to the coastal managers and the public. The workgroup decided to focus on simple and readily understandable parameters.

General criteria for selection of parameters included the following:

1. They are measurable with a low margin of error, such that a "change" can be detected after a reasonable sampling effort and decision-making time-frame.
2. They are not costly to obtain; at least the cost should be relatable to the value of information being provided.
3. They are based on consensus and "expert counsel."
4. They are responsive to environmental conditions (or stressors), preferably in a monotonic way.

Selected Parameters

The workgroup considered dozens of parameters based on the above-noted criteria and following considerable discussion on their strengths and limitations, including the ability to communicate information to the decisions-makers. Some of the "biological" measurements, for example, concentration of chlorophyll in the water column, were included in parameters selected by the "Nutrients Refinement Workgroup," and some others, for example, contaminant levels in fish tissues under the "Contaminant Refinement Workgroup." The Biology Refinement Workgroup decided to include dissolved oxygen levels, since they are critically important for describing the condition of any waterbody, and also habitat descriptors, even though they may not strictly biological in nature.

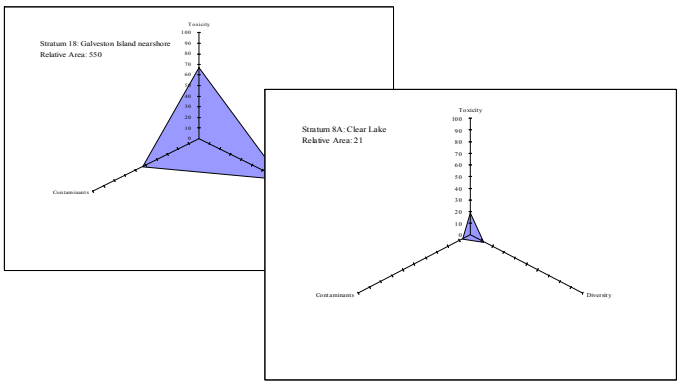
The selected parameters are listed in Table 1, and organized in three priority groups. Measurements listed as "Special" are those for which the Network would not specify sampling scheme, data reporting requirements, or data interpretation thresholds; for the most part these measurements are being made under different long-term monitoring programs sponsored by federal and state agencies. Nonetheless, data produced by those programs are of value in assessing or corroborating water-quality related conditions in estuaries or coastal bays.

The selected parameters are integrators or integrative of coastal conditions. They also have wide appeal and appreciation, and each can be measured quite reliably with current methods and technologies. Except for the Sediment Quality Triad (SQT), each of the listed measures is obvious in its meaning and purpose.

The Sediment Quality Triad was conceptualized in the mid-1980s as an approach for collecting synoptic measurements of sediment chemistry, toxicity, and benthic macro-invertebrates. The resulting data are analyzed to infer the existence and extent of contaminated sediments, toxicity associated those sediments as inferred from a suite of toxicity tests, and in situ changes in the benthic biota. Although the SQT data have been analyzed and portrayed in a number of ways, the use of the triad approach is neither constrained nor defined by any particular method of data analysis. Still, integrating and presenting a large amount of data on numerous toxic chemicals of interest (often exceeding 100), results from a battery of lethal and sub-lethal toxicity tests, and numerous measures of benthic community structures has remained a formidable task. More recently (since 2004), attempts have been made to scale and aggregate the SQT data, and then

present the resulting information as triaxial plots, with measureable areas of the triangles (Figure 1). Thus extensive and multi-disciplinary data can be illustrated for different regions of interest,

Aggregated SQT values for two sampling strata in Galveston Bay. Note the relative sizes and numerical values of the two strata (550 and 21)
(Hameedi, 2004; Hartwell and Hameedi, 2007)



for example, sampling strata or subregions, and comparisons made of their relative sediment quality (or inversely of sediment pollution). As with nearly all environmental indices, SQT aggregate index is designed as a product for management use and not necessarily an ecological acumen. The index relies on observed and derived values, and avoids the use of "trigger values" or sediment quality criteria or guidelines, many of which are either quite imprecise or questionable. The index itself is transparent, i.e., disaggregation of its components is possible for detailed examination of data sets or further analyses, e.g., principal component analysis.

Recommended Methods

The workgroup did not specify analytical methods, partly because different methods are appropriate for each of the listed measurements and in the case of remotely sensed imagery, electrochemical probes, or high precision chemical analyses new methods and approaches are continually evolving. For example, it was noted that the National Environmental Methods Index (NEMI) listed 10 different methods for dissolved oxygen level, and that trace elements [part of the Sediment Quality Triad measurements] can be measured with increasingly greater sensitivity and precision using newer techniques, such as Inductively Coupled Plasma Mass Spectrometry (ICP/MS) and Orbitrop mass spectrometry that are capable of providing concentration values on the order of parts per trillion in the sediment matrix.. It is however expected that all Network-related chemical analyses will be documented either with reference to those listed under NEMI or detailed information on the method will be documented for inclusion under NEMI.

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Priority 1

Issues: Oxygen Depletion (DO); Nutrient Over-enrichment (NUT); Toxic Contamination (TOX); Sedimentation (SED); Harmful Algal Blooms (HAB); Habitat Degradation (HD); Invasive Species (INV); Pathogens, microbes (PATH)

Parameter/Variable	Sampling	Sampling Frequency	Reporting	Rationale	Main WQ Issue(s)	Notes
Macro-algae density	Reconnaissance and fixed transect sampling; digital photography (estuary-wide as appropriate)	Aerial reconnaissance; monthly along transects	Status and change in areal coverage; biomass; C:N:P ratio?	*Ulva* or *Enteromorpha* biomass above 100 g dw/sq m may cause SAV die-off	NUT	
Habitat mapping: High resolution mapping of benthic habitats; also changes in shoreline armoring, impervious land-cover	Reconnaissance sampling using multi-beam bathymetry; Chirp Sonar profiler; field verification; satellite data for impervious cover' LIDAR for shoreline changes	Every five years or when warranted, e.g., before channel deepening or widening	Status and change in seabed bottom classifications, impervious land-cover in coastal watersheds (county to regional levels)	Delineation of habitats and documentation of fragmentation; vulnerability to water quality impairments.	HD SED	
Seagrass cover	Reconnaissance and fixed transect sampling; digital photography (estuary-wide, as appropriate)	Aerial reconnaissance; monthly along transects	Area coverage and estimated biomass distribution;	Readily reportable; historic data; keen public awareness	NUT TOX HD INV	
Incidence of pathological conditions and deformities in fish	Probabilistic sampling; use agency data (most likely targeted samplings)	Yearly for probabilistic sampling; also more frequent "directed sampling"	Types of disease and deformities and frequency of their occurrence	Easily recognized; elicits strong public response to habitat degradation (contaminants, microbes, etc.)	TOX SED HAB PATH	
Sediment Quality Triad	Probabilistic sampling; estuary specific.	Every five years or when warranted.	Holistic index of sediment quality; as well as disaggregated data.	Integrates levels of toxic chemicals, different toxicity tests, and benthic infaunal distributions; very useful to decision-	DO TOX SED INV	

				makers if presented as a holistic index; not all states have the needed resources.		
Dissolved oxygen level	Targeted sampling estuary-wide (15 sites); possible regional reconnaissance with AUVs; near-bottom measurements with sediment quality assessments	Continuous measurements with deployed sensors possible; most often at discrete sampling depths.	Levels below criteria or thresholds; percent saturation	The most significant water quality parameters in terms of biological stress.	DO NUT SED HAB HD	

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Priority 2

Parameter/Variable	Sampling	Rationale	Main WQ Issue(s)	Thresholds or criteria (TBD)	Priority (1,2)
HABs	Concentration of a particular group (e.g., cyanobacteria); relative abundance of different groups (remote sensing possible in future)	Dinoflagellate blooms exceeding 1 million cells/L become toxic; other HAB species (e.g., *Pfiesteria*) cause damage at much lower concentrations. Being monitored in other Federal-state programs	NUT HAB HD INV		2
Status of "ecologically significant" or "signature" species of an estuary	Estuary or region-specific	Species that perform key ecological function, for examples, water filtration by bivalves, unique for the region (e.g., horseshoe crab in Delaware Bay), or are accumulators of contaminants (e.g., harbor seals).	DO HD INV		2
Epiphytes	Relative biomass; once or twice a year?	Epiphytes colonizing SAVs cause die-off of the host plant	NUT		2
Chlorophyll a	Measure as concentration; estuary-specific (or estuary-type specific)	Measure of the extent and severity of eutrophic conditions; possible related to decline of SAVs, hypoxic conditions	NUT SED HAB		2
Macrobenthic fauna	Species richness and biomass (?); data suitable for IBIs	Change in biodiversity; invasive spp. documentation	DO SED HD		2

"Special" implies that the Network will not specify sampling methods, data reporting requirements, or data interpretation thresholds; information necessary for integrated assessments.

Parameter/Variable	Sampling	Rationale	Main WQ Issue(s)	Thresholds or criteria (TBD)	Priority
Bird community census	Estuary or region specific	Integrator of environmental change; indicator of successful restoration (e.g., wetlands)	HD		Special
Status of marine mammal, bird, or fish species that are considered sentinel of environmental change	Estuary or region-specific	Some mammal and bird species are routinely monitored for their health and population size; health status of bottle-nose dolphin is being monitored along the East and Gulf of Mexico coasts	DO TOX HAB HD INV		Special
Fish and shellfish landings (commercial)	Estuary or region-specific	Data are routinely compiled and reported by resource management agencies; useful for integrated or holistic assessment reports	HD		Special
Presence of non-indigenous species	Estuary or region-specific	Federal and state agencies have extensive databases; require data mining; useful for integrated or holistic assessment reports	INV		Special
Water Quality Index	Rely on NCA	Based on aggregation of ratings of five water quality measurements (DO, Chl a, N, P and water clarity); could be covered under "nutrients"	DO NUT SED		Special
Coastal habitat index	Rely on NWI/NCA; every 5 years	It is based on mean, long-term (decadal) wetland loss rate; data are generated by NWI. Ratings: good (less than 1), fair (1.0 to 1.25), and poor (greater than 1.25) Include under "wetlands"	HD		Special
Sediment Quality Index	Rely on NCA; every five years	Index is based on sediment contamination, sediment toxicity (usually one test), and sediment TOC; slightly different from SQT	DO TOX SED INV		Special