Indicator: Coastal Sediment Quality Index (333)

Contaminated sediments pose an immediate threat to benthic organisms and an eventual threat to estuarine ecosystems as a whole. Contaminants in sediments may be resuspended into the water by anthropogenic activities, storms or other natural events, where they can expose organisms in the water column, and can accumulate and move up the food chain, eventually posing health risks to humans (EPA, 2004a).

This indicator, derived in part from the sediment quality index presented in EPA's National Coastal Condition Report (EPA, 2004b), is based on two measures: sediment contaminant concentrations and sediment toxicity. The data are from probabilistic surveys conducted of these measures in all estuarine waters of the conterminous 48 states and Puerto Rico.

Sediment concentration measurements of nearly 100 contaminants, including 25 PAHs, 22 PCBs, 25 pesticides, and 15 metals, were taken at each site. Homogenized samples were analyzed using standard wet chemistry and mass spectroscopy. Sediment condition was determined by comparing the observed concentrations to "effects range low" (ERL) and "effects range median" (ERM) values developed by the National Oceanic and Atmospheric Administration (Long et al., 1995). ERL and ERM values identify threshold concentrations that, if exceeded, are expected to produce ecological or biological effects based on the literature evaluated. Sediment contamination in this indicator is rated moderate if five or more ERLs are exceeded and high if one or more ERMs are exceeded.

Sediment toxicity depends not only on the concentrations of toxic materials, but also on their biological availability, which is controlled by acid volatile sulfides, pH, particle size and type, organic content, resuspension potential, and the specific form of contaminant (e.g., mercury vs. methyl mercury). Biological availability is determined in practice by bioassays that expose test organisms to sediments and evaluate their effects on the organisms' survival. For this indicator, sediment toxicity was based on 10-day static tests conducted using the benthic amphipod *Ampelisca abdita*. For this indicator, sediments were determined to be toxic if the bioassays resulted in greater than 20 percent mortality, or non-toxic if the bioassays resulted in 20 percent mortality or less (EPA, 2004b).

What the Data Show

Nationally, high sediment contamination levels were observed in 7 percent of coastal sediments for which contamination data were available, and moderate contamination was observed in an additional 8 percent (Figure 333-1). There was considerable variability in sediment contamination from one EPA region to the next, with Region 4 showing the largest proportion of estuarine area with low concentrations of sediment contaminants (99 percent), and Region 2 showing the largest proportion with high contamination (28 percent).

Nationwide, only 6 percent of coastal sediments had high toxicity scores, although again there was considerable variability from one EPA region to the next (Figure 333-2). In Regions 4 and 9, nearly 100 percent of estuarine area exhibited low sediment toxicity, while in some other regions, as much as 20 percent of estuarine area fell into the "high toxicity" category.

Although the percentage of sediments nationwide with high contamination is similar to the proportion exhibiting high toxicity, the two measures are not necessarily correlated. This indicator does not measure correlation, although in this case, the original data source actually shows little overlap between the two measures (EPA, 2004b). This indicator also does not reflect "missing" data, which accounted for a significant portion of estuarine area in a few regions. However, the probabilistic design of the survey ensures that the data that *were* collected are representative of each region as a whole.

Indicator Limitations

- Survey data are available only for the conterminous 48 states and Puerto Rico; 75 percent of the nation's estuaries are located in Alaska, which and are not included in the survey. Data also were not available for Hawaii, the U.S. Virgin Islands, and the Pacific territories.
- Samples are collected during an index period from July to September, and the indicator is only representative of this time period, but it is not likely that contaminant levels vary from season to season.
- The ERL and ERM are general guidelines for evaluating sediment contamination, and the sediment toxicity test uses one organism as a screening tool. This design ensures that a consistent metric is applied across the nation, but the results do not necessarily reflect the extent to which sediments may be toxic to the biota that actually inhabit any particular sampling location.
- Sediments that have toxic levels of contaminants do not always exhibit toxicity in the *Ampelisca* bioassay, and vice versa (some toxic chemicals may not be bioavailable, some may not be lethal, and not all potentially toxic chemicals are analyzed—see O'Connor et al., 1998 and O'Connor and Paul, 2000).
- The indicator does not include any microbial or plant toxicity tests.
- This indicator cannot be compared quantitatively with the indicator of pesticides in agricultural area streams (040), in which thresholds are based criteria that are intended to be protective of aquatic life with a margin of safety, instead of thresholds shown to cause biological effects.

Data Sources

The data source for this indicator is the National Coastal Condition Report II, U.S. Environmental Protection Agency, 2004. http://www.epa.gov/owow/oceans/nccr/2005/downloads.html.

References

EPA. 2004a. "Contaminated Sediment in Water." Fact Sheet: http://www.epa.gov/waterscience/cs/aboutcs.

EPA. 2004b. National Coastal Condition Report II, EPA-620/R-03/002. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/owow/oceans/nccr/2005/downloads.html.

Long, E.R., MacDonald, D.D., Smith, L., and Calder, F.D. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. *Environmental Management* 19: 81-97.

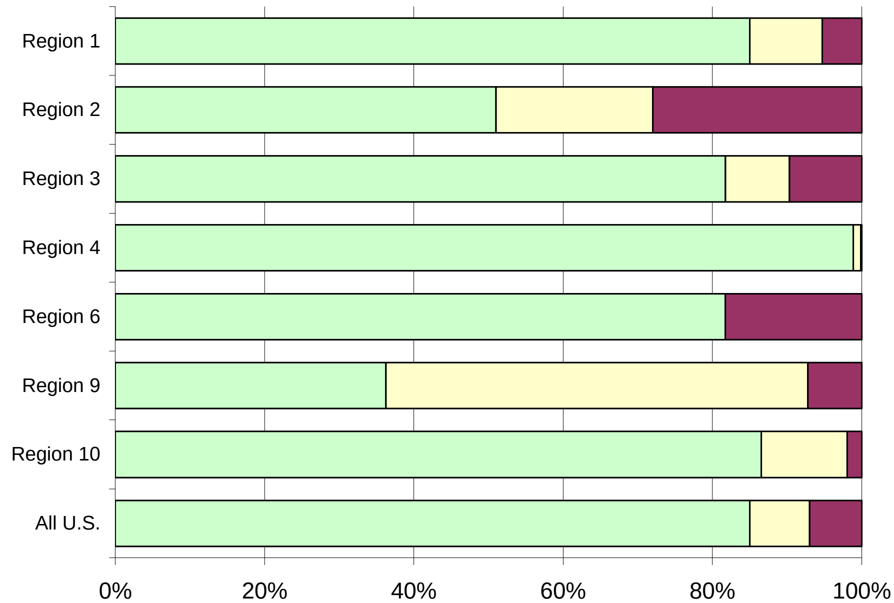
O'Connor, T.P., K.D. Daskalakis, J.L. Hyland, J.F. Paul, and J.K. Summers. 1998. Comparisons of sediment toxicity with predictions based on chemical guidelines. *Environmental Toxicology and Chemistry* 17(3): 468-471.

O'Connor, T.P., and J.F. Paul. 2000. Misfit between sediment toxicity and chemistry. *Marine Pollution Bulletin* 40(1): 59-64.

Graphics

Figure 333-1. Sediment Contamination

(Percentage of Estuarine Area)



Low: < 5 contaminants exceed ERL*

Moderate: 5 or more contaminants exceed ERL* (none exceed ERM*)

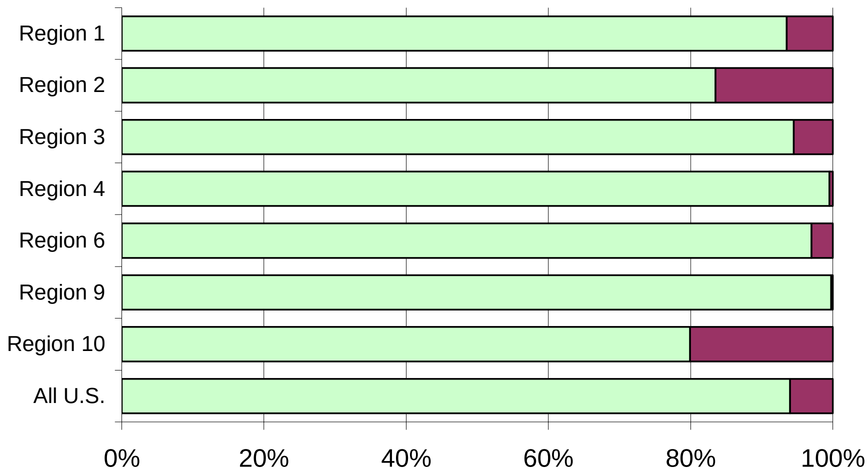
High: 1 or more contaminants exceed ERM*

Source: EPA, Office of Research and Development and Office of Water. National Coastal Condition Report II. 2004.

* ERL = effects range low; ERM = effects range median

Figure 333-2. Sediment Toxicity

(Percentage of Estuarine Area)



Low: Mortality of test species = 20% or lower

High: Mortality of test species > 20%

Source: EPA, Office of Research and Development and Office of Water. National Coastal Condition Report II. 2004.

R.O.E. Indicator QA/QC

Data Set Name: COASTAL SEDIMENT QUALITY INDEX
Indicator Number: 333 (89139)
Data Set Source: EPA/EMAP/NCA
Data Collection Date: 1999-2000
Data Collection Frequency: annually
Data Set Description: An issue of major environmental concern in estuaries is the contamination of sediments with toxic chemicals. The focus of the sediment quality index is on sediment condition, not just toxicity. The index is composed of sediment contaminant data, total organic carbon content, and toxicity to estuarine organisms.
Primary ROE Question: What are the trends in extent and condition of coastal waters?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Methods described for this survey represent a combination of standard, scientifically accepted sampling and analytical methodologies. They are described in ; US EPA 2001. National Coastal Assessment: Field Operations Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA 620/R-01/003. pp72. U.S. EPA. 1995. Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses. U.S. Environmental Protection Agency, Office of Research and Development , Narragansett, RI. EPA/620/R-95/008. http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html EPA/620/R-95/008. http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

There is an entire portion of the EMAP website dedicated to principles and implementation of the NCA monitoring design and analysis. http://www.epa.gov/nheerl/arm/index.htm Diaz-Ramos, S., Stevens, D.L., Jr and Olsen, A.R. (1996) EMAP Statistical Methods Manual. Rep. EPA/620/R-96/002, U.S. Environmental Protection Agency, Office of Research and Development, NHEERL-WED, Corvallis, Oregon. Olsen, A.R., Stevens, D.L., Jr. and White, D. (1998) Application of global grids in environmental sampling. Computing Science and Statistics, 30, 279-84. Stevens, D.L., Jr. (1997) Variable density grid-based sampling designs for continuous spatial populations. Environmetrics, 8, 167-95. Stevens, D.L., Jr. and Olsen, A.R. (1999) Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics, 4, 415-28. Stevens, D.L., Jr. and Urquhart, N.S. (1999) Response designs and support regions in sampling continuous domains. Environmetrics, 11, 13-41. Stevens, D. L., Jr. and Olsen, A. R. Variance Estimation for Spatially Balanced Samples of Environmental Resources. Environmetrics 14:593-610. Stevens, D. L., Jr. and A. R. Olsen (2004). "Spatially-balanced sampling of natural resources." Journal of American Statistical Association 99(465): 262-278.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Some researchers would prefer that the sediment triad (chemistry, toxicity, and communities) be used to assess condition. This index only includes the chemical composition and toxicity of the sediments, with benthic communities being included as an independent variable for assessing ecological condition. Only attributes in sediments that can result in unacceptable changes in the biotic communities are included. Note that the original source has a “missing” category, but for this indicator, the “missing” category has been removed. These “missing” data points have been apportioned among the remaining categories according to the distribution of the existing data. This methodology is appropriate because of the survey’s probabilistic design.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

Sampling for the indicator presents available information on a national scale for the conterminous 48 states and Puerto Rico. There are 50 sites sampled each year for each of the states or territory. Data collection began in 1999 and is ongoing in 2004.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

This indicator does not target specific plant or animal populations that may be sensitive to sediment condition. However, the indicator intentionally focuses on estuaries as a subset of coastal resources because estuaries are sensitive ecosystems in general.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

Threshold values for sediment quality indicator components are based on existing criteria, guidelines, or the interpretation of scientific literature. For this index the ERM (Effects Range Median) and ERL (Effects Range Low) of Long et al., 1995 were utilized. These values were used consistently across all geographic areas of the study. Long, E.R., D.D. MacDonald, Smith, S.L., and Calder, F.D.: 1995, Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1): 81-97.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

U.S. EPA. 1995. Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual-Estuaries, Volume 1: Biological and Physical Analyses. U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI. EPA/620/R-95/008. U.S. EPA. 2001. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/002. U.S. EPA. 2001. National Coastal Assessment Field Operations Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/003.
http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

http://www.epa.gov/emap/nca/html/data/index.html Stephen Hale, U.S. EPA, Atlantic Ecology Division, (401) 782-3048

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes, Using the documentation provided, the design can be reproduced by a competent statistician. All of the field sampling and analytical methods are also well documented.

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

U.S. EPA. 2001. Environmental Monitoring and Assessment Program (EMAP): National Coastal Assessment Quality Assurance Project Plan. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL. EPA/620/R-01/002 Hale, S., J. Rosen, D. Scott, J. Paul, and M. Hughes. 1999. EMAP Information Management Plan: 1998-2001. U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI.
http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html
http://www.epa.gov/emap/html/pubs/docs/groupdocs/estuary/index.html

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

There is an entire portion of the EMAP website dedicated to principles and implementation of the NCA monitoring design and analysis. http://www.epa.gov/nheerl/arm/index.htm Diaz-Ramos, S., Stevens, D.L., Jr and Olsen, A.R. (1996). See T1Q2. Note that the original source has a “missing” category, but for this indicator, the “missing” category has been removed. These “missing” data points have been apportioned among the remaining categories according to the distribution of the existing data. This methodology is appropriate because of the survey’s probabilistic design.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes, measurements of uncertainty are provided with each indicator.
http://www.epa.gov/nheerl/arm/index.htm

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

Inconsistency in application of the design, sample collection, or sample analysis. These are controlled through standardization of methodologies, publication of operational manuals, and training of personnel involved. It is monitored through quality assurance requirements and audits.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

Data gaps result from missing or lost samples. In this event, the analysis is performed without those sites. Any error associated with the index may only increase slightly, but would be controlled by the number of sites and the survey design. Samples are collected during an index period from July to September, and the indicator is only representative of this time period, but it is not likely that contaminant levels vary from season to season.The ERL and ERM are general guidelines for evaluating sediment contamination, and the sediment toxicity test uses one organism as a screening tool. This design ensures that a consistent metric is applied across the nation, but the results do not necessarily reflect the extent to which sediments may be toxic to the biota that actually inhabit any particular sampling location.Sediments that have toxic levels of contaminants do not always exhibit toxicity in the Ampelisca bioassay, and vice versa (some toxic chemicals may not be bioavailable, some may not be lethal, and not all potentially toxic chemicals are analyzed – see O’Connor et al. 1998 and O’Connor and Paul 2000). The indicator also does not include any microbial or plant toxicity tests.This indicator cannot be compared quantitatively with the indicator of pesticides in agricultural area streams (040), in which thresholds are based criteria that are intended to be protective of aquatic life with a margin of safety, instead of thresholds shown to cause biological effects