Use of EMAP Freshwater and Marine Data in EPA Region 10

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Abstract—*The Environmental Protection Agency (EPA) designed the Environmental Monitoring and Assessment Program (EMAP) to provide tools to monitor and assess the condition of the nation's ecological resources. Since 1993, EPA Region 10 has worked with the States in our region to demonstrate the application of the ecological indicators and statistical designs developed by EMAP to freshwater and marine assessments.*

To illustrate the types of assessment questions that can be addressed with EMAP data, we present an example study of the Western Cascades Ecoregion of Oregon and Washington. In 1999-2000, Washington Department of Ecology (DOE) and Oregon Department of Environmental Quality (DEQ), with assistance from EPA Region 10, collected biological, physical habitat, and selected water column chemistry parameters in small streams of the Ecoregion. An overall assessment of the streams in this region using in-stream biological, physical and chemical data will be presented. In addition, a discussion of how these results might better inform Clean Water Act decisions will be presented.

As a second example, the estuaries of Oregon and Washington will be examined using EMAP Coastal data. Washington DOE and ODEQ, with assistance from National Marine Fisheries Service (NMFS) and EPA Region 10, collected water column chemistry, sediment characteristics, and chemistry, benthic organisms and fish trawl data. A discussion of how this data relates to EPA Regional reporting will be presented.

Introduction

The Environmental Protection Agency (EPA) designed the Environmental Monitoring and Assessment Program (EMAP) to provide tools to monitor and assess the condition of the nation's freshwater and coastal systems. This program was developed by EPA's Office of Research and Development (ORD). EMAP examines associations between these indicators and natural and anthropogenic stressors. The two major features of EMAP are the random, probability based sample site selection and the use of ecological indicators. In 1994, Region 10 began a partnership with the EPA ORD and the States to begin to use an EMAP-type sampling approach in selected areas for rivers and streams. These projects are called Regional EMAP (R-EMAP), and they use the same indicators and sample design as other EMAP projects, but at a smaller geographic scale. Table 1 shows the R-EMAP projects for Region 10.

In 1999, Western EMAP was initiated to focus on the aquatic systems and landscape features of the states encompassed by EPA Regions 8, 9 and 10. There are three major components of the Program - Coastal, Surface Waters (rivers and streams), and Landscapes. The Western EMAP is a partnership between EPA, the States, and others. All field data for Western EMAP in EPA Region 10 is collected by the state and tribal environmental agencies.

Overview of EMAP Surface Waters in Region 10

Western EMAP applies tools developed by ORD to monitor and assess rivers and streams across the contiguous western States. Water chemistry, physical habitat, benthic macroinvertebrate, fish, and periphyton data are combined to describe the current river and stream conditions. Idaho Department of Environmental Quality (IDEQ), Oregon DEQ, Washington DOE, and the Nez Perce Tribe have conducted most of the sampling for Western EMAP in Region 10.

The Western EMAP surface water component evaluates the ecological condition of rivers and streams at two scales (table 1). The broad scale assessment is useful for evaluating the overall condition of rivers and streams for each State and the entire Region. For this scale assessment, approximately 150 stream sites are in the process

Table 1. Freshwater monitoring projects in EPA Region 10 using EMAP design and indicators.

Geographic Scope	Year	Number of Sites	Agency Conducting Sampling
Regional EMAP Projects			
Coast Range ecoregion	1994-1995	104	Washington DOE and Oregon DEQ
Upper Chehalis basin	1997	26	Washington DOE
Upper Deschutes basin	1997	30	Oregon DEQ
Western Cascades Ecoregion	1999-2000	79	Washington DOE and Oregon DEQ
Western EMAP - Statewide scale			
Idaho	2000-2004	50	Idaho DEQ
Oregon	2000-2004	60	Oregon DEQ
Washington	2000-2004	50	Washington DOE
Western EMAP - Focus Studies:			
Deschutes/ John Day Basins	2000-2004	96	Oregon DEQ
Medium to large rivers of Idaho	2000-2004	45	Idaho DEQ
Wenatchee Basin	2000-2004	54	Washington DOE
National State Monitoring, Assessment, and Reporting Program Grants (EMAP design and indicators)			
Yukon (Tanana) basin	2004-2005	50	Alaska DEC and University of Alaska

of being sampled in Idaho, Oregon, and Washington over a four to five year period, beginning in 2000. Over the same time period, approximately 50 river sites will also be sampled across these three States.

The second scale of evaluation is smaller and more localized. This smaller scale is useful for more intensive assessments of particular geographic areas or resource types. These areas will be sampled over the same four year period as the broad scale sample sites. For streams, we will be intensifying the EMAP sampling effort in three focus areas: the John Day and Deschutes basins of Oregon, the Wenatchee Basin of Washington, and the medium to large sized rivers of Idaho. The sampling of the John Day and Deschutes and Wenatchee basins began in 2000. The river sampling in Idaho began in 2002.

During the summers of 2003-2004, as part of the National State Monitoring, Assessment, and Reporting Program Grants, 50 wadeable streams will be monitored in Alaska. Water chemistry, physical habitat, benthic macroinvertebrate, and periphyton assemblage data will be collected using EMAP field protocols. Alaska Department of Environmental Conservation (DEC) has selected the Yukon River Lowlands/Yukon Tanana Uplands (Hydrologic Assessment Unit number 1904) as the study area. This unit is located in interior Alaska, north of the Alaska Range. It extends from Denali National Park and Preserve east to the Yukon Territory border. The project will be managed by Alaska DEC in collaboration with the University of Alaska Environmental and Natural Resources Institute, Alaska Cooperative Fish and Wildlife Research Unit and the U.S. Geological Survey, Alaska office.

Overview of Coastal EMAP in Region 10

The coastal component of Western EMAP applies EMAP's monitoring and assessment tools to create an integrated and comprehensive coastal monitoring program of the west coast. Water column measurements, sediment characteristics and chemistry, benthic organisms, and data from fish trawls are combined to describe the current estuarine condition.

Sampling has focused on a different type of estuarine resource each year (table 2). The Washington DOE and the Oregon DEQ sampled small estuaries in 1999. Oregon sampled a second set of small estuaries in 2001. Sampling of larger systems (Puget Sound, Columbia River Estuary) was completed in 2000. An intensified study of Tillamook Bay, Oregon was also conducted in 1999.

In 2002, samples were collected from the south central coast of Alaska (called the Alaskan Biogeographic Province), which includes both Cook Inlet and Prince William Sound. The Alaska DEC managed this effort with support from the Cook Inlet Regional Citizens Advisory Council (CIRCAC). The Oregon and Washington intertidal zone, including low salt marsh, intertidal flats, and shallow subtidal habitats of estuaries, was also sampled in 2002.

In 2003, the National Oceanographic and Atmospheric Administration (NOAA), EPA, and partnering west coast states (WA, OR, CA) combined efforts to conduct a survey of ecological condition of aquatic resources in

Table 2. Coastal monitoring projects in EPA Region 10 using EMAP design and indicators.

Year	Project area	Sites	Agency conducting sampling
1999	Small estuaries of Oregon and Washington	100	Oregon DEQ, Washington DOE, NMFS
1999	Tillamook Bay, Oregon	30	Oregon DEQ
2000	Large estuarine systems of Puget Sound and the Columbia River	71/ 50	Washington DOE, Oregon DEQ and NMFS
2002	South Central Alaska, including Cook Inlet and Prince William Sound	50	CIRCAC and Alaska DEC
2002	The intertidal zones of Oregon and Washington	100	Oregon DEQ and Washington DOE
2003	The continental shelf off Oregon and Washington	100	Oregon DEQ and Washington DOE
2004	Small estuaries of Oregon and Washington	100	Oregon DEQ, Washington DOE and NMFS
2004	SE Alaska estuaries	50	CIRCAC, NMFS and Alaska DEC

near-coastal waters along the U.S. western continental shelf. Sampling was conducted at approximately 50 stations along the coast of each western coast state, for a total of approximately 150 stations. This survey provided the data necessary for this first-ever comprehensive assessment of ecological conditions of near-coastal waters (30-120 m depth) along a major portion of the U.S. western continental shelf, from the Straits of Juan de Fuca in Washington State to the Mexican border. The survey included stations in all five of NOAA's National Marine Sanctuaries on the west coast, thus providing an opportunity to assess condition in sanctuaries as compared to non-sanctuary areas of the shelf.

Examples of Uses of EMAP Data—Example 1: Freshwater

The data summarized below was collected in the Western Cascades ecoregion of Washington and Oregon as part of the R-EMAP (Hayslip and others 2004). The project was a cooperative effort between EPA ORD, EPA Region 10, Washington DOE, and Oregon ODEQ. Washington DOE and Oregon DEQ conducted all field sampling for this project in 1999-2000. R-EMAP provides States and EPA Regional offices opportunities to use EMAP indicators to answer questions of regional interest.

Geographic Scope

The Western Cascades ecoregion is located in the Cascade Mountain Range in Oregon and Washington. Most of the ecoregion is between 2,000 and 7,000 ft in elevation and is densely forested (Pater and others 1998). The Western Cascades ecoregion is 10,859 square miles in area. It supports forest dominated by Pacific silver fir, western hemlock, mountain hemlock, Douglas fir, and noble fir (Omernik and others 1987).

The predominant land cover type in the Western Cascades ecoregion is forest (87 percent). The next most common land cover type is transitional, which is defined as areas with sparse vegetation (<25 percent) that are dynamically changing from one land cover to another often due to land use activities (for example, forestry clear cuts, construction) and natural processes (for example, fire, flood). There is no urban land cover and very limited agriculture (1 percent) in the Western Cascades ecoregion. Timber harvest is the major industry in this area and the primary land ownership is Federal. In Washington, the federal land ownership is primarily the U.S. Forest Service (41 percent) followed by the National Park Service. In Oregon, the U.S. Forest Service (58 percent) is also the primary federal landowner, followed by the Bureau of Land Management.

Site Selection

Environmental monitoring and assessments are typically based on subjectively selected stream reaches. Peterson and others (1998, 1999) compared subjectively selected localized lake data with probability-based sample selection and showed the results for the same area to be substantially different. The primary reason for these differences was lack of regional sample representativeness of subjectively selected sites. Stream studies have been plagued by the same problem. A more objective approach was needed to assess overall stream quality on a regional scale.

EMAP uses a statistical sampling design that views streams as a continuous resource. This allows statements to be made in terms of length of the stream resource in various conditions (Herlihy and others 2000). Sample sites are randomly selected using a systematic grid based on landscape maps overlaid with stream traces. The EMAP systematic grid provides uniform spatial coverage, making it possible to select stream sample locations in proportion to their occurrence (Overton and others 1990). This design allows one to make statistically valid estimations from the sample data to the entire length of stream in a study area (the Western Cascades ecoregion), such as estimates of the number of stream miles or kilometers that are in "poor" condition.

Study sites were selected from a stream population of all mapped (1:100,000 scale) 2nd and 3rd order streams in the Western Cascades ecoregion, using EMAP-Surface Water protocols (Herlihy and others 2000). There are approximately 19,489 total km (12,100 mi) of streams in the Western Cascades ecoregion. The 2^{nd} and 3^{rd} order streams represent 26.8 percent or 5224 km (3,246 mi) of streams in this ecoregion.

The EMAP probability design was used to select a random sample of the target population. In this study, the "target" population was 2nd and 3rd order streams. A total of 108 sites were evaluated for field sampling. Of these, 79 were selected as "target sites" (useable sample sites). Sites determined to be useable or "target" sites if they were 2^{nd} and 3^{rd} order streams that were accessible, wadeable, perennial, and free of manmade physical barriers. Each of 79 sites was sampled at least once during the 1999-2000 field season. Sites were sampled July 5^{th} through October 19^{th}.

In addition to the 79 sites selected using the EMAP probability design, an additional 22 sites were hand selected and sampled to determine reference condition. The reference condition represents the biological potential or goal for the waterbody. The reference condition establishes the basis for making comparisons and for detecting impairment. The most common way to establish the reference condition is to collect field data from a number of sites that represent condition with minimal human disturbance. The data is then aggregated from these sites to develop a reference condition for that area, ecoregion, or class of waterbody.

For this project, the reference condition for each indicator metric is the average value calculated from these 22 sites. The reference sites were selected by the state environmental agencies (Oregon DEQ and Washington DOE) from 2^{nd} and 3^{rd} order streams in the Western Cascades ecoregion to represent minimal human disturbance. The reference sites were sampled using the same field methods as the probability selected sites, therefore these data are compatible with the probability dataset.

Ecological Indicators

The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. To implement the Clean Water Act, States adopt water quality standards. These standards are designed to protect public health or welfare, enhance the quality of water, and protect biological integrity.

In general terms, a water quality standard defines the goals of a waterbody by designating the use or uses to be made of the water (such as aquatic life, coldwater biota, or salmonid spawning), setting criteria necessary to protect those uses, and preventing degradation of water quality. Therefore, in order to assess the nation's waters, it is important to measure water quality (stream water parameters), physical habitat (watershed, riparian and in-stream measurements), and biological (vertebrate and invertebrates communities) condition. EMAP uses ecological indicators to quantify these conditions. EMAP field methods were primarily used and additional detailed information is available in Lazorchak and others 1998.

Summary

The often complex results of environmental data analyses must be communicated in a straightforward manner to water resource managers and the public. In order to determine the extent of the 2^{nd} and 3^{rd} order streams in the Western Cascades ecoregion that are in good, fair, and poor condition, we measured chemical, physical, and biological indicators in a statistical probability sample of stream reaches (probability sites).

Stream water chemistry

For stream water chemistry indicators, we compared these results to water quality criteria for Oregon and Washington or literature values where no criteria existed (fig. 1). Over 90 percent of the 2^{nd} and 3^{rd} order stream length in the Western Cascades ecoregion was in "good" condition for pH, phosphorus and nitrite-nitrate.

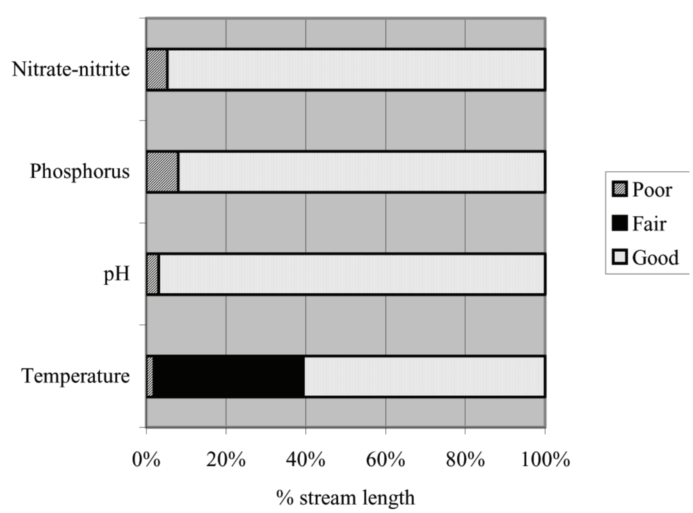

Figure 1. Quality of selected water chemistry indicators.

Streams were determined to be in "good" condition for pH between 6.5-8.8, below 0.1 mg/L for phosphorus and below 0.3 mg/L for nitrate-nitrite. For temperature, 61 percent of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "good" condition. We defined "good" as below 12°C. Thirty-seven percent of the stream length was in "fair" condition (between 12°C and 16.0°C). Only 2 percent of the stream length was in "poor" condition (warmer than 16°C). However, the use of a single measurement is unlikely to catch peak stream temperatures.

Physical habitat and biological indicators

For physical habitat and biological assemblages, we compare the results of the ecoregion-wide assessment (using probability sites) to that of the reference condition (using reference sites) as there are no applicable numeric water quality criteria. The range of scores at reference sites for each habitat and biological indicator represents a distribution that we used to define reference condition. Although the reference sites are minimally disturbed by human influence, however some level of human disturbance has occurred at least at some of these sites. Therefore, we have set our scoring criteria conservatively. The 25th percentile of this reference distribution is the criteria that we used to distinguish probability sites in "good" condition from those in "fair" condition (Barbour and others 1999). The 5th percentile value of reference separates sites in fair condition from those in "poor" condition (figs. 2 and 3). These criteria provide a margin of safety, as they would designate 5 percent of the reference sites in "poor" condition.

Generally, Large Woody Debris (LWD) was more prevalent in the reference sites in all categories, including the large class. For the amount of LWD in the large and very large size classes, 23 percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites. An additional, 49 percent of the stream length was in "fair" condition for large and very large LWD (fig. 2).

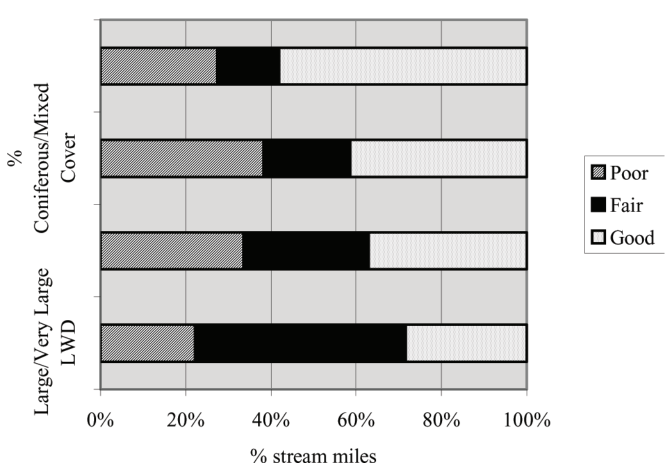

Figure 2. Quality of selected physical habitat indicators.

The amount of mid-channel shade was fairly high for both the probability and reference sites. However, 34 percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition for percent mid-channel canopy cover as compared to the reference sites. An additional 30 percent of the stream length was in "fair" condition for mid-channel shade (fig. 2).

Mixed cover was the most common type of riparian canopy cover for both reference and probability sites. For the probability sites, the next most common riparian cover was deciduous. For the reference sites, the next most common riparian cover was coniferous. Thirty-seven percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites for percent coniferous plus mixed canopy cover types (fig. 2).

Cobble-sized (<64 to 250 mm) substrate was the most common surface substrate for both the probability and reference sites. The percent of fines-sized (.06mm) substrate was relatively abundant in the Ecoregion. Compared to the reference condition, 27 percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition for percent fine-sized substrate. An additional, 16 percent of the stream length was in "fair" condition for percent sands or fines (fig. 2).

Salmonids were common in both with ecoregion-wide sites having slightly higher salmonid species richness than reference sites. Coldwater guild species were the dominant temperature guild in both site types. Reference sites differed from the probability sites in that they had higher amphibian species richness. For total vertebrate richness, 8 percent of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to reference sites (fig. 3). The reference sites also had higher relative abundance of sensitive aquatic vertebrate guild species. Twenty-seven percent of the 2nd and 3rd order stream length was in "poor" condition as compared to the reference sites for sensitive aquatic vertebrate species relative abundance. Overall, vertebrate species diversity based on the Shannon-Weiner diversity was "poor" in 16 percent of the 2nd and 3rd order stream length in the Western Cascades ecoregion as compared to the reference sites (fig. 3).

For benthic macroinvertebrates (fig. 3), three indicators were considered (1) the percent of the individuals in the sample that were from the orders Ephmeroptera,

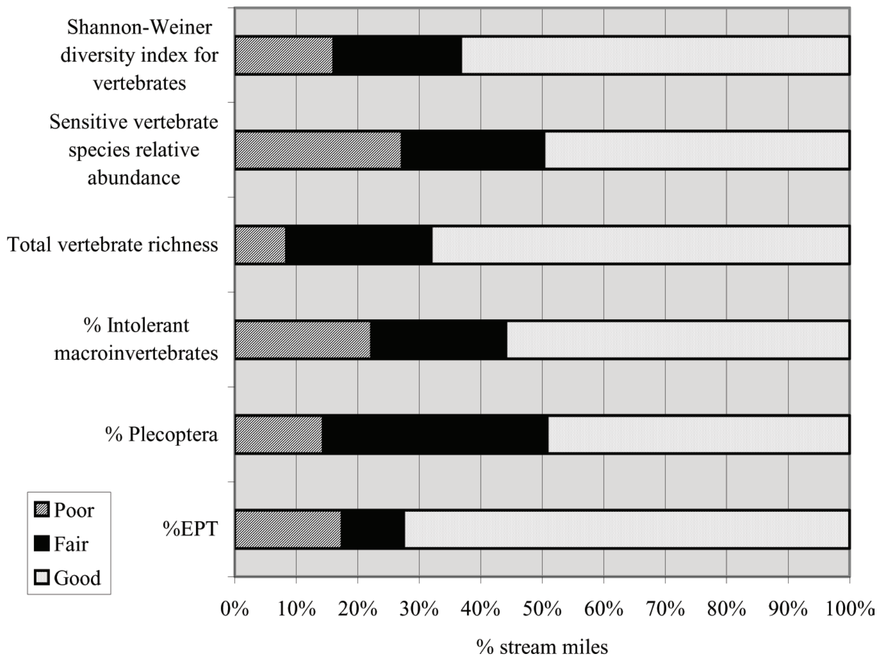

Figure 3. Quality of selected biological indicators.

Plecoptera, Trichoptera (EPT); (2) the percent Plecoptera individuals; and (3) the percent intolerant macroinvertebrates. For all three indicators, metrics values were lower for the probability sites as compared the reference sites. For the percent of individuals in the sample that were EPT (percent EPT), 17 percent of the 2nd and 3rd order stream length in the Western Cascades ecoregion were in "poor" condition as compared to the reference sites. Fourteen percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites for the percent of Plecoptera individuals.

For the percent of individuals in the sample that are intolerant individuals, 22 percent of the of the 2nd and 3rd order stream length in the Western Cascades ecoregion was in "poor" condition as compared to the reference sites. An additional 21 percent of the stream length was in "fair" condition for percent sensitive (fig. 3).

This project was designed to evaluate the overall condition of 2nd and 3rd order streams in the Western Cascades ecoregion. In this assessment we used direct measurements of the biota themselves as indicators of ecological condition. The organisms that live in a stream integrate many of the physical and chemical stressors and factors that are acting in, and on, the stream ecosystem. Information on the stream biota is supplemented by indicators of stress, which are measurements of other stream characteristics or factors that might influence or affect stream condition, especially stream water chemistry and physical habitat.

In conclusion, very few (3-8 percent) of the of the 2nd and 3rd order stream kilometers in the Western Cascades ecoregion were in "poor" condition using stream water indicators. However, physical habitat indicators showed a greater extent of the 2nd and 3rd order stream length in the Western Cascades ecoregion in "poor" condition (22-38 percent). The biological indicators (fish, amphibians, and macroinvertebrates) are likely responding to physical habitat conditions, as 8-27 percent of the 2nd and 3rd order stream kilometers in the Western Cascades ecoregion were in "poor" condition based on these biological indicators.

Examples of Uses of EMAP Data—Example 2: Coastal

The data described below were collected in the estuaries of Washington and Oregon as part of the coastal component of Western EMAP in 1999 and 2000. This project applied EMAP's monitoring and assessment tools to create an integrated and comprehensive coastal monitoring program along the west coast. The project is a cooperative effort between EPA ORD, EPA Region 10, NMFS, Washington DOE, and Oregon ODEQ. Washington DOE and Oregon DEQ conducted all field sampling in Region 10, with assistance from NMFS, for this project in 1999-2000.

In Coastal EMAP, water column measurements are combined with information about sediment characteristics and chemistry, benthic organisms, and data from fish to describe estuarine conditions. The first year's effort (1999) constituted an assessment of the condition of the small estuarine systems (< 250 km^2) in Oregon and Washington, using 100 randomly selected sites. Also in 1999, 30 sites were selected in Tillamook Bay, Oregon, to demonstrate the EMAP design at a smaller scale.

In 2000, EMAP samples were collected from 50 locations in the lower Columbia River estuary and 71 locations in the Puget Sound. While a great deal of data was collected during this project, only a small portion of the information will be described below.

An important part of making policy and management decisions is understanding the relative magnitude and extent of current stressor to aquatic systems. Estuaries are threatened because of the numerous ways that humans use them and use the land areas, or watersheds, that drain into them. Under the Clean Water Act, States are required to report on the condition of the states' waters, including estuaries. There are many stressors that influence the ecological condition of estuarine waters in Region 10.

For example, an excess of nutrients, such as nitrogen and phosphorus, from runoff can lead to euthrophication, a condition in which blooms of algae rob oxygen from other organisms. Dissolved oxygen (DO) is a fundamental requirement for estuarine biota. Another common stressor to estuarine systems comes from potentially toxic substances that reach estuaries from industrial and municipal sources and storm water runoff. These toxic substances bind to particles in the water and settle to the bottom, contaminating sediments.

Non-indigenous species are another estuarine stressor, but are rarely addressed in state or regional monitoring studies. The term "non-indigenous species" (NIS) can refer to any plant, animal, or other viable biological material that enter an ecosystem beyond its historic range. They are also called "invasive species," "nonnative species," "aquatic nuisance species," "introduced species," "exotic organisms," and other terms as well. Invasive species can successfully invade any terrestrial or aquatic ecosystem, and may enter through a wide variety of introduction mechanisms. Human activities, both intentional and non-intentional, are the chief cause of invasive species introductions. Non-indigenous aquatic species impact biological and economic resources and can also impact human health. NIS disturb native species through predation or displacement, clog intake pipes for water supplies, and pose serious human health risks. Not all non-native species become pests, or even survive, in new locations. But when they do, they often displace a whole suite of native species to become dominant.

EMAP coastal data will be used to develop an indicator for NIS for possible inclusion in future reporting and strategic planning. The extent of NIS will be compared to other, more traditional stressors, dissolved oxygen and sediment toxicity. The data that follows is from the 1999-2000 EMAP study of the estuaries of Oregon and Washington.

The three stressors that are compared are dissolved oxygen, sediment toxicity, and NIS. For dissolved oxygen, any location with less than 2.0 ppm DO fails, or is considered in "poor" condition. For sediment toxicity, condition is evaluated using a combination of several different approaches including sediment contaminant concentrations, organic carbon concentration, and amphipod survival in toxicity tests. If the site fails any one of the criteria, it is considered to be in "poor" condition for sediment toxicity. For non-indigenous species, a site with NIS comprising 25 percent or more of the individuals **<u>or</u>** of the species fails or is or is considered in "poor" condition, for NIS.

In the estuaries of Oregon and Washington, only 0.5 percent of the estuarine sites failed the dissolved oxygen cut-point and 15 percent of the sites failed the sediment toxicity cut-points. However, 48 percent of the sites in the estuaries of Oregon and Washington failed the NIS cut-point. Yet, NIS is not typically included in reports showing the condition of estuarine waters. We will be using this data to demonstrate the importance of including NIS in our regional and state reporting on the condition of the estuaries of Region 10.

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