Sediment Quality Triad Index in Puget Sound

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PSAMP/NOAA Partnership

In 1997, the Department of Ecology's Marine Sediment Monitoring Team entered into a cooperative agreement with the National Oceanic and Atmospheric Administration (NOAA) to combine the Puget Sound sediment monitoring efforts of Washington's Puget Sound Ambient Monitoring Program (PSAMP), with NOAA's National Status and Trends Program's efforts to study sediment quality in estuaries around the U.S. Over a three-year period, these two programs applied a random, stratified study design to spatially characterize the quality of sediments at 300 stations distributed throughout Puget Sound (Figure 1).

Samples were tested for a suite of sediment quality parameters, including determination of acute toxicity in four laboratory tests, quantification of the concentrations of 180+ chemical contaminants, and description of the invertebrate communities residing in the sediments. Standardized methods, quality assurance, and quality control procedures adopted by both Ecology and NOAA were applied in this survey to ensure acquisition of standardized, high quality data.

Data were used to classify sediment quality at each station using a Sediment Quality Triad Index, and then to calculate the spatial extent of sediment quality for six regions and five anthropogenic-use strata defined for Puget Sound.

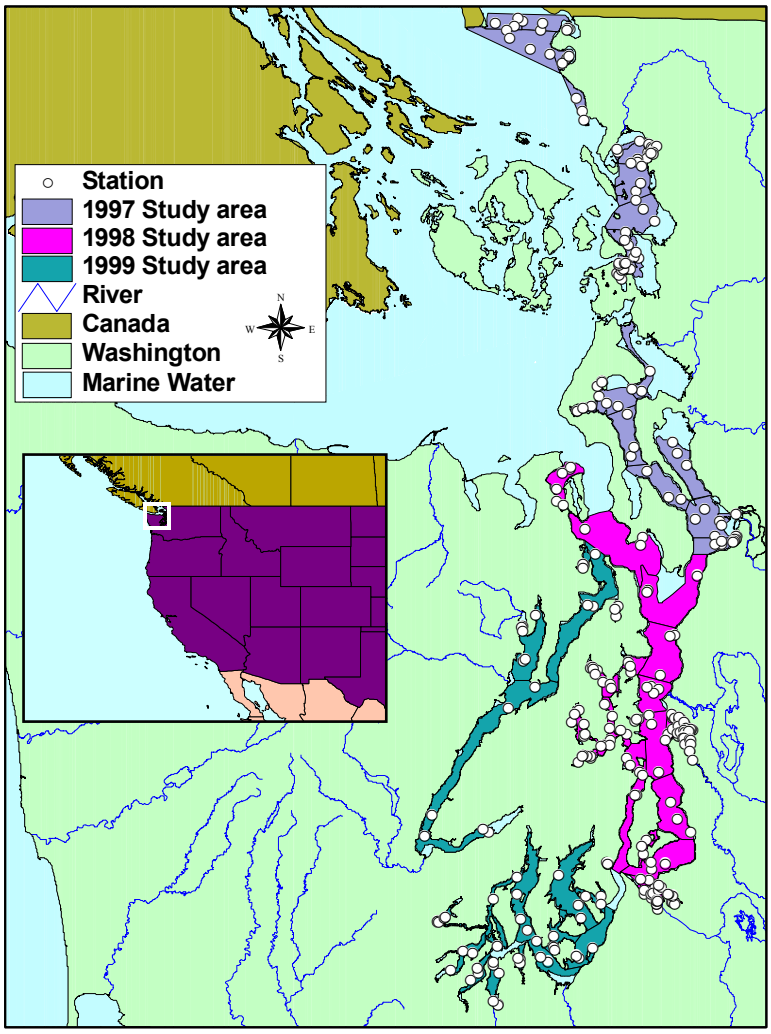

Figure 1. Puget Sound study area and sampling stations for the PSAMP/NOAA Sediment Quality Survey.

What Is The Sediment Quality Triad Index?

The Sediment Quality Triad Index was developed as a weight-of-evidence approach that combines the results of the sediment chemistry, toxicity, and benthic invertebrate analyses generated in this study to classify the overall quality of the sediment samples. Four categories of sediment quality were generated to define each station and, ultimately, each sediment monitoring region and strata of the study, including:

- **High Quality** – no degradation detected in any of three test parameters
- **Intermediate/High Quality** – degradation detected in one of three test parameters
- **Intermediate/Degraded Quality** – degradation detected in two of three test parameters
- **Degraded Quality** – degradation detected in all three test parameters

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Evaluation of Sediment Quality in Monitoring Regions

The spatial extent of sediment quality in six Puget Sound study regions was calculated as both percent of stations in each category and as percent of area affected within each region (Figure 2). Sediment monitoring regions are defined by their unique hydrologic, bathymetric, and geological features, as well as by the distribution of biota (fish, birds, and marine mammals) within each region.

The regions differed dramatically in their degree of sediment quality. All samples from Admiralty Inlet were high quality, as were the majority of stations and percent area in the Strait of Georgia, Hood Canal, and Whidbey Basin regions. Most samples classified as degraded were collected in the Whidbey Basin, Central Sound, and South Sound regions, representing only 1%, 3%, and <1%, respectively, of the areas within those regions. Degraded sediments in these three regions were identified primarily from Everett Harbor, Elliott and Commencement bays, and Budd Inlet. The largest percentages of samples and areas in the intermediate categories were found in the Central Sound and South Sound regions.

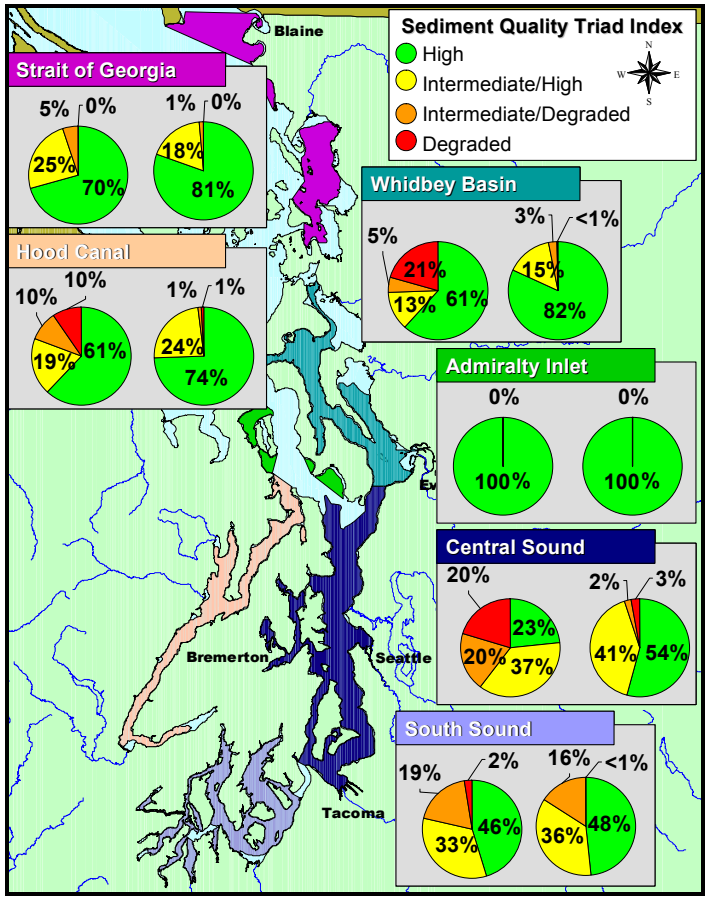

Figure 2. Sediment Quality Triad Index in six Puget Sound monitoring regions. Percent of stations (left pie chart) and percent of area (right pie chart) representing each index category are depicted for each region.

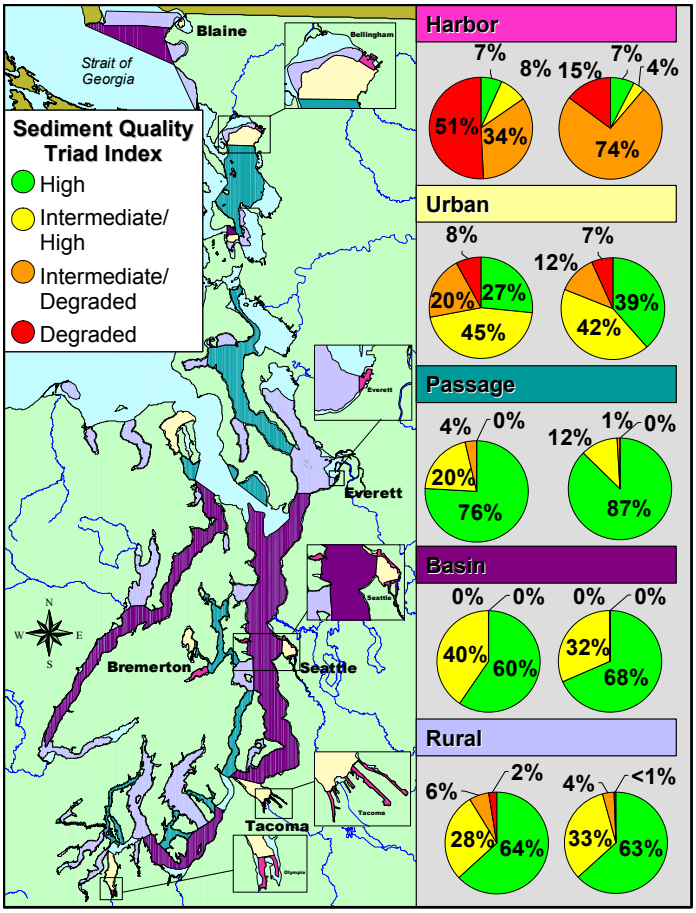

Figure 3. Sediment Quality Triad Index in five Puget Sound monitoring strata. Percent of stations (left pie chart) and percent of area (right pie chart) representing each index category are depicted for each stratum.

Evaluation of Sediment Quality in Monitoring Strata

The spatial extent of sediment quality also was calculated for five areas delineated as sediment monitoring strata: harbor, urban, passage, basin, and rural (Figure 3). These strata characterize Puget Sound sediments in areas defined by their major geographic features and degree of anthropogenic activity (see Long et al., 2003 for descriptions of each).

Sediment quality differed dramatically among the strata. The largest percentage of samples (51%) with degraded sediment quality was found in the harbor stratum. Intermediate sediment quality also was most pervasive in the harbors, followed by the urban embayments. Highest sediment quality was prevalent in the passages, deep basins, and rural embayments. Ecologically, the higher degree of degradation in the harbor and urban strata may disproportionately affect important fish, shellfish, and aquatic plant species, as these strata include significant areas of nearshore critical habitat for these species.

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Evaluation of Sediment Quality in the Entire Study Area

The Sediment Quality Triad Index indicated that sediment from approximately 23 km^2, or 1% of the Puget Sound study area, were degraded, with impairment apparent in all three indicators. Sediments with intermediate quality, or a mixture of impaired sediment quality indicators, were distributed over 724 km^2, or about 31% of the area. High quality sediments, as indicated by low chemical concentrations, absence of toxicity, and presence of abundant and diverse infaunal communities, were found in approximately 1616 km^2, representing 68% of the study area.

Table 1. Sediment Quality Triad Index in the entire Puget Sound study area.

Sediment Quality Index Category	Stations		Area	
	No.	Percent	km^2	Percent
Total Study Area	300	100.0	2363.3	100.0
High	138	46.0	1616.1	68.4
Intermediate/High	85	28.3	627.6	26.6
Chemistry	13	4.3	92.8	3.9
Toxicity	68	22.7	524.0	22.2
Infaunal	4	1.3	10.8	0.5
Intermediate/Degraded	40	13.3	96.5	4.1
Chemistry/Toxicity	19	6.3	26.3	1.1
Chemistry/Infaunal	1	0.3	1.6	0.1
Infaunal/Toxicity	20	6.7	68.6	2.9
Degraded	37	12.3	23.1	1.0

How Does Puget Sound Compare With Other U.S. Estuaries?

To provide perspective, the results of the present study were compared with similar sediment quality data from surveys conducted by NOAA and EPA in other U.S. estuaries. Comparison of these data sets indicated that the percent of samples and/or study areas with either chemical contamination, acute toxicity, or depressed benthos were often lower in the entire Puget Sound study area than elsewhere in the nation (Table 2). Some of the differences between conditions in Puget Sound and other regions, however, could be attributable, in part, to natural differences in physical, chemical, and biological characteristics and the functions of these estuaries (e.g., total size, geologic, bathymetric, circulatory, and other estuarine/oceanographic conditions), as well as differences in the degree of anthropogenic activity in these estuaries. Given the overall size of Puget Sound, its depth, and the number of unique regions, it may be more appropriate to compare specific Puget Sound regions to other U.S. estuaries with matching characteristics. Further comparisons would be needed to adequately understand impacts of differing sediment quality and conditions in estuaries around the nation.

Table 2. Comparison of percent of samples and/or study areas with chemical contamination, acute toxicity, or depressed benthos between surveys performed in this Puget Sound study and by NOAA and U.S. EPA in estuaries nationwide.

Parameter	Puget Sound (n=300)		Nationwide averages			National Inventories
	% of samples adversely impacted	% of area adversely impacted	% of samples adversely impacted	% of area adversely impacted	n	
Chemical Contamination	13.0	1.3	27.2	NA	1068	NOAA/EMAP database (Long et al., 1998)
Toxicity Displayed in Sediments						
Amphipod Survival Test	0.3	<0.1	NA	5.9	NA	Nationwide NOAA database (Long, 2000)
Amphipod Survival Test	0.3	<0.1	NA	7.3	NA	4 EMAP provinces - cumulative total (Long, 2000)
Urchin Fertilization Test	10.7	4.0	NA	25.3	1309	Nationwide NOAA database (data from 22 US bays and estuaries) (Long, 2000)
Microbial Bioluminescence Test	2.7	0.4	NA	39	1215	Nationwide NOAA database (data from 18 US bays and estuaries) (Long, 2000)
Cytochrome p-450 HRGS Test	16.0	2.8	NA	12.2	664	Nationwide NOAA database (data from 6 US bays and estuaries) (Long, 2000)
Impacted Benthos (sediment-dwelling invertebrates)	20.7	4.4	NA	22.0	NA	EMAP Atlantic and Gulf coasts (US EPA, 2001)

Sediment Quality in Puget Sound – What does it mean?

This sediment quality survey indicated that the large majority (68%) of the Puget Sound study area has relatively high quality surficial sediments, and that the area classified as degraded is relatively small (1%) and located in and around the urban/industrial embayments of the sound. Although small in area, these degraded sediments may play a very important, broad-reaching role in the ecological health and functioning of the Puget Sound ecosystem.

Data collected from other PSAMP and related surveys (Puget Sound Water Quality Action Team, 2002) indicate that high levels of toxic chemicals are present, or are linked to health impairment, in organisms which reside in, or whose food resources are tied to, the more urban and industrialized embayments of central and southern Puget Sound. Examples include high levels of PAHs and/or PCBs measured in the bodies of shellfish (Dungeness crab), fish (English sole, demersal rockfish, coho salmon, and Pacific herring), birds (high PCB levels in Bald Eagle eggs collected from Hood Canal), and marine mammals (southern Puget Sound harbor seals and southern resident orca whales), all associated with the more highly contaminated central and southern Puget Sound basins. Different populations of many of these species residing in northern Puget Sound and the Strait of Georgia, or feeding on prey from these cleaner locales, had lower contaminant levels in their tissues. In addition to high levels of contaminants in their bodies, populations of some species (some salmon, marine birds, and orca whales) are in decline in Puget Sound. A better understanding of how degraded sediments are linked to the health of these Puget Sound species is essential. Interdisciplinary studies need to be conducted to better understand the toxic effects of sediment contaminants on biota and pathways of toxins through the food web, and to integrate sediment contaminant data with population data and life history patterns. Factors other than chemical contaminants (e.g., dissolved oxygen levels, sediment deposition rates) also can play a role in sediment condition and quality. Further studies are required to distinguish between these environmental stressors.

In addition to focused attention on the 1% of the study area with degraded sediments, there is a sizeable area (31%) classified with intermediate quality sediments. Future attention and monitoring will occur in these areas to determine whether sediment conditions improve, remain stable, or deteriorate further. Values from this survey will be used as a baseline and will be compared with similar values generated by the PSAMP Sediment Component in the future to determine changes in sediment condition over time throughout Puget Sound.

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General information and all data generated during this survey can be accessed from Ecology's Marine Sediment Monitoring website:
http://www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html

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