

SEDIMENT QUALITY IN THE SAN JUAN ISLANDS, EASTERN STRAIT OF JUAN DE FUCA, AND ADMIRALTY INLET

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I. Abstract

Sediment quality is monitored by the Department of Ecology annually as a component of the Puget Sound Ambient Monitoring Program (PSAMP). The primary objectives of this monitoring program are to quantify the spatial extent and geographic patterns in degraded sediment quality. In June 2002 and June 2003, the Department of Ecology collected 81 samples in the bays and inlets of the San Juan Islands, eastern Strait of Juan de Fuca, and Admiralty Inlet. A stratified random method was used to identify sampling locations. Analyses included quantitation of 118 potentially toxic chemicals, a battery of four laboratory toxicity tests, and the evaluation of infaunal community composition. The results of these analyses were compiled from the two survey periods and merged with data from 9 samples previously collected using comparable methods to identify spatial patterns and spatial extent of degraded sediment quality in these three regions. The triad analysis suggests that the sediment quality in this study area is comparable to some of the least degraded regions in Puget Sound.

II. Study Design

The Marine Sediment Monitoring Component of PSAMP annually determines the quality of recently deposited sediments in Puget Sound utilizing the Sediment Quality Triad, a weight-of-evidence approach which relies upon measures of chemical contamination, toxicity, and benthic infaunal impacts. Beginning in 2002, the annual studies followed a rotating sampling scheme, each year sampling at least one of 8 different regions in the greater Puget Sound basin. During the annual studies, samples are collected in locations selected using a generalized random tessellation stratified multi-density survey design, patterned after the designs used previously in surveys completed during 1997-1999 with NOAA and in the EPA's Environmental Monitoring and Assessment Program. In 2002 and 2003, 81 stations were sampled in the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet regions (Figure 1). Results from nine stations in the Admiralty Inlet region sampled in 1998 were combined with the samples collected in 2002 and 2003 to obtain a sample size of 30 in each of the sampling regions (Figure 1).

III. Using the Sediment Quality Triad to Determine the Distribution of Degraded Sediments

Incidence and spatial extent of degraded sediment quality were determined by identifying samples in which critical values for chemistry, toxicity and infaunal indices were exceeded. Sediment chemistry results were compared with State Sediment Quality Standards (SQS) and NOAA Effects Range Median (ERM) guidelines. Critical values for toxicity were exceeded when;

- mean amphipod survival with *Eohaustorius estuarius* was < 80% and significantly different than in the reference ($p < 0.05$, t-test)
- mean urchin fertilization with *Strongylocentrotus purpuratus* was < 80% of the controls and significantly different (Dunnett's t-test, < 0.05) in the 100% porewater fraction,
- Microtox 5- and 15-min bioluminescence test of pore waters with *Vibrio fischeri* responses in undiluted pore water was < 80% and significantly different from controls ($p < 0.05$, t-test), and/or
- when the normal development + survival endpoint in the 48-h embryo development test of sediment-water mixtures with *Dendroaster excruciatu*s was < 85% and significantly different from the reference ($p < 0.05$, t-test).

Currently there are no quantitative criteria for benthic indices in Puget Sound; therefore benthic infaunal communities were evaluated by calculating and comparing nine measures of abundance and diversity to median values from the PSAMP baseline for Puget Sound ($n = 300$). Dominant species were also evaluated for indicators of degraded benthic infaunal composition.

Results of sediment chemistry, toxicity, and benthic invertebrate analyses were combined, and each site was allocated into one of the following four sediment quality categories:

- 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

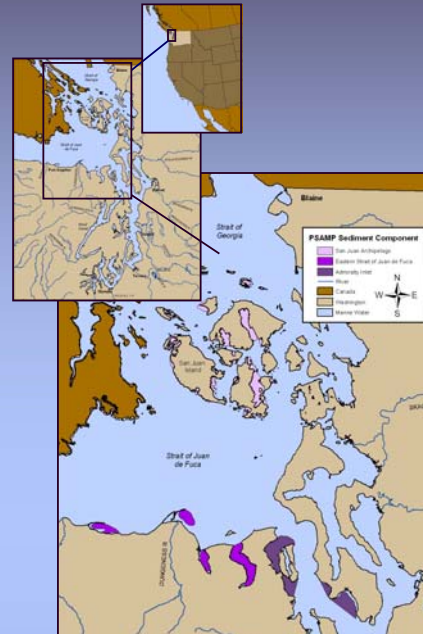


Figure 1. Marine sediment monitoring regional boundaries for the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet study regions.

Table 1. Estimated incidence and spatial extent of the Sediment Quality Triad for the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet study areas.

Sediment Quality Index category	Incidence	Spatial extent
	No. (%) of	km ² (%)
San Juan Archipelago	30 (100.0)	80.7 (100.0)
High	3 (10.0)	8.1 (10.0)
Intermediate/high	11 (36.7)	29.6 (36.7)
Chemistry	3 (10.0)	8.1 (10.0)
Toxicity	0 (0.0)	0.0 (0.0)
Infaunal	8 (26.7)	21.5 (26.7)
Intermediate/degraded	12 (40.0)	32.3 (40.0)
Chemistry/toxicity	4 (13.3)	10.8 (13.3)
Chemistry/infaunal	5 (16.7)	13.5 (16.7)
Infaunal/toxicity	3 (10.0)	8.1 (10.0)
Degraded	4 (13.3)	10.8 (13.3)
Eastern Strait of Juan de Fuca	30 (100.0)	61.8 (100.0)
High	9 (30.0)	14.7 (21.3)
Intermediate/high	13 (43.3)	26.8 (43.4)
Chemistry	6 (20.0)	7.6 (12.4)
Toxicity	1 (3.3)	2.7 (4.4)
Infaunal	6 (20.0)	16.4 (26.6)
Intermediate/degraded	5 (16.7)	13.7 (22.1)
Chemistry/toxicity	0 (0.0)	0.0 (0.0)
Chemistry/infaunal	0 (0.0)	0.0 (0.0)
Infaunal/toxicity	5 (16.7)	13.7 (22.1)
Degraded	3 (10.0)	6.6 (10.7)
Admiralty Inlet	30 (100.0)	69.2 (100.0)
High	11 (36.7)	23.8 (34.4)
Intermediate/high	16 (53.3)	36.1 (52.2)
Chemistry	14 (46.7)	30.8 (44.4)
Toxicity	1 (3.3)	1.5 (2.2)
Infaunal	1 (3.3)	3.8 (5.5)
Intermediate/degraded	2 (6.7)	5.4 (7.8)
Chemistry/toxicity	1 (3.3)	3.8 (5.5)
Chemistry/infaunal	1 (3.3)	1.5 (2.2)
Infaunal/toxicity	0 (0.0)	0.0 (0.0)
Degraded	1 (3.3)	3.8 (5.5)



Figure 2. Spatial patterns in sediment quality for the San Juan Archipelago sampling region.

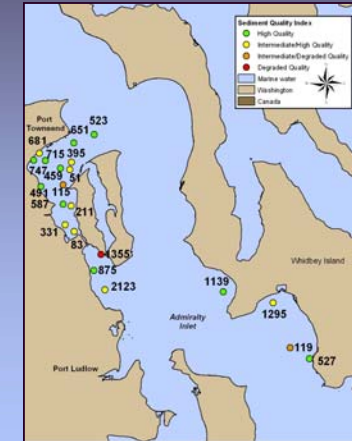


Figure 3. Spatial patterns in sediment quality for the Admiralty Inlet sampling region.

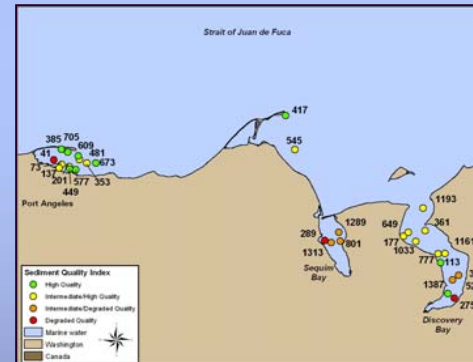


Figure 4. Spatial patterns in sediment quality for the Eastern Strait of Juan de Fuca sampling region.

IV. Results

Three regions, the San Juan Archipelago, eastern Strait of Juan de Fuca, and Admiralty Inlet, were sampled with 30 stations each, encompassing approximately 80.7, 61.8, and 69.2 km², respectively, for a total study area of 211.7 km² (Table 1). In the San Juan Archipelago the Sediment Quality Triad indicated three sites with high quality sediments, representing 8.1 km² or 10% of that study area. The majority, 23 of the 30 sites, had intermediate quality sediments, representing 61.9 km² or 77% of the San Juan Archipelago. Degraded sediment quality was found at 4 sites, representing 10.8 km² or 13% of the study area. Degraded sites were located in Deer Harbor, Lopez Sound, East Sound, and West Sound.

The Sediment Quality Triad Index indicated 9 sites with high quality sediments, representing 14.7 km² or 21% of the eastern Strait of Juan de Fuca study area. As in the San Juan Archipelago the majority, 18 of the 30 sites, had intermediate quality sediments, representing 40.5 km² or 66% of the study area. Of these 18 intermediate sites, 13 were of intermediate/high quality and 5 were of intermediate/degraded quality, representing 26.8 and 13.7 km², or 43% and 22%, of the eastern Strait of Juan de Fuca study area, respectively. Degraded sediment quality was found at 3 sites, representing 6.6 km² or 11% of the study area. These sites were located in the inner portions of Port Angeles Harbor, Sequim Bay, and Discovery Bay.

The Sediment Quality Triad Index showed a similar pattern in Admiralty Inlet as in the San Juan Archipelago and the eastern Strait of Juan de Fuca. High quality sediments were found at 11 sites, representing 23.8 km² or 34% of the study area. Again the majority, 18 of the 30 sites, had intermediate quality sediments, representing 41.5 km² or 60% of the study area. Of these 18 intermediate sites, 16 were of intermediate/high quality and 2 were of intermediate/degraded quality, representing 36.1 km² (52.2%) and 5.4 km² (7.8%), of the Admiralty Inlet study area, respectively. Degraded sediment quality was found at only 1 site, Oak Bay, representing 3.8 km² or 6% of the study area.

All three study regions had similar patterns in sediment quality, with the greatest number of sites in the intermediate sediment quality category and relatively few sites with degraded quality sediments. Degraded sediments were usually found in the inner portions of embayments or harbors. Sediment quality was highest in the Admiralty Inlet region and the most degraded in the San Juan Archipelago.

V. Summary

- The PSAMP Sediment Component collected sediments from 90 sites in three regions: the San Juan Archipelago, eastern Strait of Juan de Fuca, and Admiralty Inlet selected with a stratified random sampling method.
- A weight-of-evidence approach that combines the results of sediment chemistry, toxicity, and benthic invertebrate analyses was applied.
- All three regions had similar patterns in sediment quality.
- The majority of sites had intermediate quality sediments.
- Relatively few sites had degraded quality sediments. These sites were found in the inner portions of bays and harbors.
- Sediment quality was highest in the Admiralty Inlet region and the most degraded in the San Juan Archipelago.

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.htm



Photographs by Charles Eaton