Sediment Quality in Port Gardner Bay, 2012

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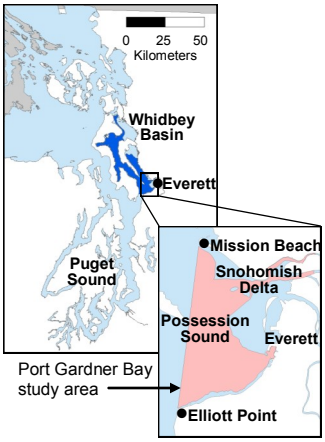
Findings

- Overall sediment quality was generally high.
  - Exposure to contaminants was *minimum* for 80% of the area and *low* for the remainder.
  - Sediments were *non-toxic* almost everywhere (93% of the study area).
  - The Triad Index classified sediments as *unimpacted or likely unimpacted* almost everywhere.
- *Adversely affected* benthos were found in one-third (33%) of the study area.
- The Chemistry and Triad Indices met their respective Puget Sound Partnership targets.

In 2012, the Washington Department of Ecology (Ecology) sampled sediments in Port Gardner Bay to characterize sediment quality as part of an urban bays status-and-trends monitoring program. Surface sediments (top 2-3 cm) from 30 randomly selected locations were analyzed to determine:

- Concentrations of potentially toxic chemicals.
- Degree of response in laboratory tests of toxicity.
- Condition of sediment-dwelling invertebrates (benthos).

The sediment contaminant, toxicity, and benthic invertebrate data were rolled up into Ecology's Chemistry, Toxicity, Benthic, and combined Triad Indices.



Overall Results

Overall sediment quality, as measured by the Triad Index, and contaminant exposure (Chemistry Index) met Puget Sound Partnership (PSP) targets. The Toxicity, Benthic, and Triad index values for the study area in 2012 (Figure 1, light bars) were statistically similar to those for the encompassing Whidbey Basin region (dark blue area in Puget Sound map, above) in 2007 (Figure 1, dark bars).

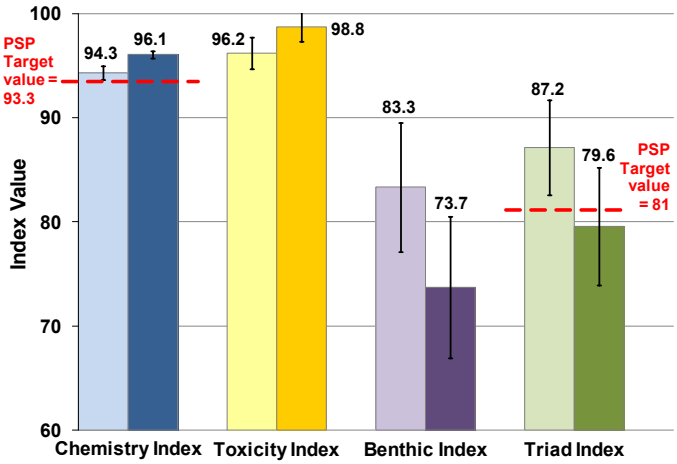


Figure 1. A comparison of weighted mean index values for the Port Gardner Bay study area in 2012 (light bars) and the surrounding Whidbey Basin in 2007 (dark bars), with 95% confidence intervals. Also shown are the PSP target values for the Chemistry and Triad Indices (red dashed lines). Index values range from 0 (poor quality) to 100 (high quality).

We are on the web

This report covers only the primary results of the 2012 Port Gardner Bay survey. Data and supporting information are available on Ecology's website: **www.ecy.wa.gov/programs/eap/sediment.**

Sediment Monitoring of Port Gardner Bay

Ecology sampled sediments in June 2012 under the Puget Sound Ecosystem Monitoring Program (PSEMP). The study area covered the subtidal portion of eastern Possession Sound, from Mission Beach to Elliott Point (pink in inset map), and included portions of the Port of Everett and the Snohomish River Delta. The survey designs weight sample results by area, which enables Ecology to estimate the percent of area (spatial extent) with given sediment conditions and to compare results from multiple surveys. Comparisons of spatial extent of sediment conditions follow Kincaid (2012). The study design, sampling and analytical methods, and list of parameters are described in Dutch et al. (2009, 2011) and on Ecology's website.

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Physical Conditions

Station depths were 2-12 meters (m) in the Snohomish Delta, East Waterway, and the sloughs; and 22-148 m in Port Gardner and Possession Sound. Salinities ranged from 5 to 25 parts-per-thousand (ppt), mostly 15-22 ppt, reflecting the strong influence of the Snohomish River.

Sediments were generally composed of sand or mixtures of silt and sand. Sediment total organic carbon (TOC) content was 2% or less throughout most of the study area. The exception was East Waterway, where TOC content was 6-10% by weight. Wood debris was present in samples in East Waterway and the west edge of the Snohomish Delta.

Chemical Contamination

Samples were analyzed for the concentrations of 136 potentially toxic chemicals, including metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and other organic compounds. Metals and PAHs were usually detected and measurable (87% of samples, ranging from 91% for metals to 81% for low-molecular-weight PAHs). The other target organic compounds (e.g., PCBs, pesticides) were detected in fewer than 8% of samples, on average.

No chemical concentrations were found above (not meeting) the Washington State Sediment Cleanup Objective (SCO*) benthic chemical criteria (Ecology, 2013) at any of the sites. SCOs are sediment chemical concentrations below which no adverse biological effects to the benthic community are expected to occur. These criteria apply to the benthic community within the biologically active zone of surface sediment, typically the top 10 cm.

A separate survey conducted in 2012 in just East Waterway found a few chemicals above the SCO benthic chemical criteria (Coots, 2013) in the top 10 cm of the sediment. The 10 cm sample depth included older sediment than the top 2-3 cm evaluated in this study.

Chemistry Index

Ecology's Chemistry Index (Long et al., 2013) is a multi-chemical index that accounts for the presence, concentrations, and potential toxicity of mixtures of chemicals. It is used to categorize sediments as having *minimum*, *low*, *moderate*, or *maximum* levels of exposure to the benthic community for chemicals which have defined SCO benthic chemical criteria (Ecology, 2013).

The Chemistry Index indicated that 80% of the study area in 2012 had *minimum exposure* to chemical contaminants (Figure 2). *Low exposure* to chemicals was found primarily in East Waterway and portions of Port Gardner, and represented 20% of the study area. No sediments were classified as having *moderate* or *maximum exposure*.

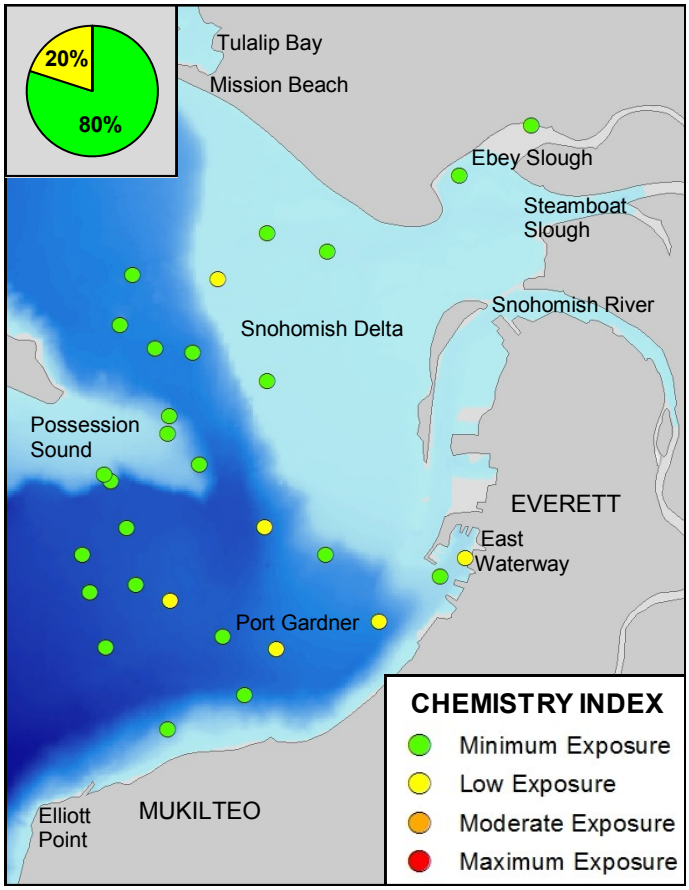

Figure 2. Spatial patterns at sampling stations and estimated spatial extent (percent of area, shown in pie chart) for the Chemistry Index categories for the Port Gardner Bay study area in 2012.

* formerly called Sediment Quality Standard (SQS)

Toxicity Index

Each sediment sample was analyzed with a 10-day amphipod survival test to gauge acute toxicity. The test involves exposing adult amphipods to sediments in the laboratory. Test results were used to generate Ecology's Toxicity Index (Dutch et al., 2014), which characterizes sediment toxicity into four categories, from *non-toxic* to *high toxicity* (Table 1).

The Toxicity Index indicated that 93% of the study area in 2012 had *non-toxic* sediments. *Low toxicity* was found in the western portion of the study area, representing 7% of total area (Figure 3). No *moderate* or *high toxicity sediments* were found with the amphipod survival test.

Although laboratory toxicity tests may indicate that the sediment and/or porewater is harmful to benthic organisms under controlled conditions, they do not indicate why; i.e., what specific factor(s) may be causing the adverse effects.

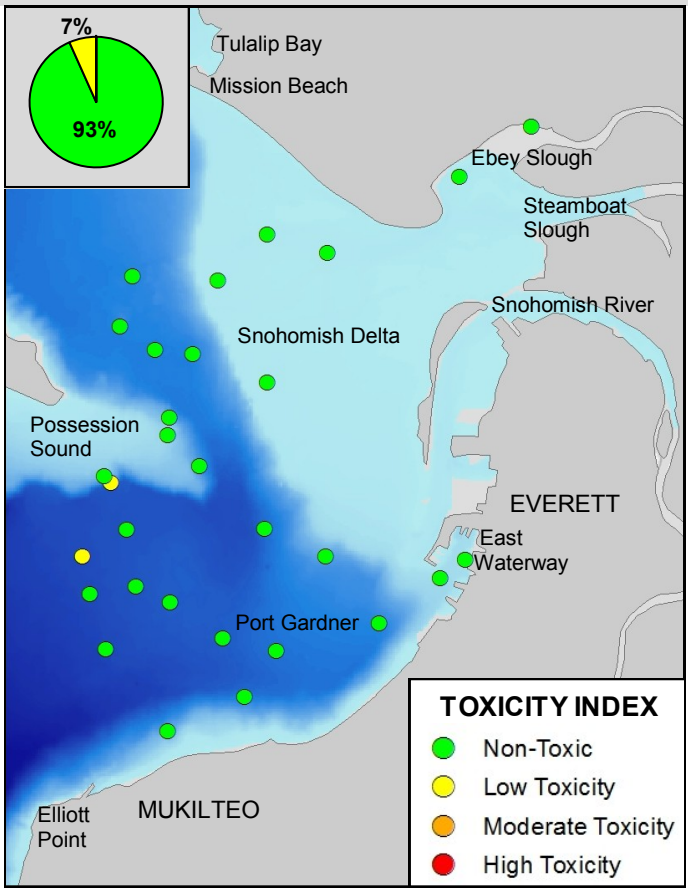

Figure 3. Spatial patterns at sampling stations and estimated spatial extent (percent of area, shown in pie chart) for the Toxicity Index categories for the Port Gardner Bay study area in 2012.

Table 1. Toxicity Index category descriptions.

Category	Description
Non-Toxic	Mean control-adjusted test results were not significantly lower than the controls **or** were ≥90% of controls
Low Toxicity	Mean control-adjusted test results were significantly lower than the controls **and** between <90-80% of controls
Moderate Toxicity	Mean control-adjusted test results were significantly lower than the controls **and** between <80-50% of controls
High Toxicity	Mean control-adjusted test results were significantly lower than the controls **and** <50% of controls

Seals sunning on log raft, East Waterway.

Benthic Index

Benthic invertebrate organisms (benthos) were identified and counted for all 30 locations sampled in 2012. Multiple community measures were calculated from the species and count data to characterize benthic invertebrate abundance and diversity.

Ecology's Benthic Index is a determination of whether the invertebrate assemblages appear to be *adversely affected* or *unaffected* by natural and/or human-caused stressors. The determination is made by benthic experts, based on a suite of calculated indices, including total abundance, major taxa abundances, taxa richness, evenness, and species dominance, compared to median values for all of Puget Sound. Abundances of stress-sensitive and stress-tolerant species at each station are also considered.

The benthic assemblages from the 2012 Port Gardner Bay survey were judged to be *adversely affected* for one-third of the samples, representing 33% of the study area (Figure 4). The remainder of the study area had *unaffected* benthos. Many of the *adversely affected* samples were from shallow, sandy, low-salinity areas which may not support diverse or abundant communities.

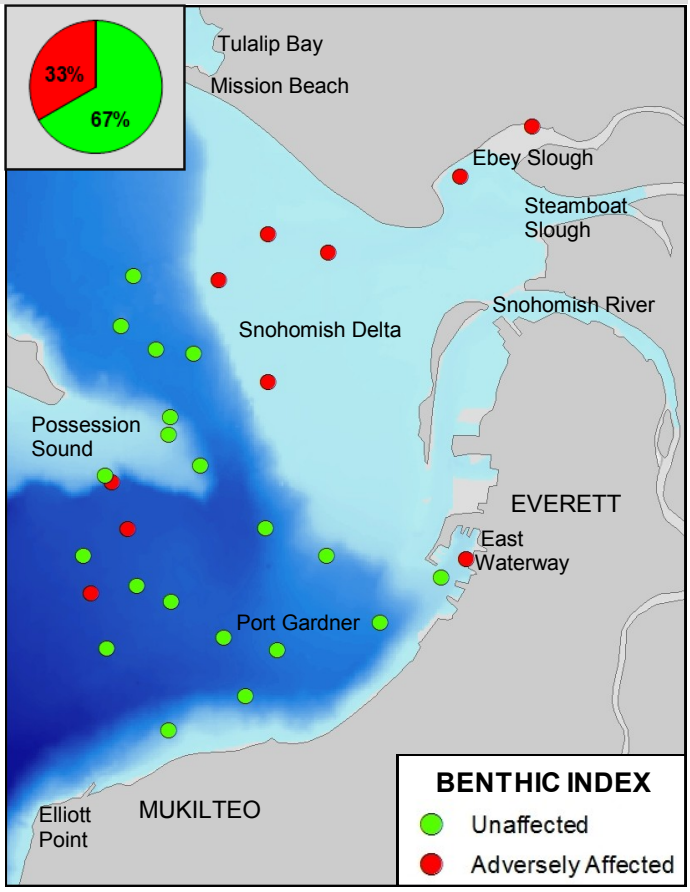

Figure 4. Spatial patterns at sampling stations and estimated spatial extent (percent of area, shown in pie chart) for the Benthic Index categories in the Port Gardner Bay study area in 2012.

Benthic Invertebrates

Molluscs, primarily bivalves (clams), numerically dominated the assemblages at the majority of stations. Polychaetes (marine worms) were dominant at most of the rest of the stations. Two stations were dominated by arthropods. The sample from a third station, in Ebey Slough, contained only 20 arthropods (mostly amphipods) and no other animals.

The animals found in highest abundance were species known or suspected to be tolerant of stressful conditions, such as the small bivalve *Axinopsida serricata* (Figure 5).

Very few echinoderms were found throughout the study area.

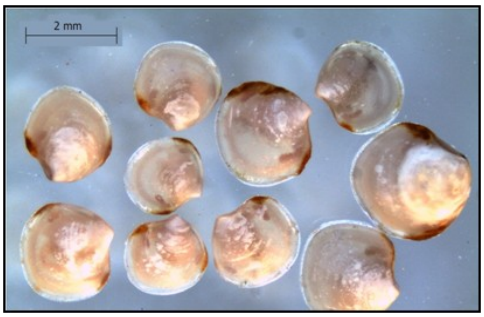

Figure 5. The small bivalve *Axinopsida serricata*, found in high abundance in Port Gardner Bay samples.

Table 2. Specific combinations of index results (chemistry, toxicity, benthic) that led to Triad Index categories for the Port Gardner study area in 2012. Spatial extent (percent of study area) is given for each combination.

Chemistry Index	+ Toxicity Index	+ Benthic Index	= Triad Index	% of Area
Minimum exposure	Non-Toxic	Unaffected	Unimpacted	50.0%
	Low			3.3%
Low exposure	Non-Toxic			13.3%
Minimum exposure	Non-Toxic	Adversely affected	Likely unimpacted	23.3%
Low exposure				6.7%
Minimum exposure	Low		Inconclusive	3.3%

Triad Index

The sediment triad concept of characterizing sediment condition is an empirical weight-of-evidence approach, originally conceived of and reported for Puget Sound (Long and Chapman, 1985).

Ecology's Triad Index combines evidence from the triad of measures (chemistry, toxicity, and benthos) to classify sediment quality into six categories of impact by chemical contamination and/or other environmental stressors (Dutch et al., 2014). Categories range from *unimpacted* to *clearly impacted*, and *inconclusive* when lines of evidence are conflicting. This multiple-lines-of-evidence approach was adapted from methods developed for the state of California to classify sediment quality (Bay and Weisberg, 2012).

Two-thirds (67%) of the area was classified as having *unimpacted* sediment quality (Table 2; Figure 6). The remainder of the study area was classified as either *likely unimpacted* (30%) or *inconclusive* (3%), driven by the presence of *adversely affected* benthic communities.

No *possibly*, *likely*, or *clearly impacted* sediments were found in the samples in **this** study. However, it must be noted that the Everett waterfront, from East Waterway up into the Snohomish River, is known to have contaminated sediments from historical industries and is scheduled for cleanup under the Puget Sound Initiative (Ecology, 2014). The timeframe, sample design, and methods used to determine local-scale sediment quality for regulatory purposes are not the same as those for assessment of only the most recently deposited sediments on a wide geographical scale, as in this study.

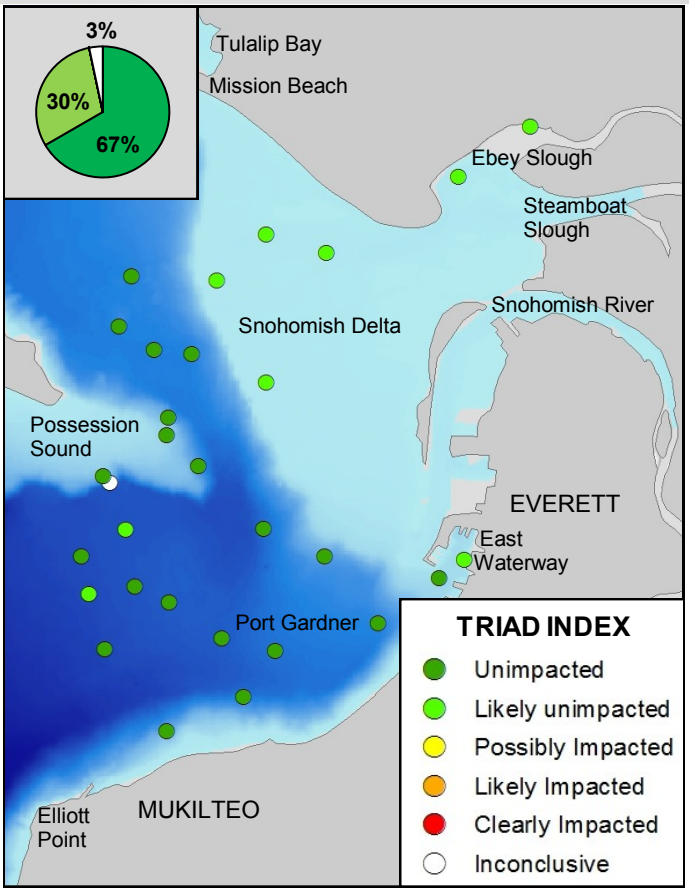

Figure 6. Spatial patterns at sampling stations and estimated spatial extent (percent of area, shown in pie chart) for the Triad Index results in the Port Gardner Bay study area in 2012.

Port Gardner Bay Compared to Whidbey Basin and All of Puget Sound

Comparison of the 2012 Port Gardner Bay Triad Index results to those for the Whidbey Basin region in 2007 and the 1997-2003 Puget Sound baseline shows that sediment quality in the Port Gardner Bay study area was almost identical to that for Puget Sound as a whole and significantly higher than in the encompassing region (Figure 7).

Port Gardner in 2012 had a higher proportion of area with *unaffected* benthos than did Whidbey Basin in 2007 (Partridge et al, 2013), which accounts for the higher proportion of *unimpacted* sediment quality. Slightly lower contaminant exposure in the study area than in the region also contributed to the Triad Index results.

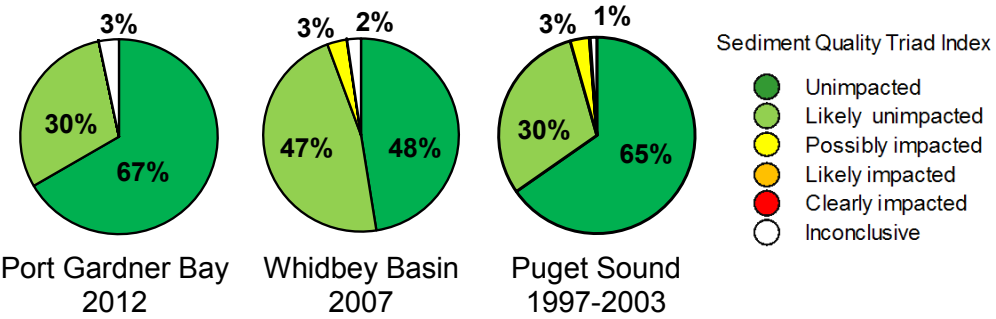

Figure 7. Spatial extent (percent of area) for the Triad Index categories for the Port Gardner Bay study area in 2012 (from Figure 6), compared to the surrounding Whidbey Basin in 2007 and the Puget Sound 1997-2003 baseline. Proportions smaller than 1% are not shown.

The Chemistry Index and the Triad Index as "Vital Signs" Indicators for the Puget Sound Partnership

Ecology's Chemistry and Triad Indices, and also the percent of chemicals above (not meeting) Washington Sediment Cleanup Objective (SCO) benthic chemical criteria (Ecology, 2013), were adopted by the Puget Sound Partnership (PSP) to serve as "Vital Signs" indicators of the condition of Puget Sound (www.psp.wa.gov/vitalsigns/index.php).

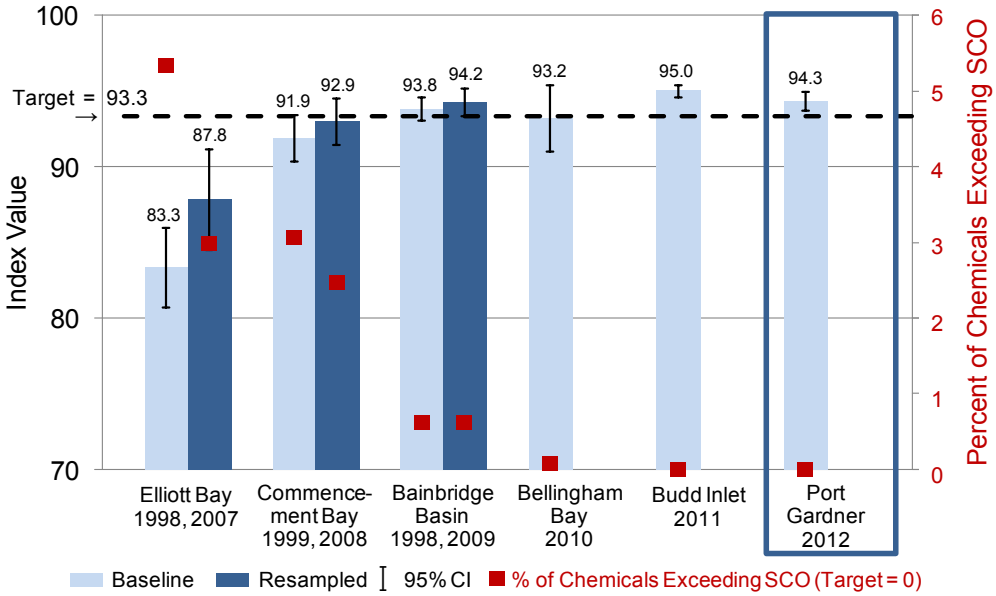

Figure 8. Change over time in Chemistry Index values for six urban bays in Puget Sound. Weighted means from baseline (lighter bars) and resample (darker bars) surveys are displayed with 95% confidence intervals. The PSP's 2020 target value of 93.3 is shown as a dashed black line. Red squares illustrate the percentages of chemicals with concentrations exceeding (not meeting) SCO benthic chemical criteria.

Weighted mean Chemistry and Triad Index values are compared with target values for highest quality for 2020, adopted by the PSP. The indices also are compared between years of repeated sampling to determine changes over time, as well as among urban bays.

The weighted mean Chemistry Index value for Port Gardner was above the 2020 target value of 93.3 (Figure 8). The Port Gardner study area was similar to the other recently-surveyed urban bays except Elliott Bay.

The percent of chemicals in Port Gardner Bay in 2012 exceeding SCO benthic chemical criteria met the PSP target of zero (Figure 8).

The weighted mean Triad Index value for the 2012 Port Gardner Bay survey was above (met) the PSP target value of 81 and was statistically similar to Elliott Bay, Commencement Bay, and the Bainbridge Basin (Figure 9). The PSP target value corresponds to the minimum value in the *unimpacted* Triad Index category.

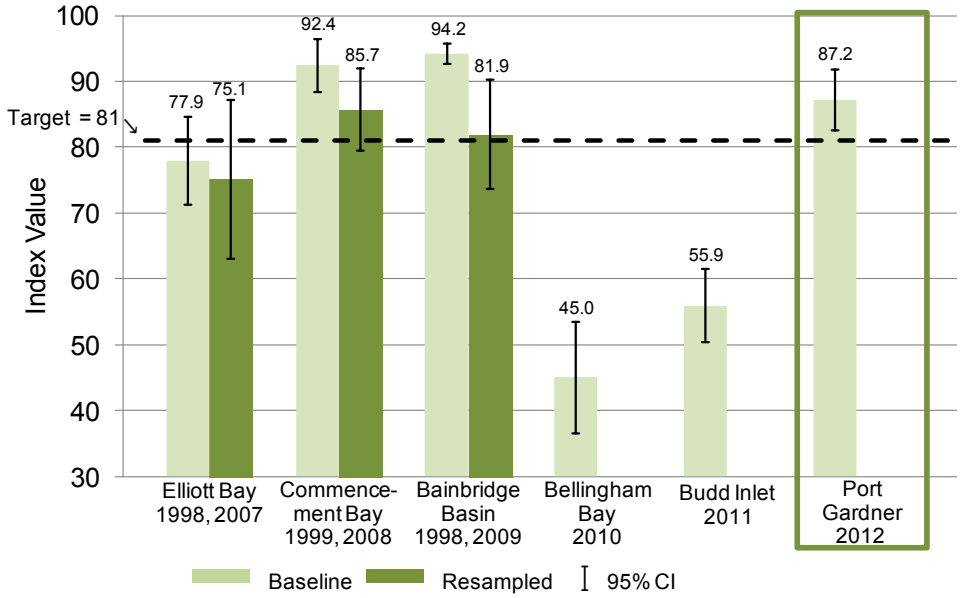

Figure 9. Change over time in Triad Index values for six urban bays in Puget Sound. Weighted means from baseline (lighter bars) and resample (darker bars) surveys are displayed with 95% confidence intervals. Also shown is the PSP's 2020 target value of 81 (dashed black line).

Summary and Conclusions

Sediment quality in the Port Gardner Bay study area in 2012 was *unimpacted* or *likely unimpacted* almost everywhere. Exposure to chemical contaminants was *minimum* or *low*. Sediments were almost always *non-toxic*. The two-thirds of the study area with *unaffected* benthic invertebrate community condition was categorized by the Triad Index as having *unimpacted* sediment quality. The *adversely affected* benthos in the remaining one-third of the area resulted in sediment quality being classified as *likely unimpacted* or *inconclusive* (the latter indicating conflicting conditions).

The results of this survey form a baseline of sediment conditions in Port Gardner Bay, for comparison in the future, when this urban bay will be resampled (next scheduled for 2018). Again, we reiterate that this was a bay-wide assessment of only the most recently deposited sediments, not older sediments at a specific site known or suspected to have industrial point source contamination. However, it is likely that cleanups and source control in the area have resulted in cleaner sediments entering the bay in recent years.

Although it is not possible to state why benthos were *adversely affected*, given the physical environment in the Snohomish Delta, the benthic community condition is possibly due to the natural physical characteristics of the habitat.

Future Directions

Ecology's Marine Sediment Monitoring Program is working to develop a more sensitive indicator of benthic condition that would enable categorizing benthic communities more finely than the current Benthic Index's binary designations.

The current Chemistry Index used for characterization of exposure of benthic organisms to chemical contaminants was developed for the heavy metals and industrial chemicals which were the primary pollutants identified in estuaries in the 1970s and 1980s. Such chemical contaminants have been the focus of cleanup actions and source control by multiple agencies over the past several decades. However, there are many more chemicals entering Puget Sound and surrounding waters, many of which are associated with human population growth and settlement rather than industrial output; i.e., non-point vs. point sources. We are currently revising the list of chemical contaminants for future sediment monitoring.

In addition, there are many more effects of unhealthy sediment conditions on animals than measured by the long-used amphipod survival toxicity test. We are exploring newer technologies in toxicity tests that can give reliable indications of other types of harm (such as reduced reproduction) to benthic organisms.

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[1] Now called the Puget Sound Ecosystem Monitoring Program.

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