Urban Bays Monitoring 2013: Sediment Quality in Elliott Bay, Seattle WA

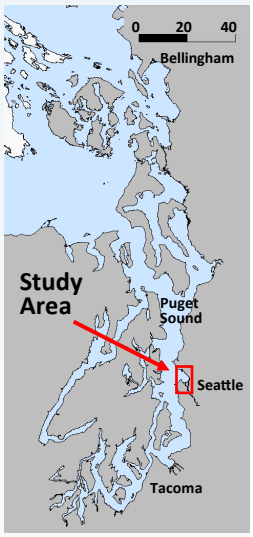
August 2016

Monitoring Sediment Quality

As part of the Washington State Department of Ecology's Urban Bays monitoring program, Elliott Bay surface sediments were sampled in 1998, 2007, and again in 2013. Sediment condition was evaluated with calculated indices based on results of laboratory analyses including:

- Chemistry - concentrations of potentially toxic chemicals
- Toxicity - sediment and porewater toxicity to test organisms
- Benthic - presence of sediment-dwelling invertebrates
- Triad - overall sediment quality; a combination of the chemistry, toxicity, and benthic indices

The program is designed to evaluate and compare results across multiple surveys and over time.



Overall Results

A significant increase in the Triad Index from 1998 to 2013 shows that Elliott Bay sediment quality has improved, meeting the Puget Sound Partnership (PSP) ecosystem recovery target value of 81 (Figure 1). Although the Chemistry Index showed a statistically significant increase from 1998, it still did not meet the PSP target of 93.3. Both the Toxicity and the Benthic Indices showed no significant changes between the surveys. However, slight increases in the Benthic Index are reflected in the overall increase of the Triad Index.

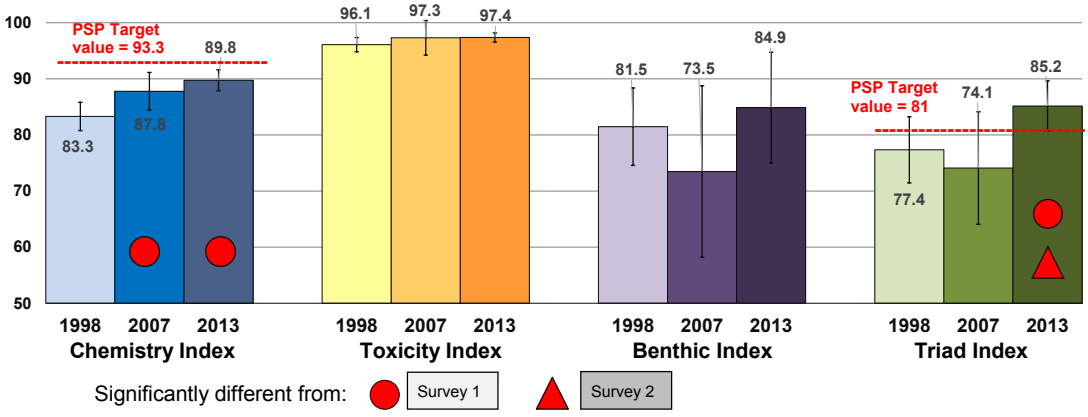


Figure 1. A comparison of weighted mean index values for Elliott Bay, with 95% confidence intervals. The PSP target values for the Chemistry and Triad Indices are shown in red. Numerical values of the indices range from 0 (poor) to 100 (high quality).

Findings

- Overall sediment quality in Elliott Bay is improving and met the Puget Sound Partnership Vital Sign target for the Triad Index.
- The Puget Sound Partnership targets for chemistry were not met, despite more chemicals meeting the Sediment Cleanup Objectives.

Want more information?

This report covers only the primary results of the 2013 survey. Data and supporting information are available on Ecology's website: www.ecy.wa.gov/programs/eap/sediment.

Methods are in Dutch et al., 2009, 2013.

Publication No. 16-03-010

Physical Condition

As in the previous two surveys, station depths ranged from 6 to 159 meters, with shallower stations in the Duwamish Waterway and along the shoreline and deeper stations in the center and outer portions of the bay. Elliott Bay sediments were predominantly composed of sandy and mixed particle sizes in the shallower stations. Finer-grained sediments, silts and clays, were associated with the deeper stations found in the center and outer sections of the bay.

Total organic carbon (TOC) content in 2013 ranged from 0.2% to 3.3%, with a median value of 1.7%. Measurements in 2013 were not statistically significantly different than those collected in 1999 or 2007.

Chemical Contamination

Many of the concentrations of individual chemicals were qualified as undetected, including pharmaceuticals and personal care products (PPCPs), perfluoroalkyl substances, (Dutch et al., 2014a), and base/neutral/acid organic compounds. Chemical classes that were most often detected included metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Concentrations of several of these chemicals did not meet their respective Sediment Cleanup Objectives (SCO) (Ecology, 2013). SCOs were not met at 13 locations, representing 17% of the Elliott Bay study area.

When compared to the previous Elliott Bay surveys, concentrations of all measured chemicals had statistically significant declines or stayed the same, with the exception of 1,6,7-Trimethylnaphthalene, a PAH, for which concentrations increased.

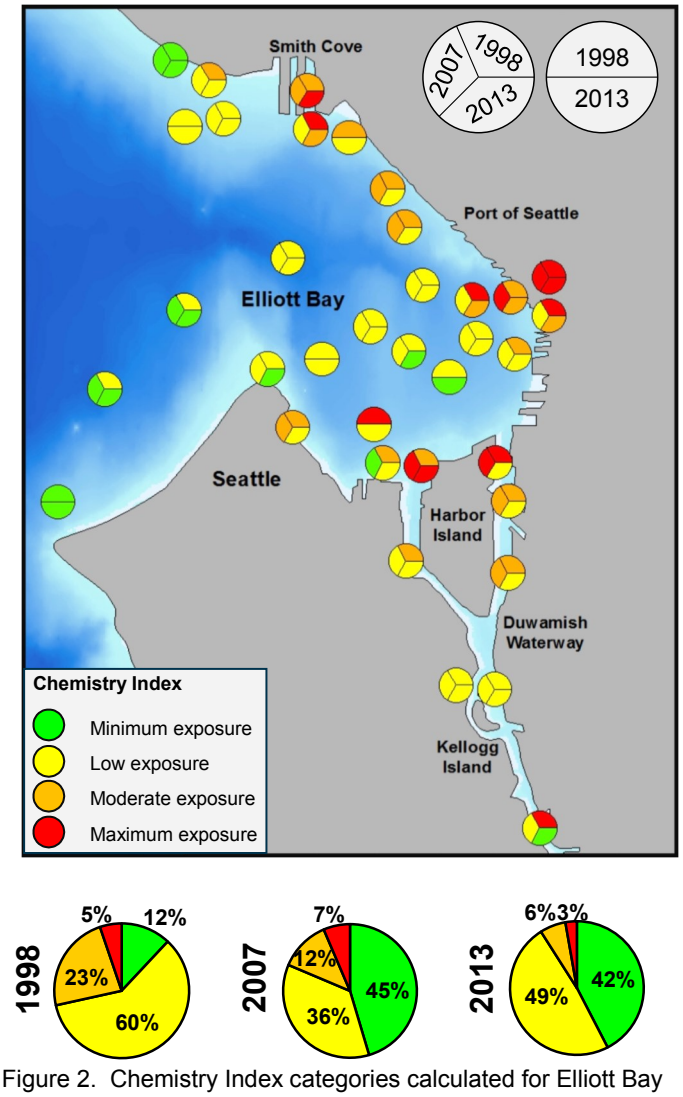


Figure 2. Chemistry Index categories calculated for Elliott Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

Chemistry Index

The Sediment Chemistry Index (Long et al., 2013) indicated that 42% of the study area in 2013 had *minimum exposure* to 39 chemical contaminants for which the State of Washington has Sediment Management Standards (Figure 2). In 2013 sediments with *minimum exposure* were found at the head of the Duwamish Waterway and in the central and outer portions of the bay. Sediments with *moderate* and *maximum exposure*, representing 6% and 3% of the study area, respectively. Maximum exposure sites were found at three sites, one north-west of Harbor Island and two along the northeastern shoreline. The remainder of the study area (49%) had *low exposure* to those contaminants.

Compared to the 1998 Elliott Bay survey, exposure to potentially harmful chemicals has decreased. The area with *minimum exposure* to chemicals has had a statistically significant increase since 1998, with a concurrent significant decrease in the area with *moderate exposure* (Figure 2).

Toxicity Index

In the 2013 survey, each sediment sample was analyzed with two laboratory tests of acute toxicity:

(1) 10-day survival of adult amphipods exposed to solid-phase sediments and

(2) fertilization of sea urchin gametes exposed to sediment porewater.

Test results were characterized into the four toxicity ranges of Ecology's Toxicity Index (Dutch et al., 2014b). These range from *non-toxic* to *high toxicity* (Table 1).

The amphipod survival test results indicated 21% of the study area as having *low toxicity*. The urchin fertilization test, however, designated the entire study area as *non-toxic*.

Test results were then combined, characterized according to the four toxicity categories, mapped, and the spatial extent calculated for the study area (Figure 3). The Toxicity Index indicated that 79% of the study area in 2013 had *non-toxic* sediments. *Low toxicity* was found at only two stations in the outer southwest portion of the bay, representing 21% of the total area (Figure 3). This is notably different from the previous surveys, in which toxicity was found near the northern portion of Harbor Island and along the shoreline of the bay. *Moderate* and *high toxicity* sediments were found in the northern portion of the Bay in previous surveys but not in 2013.

All of the stations that showed some level of toxicity in the previous two surveys had no toxicity in 2013. Conversely, two stations that were previously designated as *non-toxic* showed low toxicity in 2013. These stations are located in the outer portion of the bay and represent a larger area than the inner bay locations. Therefore, the toxicity index showed a statistically significant increase in *low toxicity* from the 2007 survey.

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

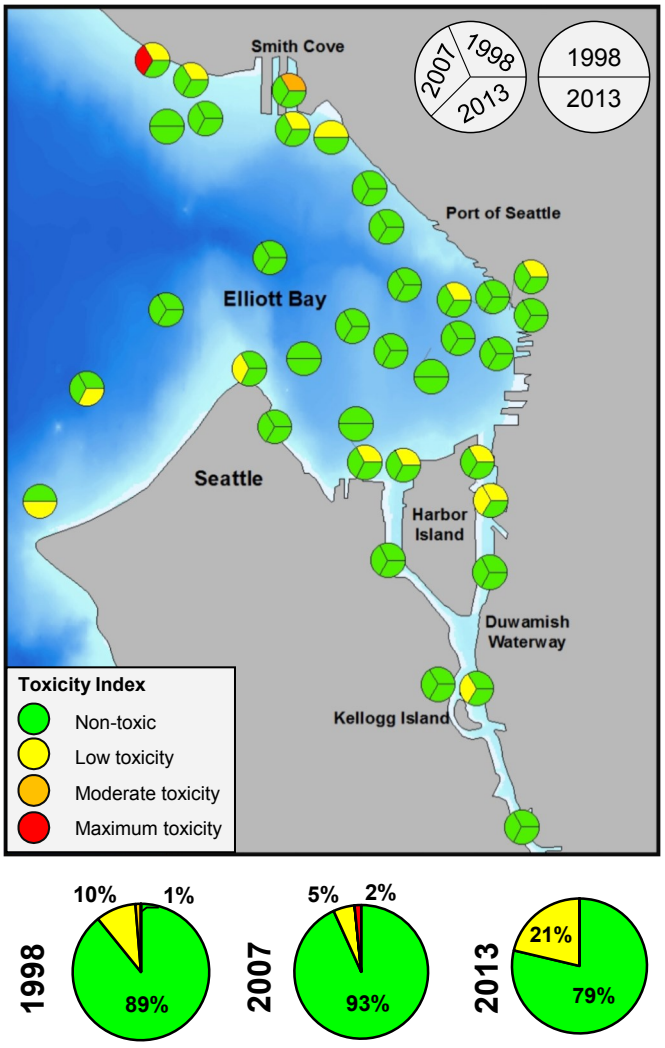


Figure 3. Toxicity Index categories calculated for Elliott Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

Benthic Invertebrates

Benthic invertebrate organisms (benthos) were identified and counted for all 36 locations sampled in 2013. Polychaetes (marine worms) were numerically dominant at 47% of the stations in the Elliott Bay study area. The remaining stations were dominated by molluscs. All stations had arthropods present. Echinoderms and miscellaneous taxa were found at 24 and 23 sites, respectively, but accounted for less than 10% of the total abundance at those sites.

The animals found in highest abundance and frequency were species known or suspected to be tolerant of stressful conditions. They include the two small bivalves *Axinopsida serricata*, present at all but one site and dominant at 36% of the sites, and *Parvilucina tenuisculpta*, occurring at 94% and dominant at 25% of the sites. The polychaete *Aphelochaeta glandaria* Complex was also highly abundant, occurring at 83% and dominating 14% of the sites.

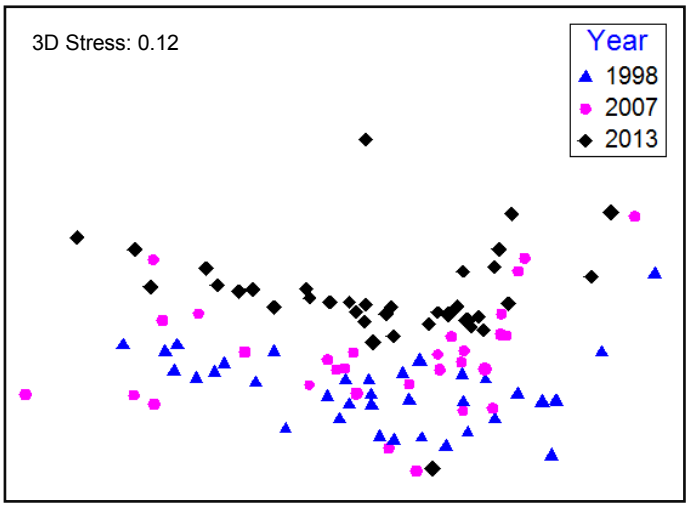


Figure 4. Non-metric multidimensional scaling (nMDS) map of benthic invertebrate assemblages in Elliott Bay, based on Bray-Curtis similarities of 4th-root-transformed species abundances. Degree of similarity or dissimilarity between assemblages is depicted by relative closeness or distance in this three-dimensional map.

The overall benthic community shifted over the three surveys, yet the community structure, as reflected by the relative similarities of the stations to each other, remained similar over time (Figure 4). The shift was driven primarily by a few dominant and highly abundant species.

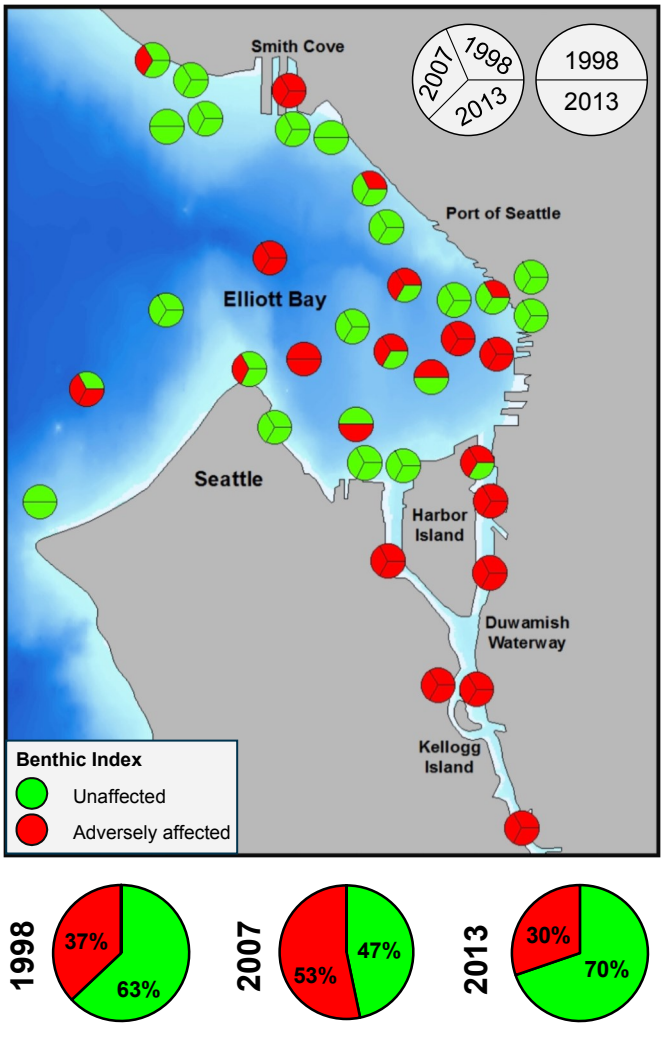


Figure 5. Benthic Index categories calculated for Elliott Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

Benthic Index

Multiple community measures were calculated from the benthic invertebrate species data to characterize abundance and diversity. Ecology's Benthic Index is a determination of whether the benthic 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 2013 Elliott Bay survey were judged to be *adversely affected* for 30% of the study area (Figure 5). The remainder of the study area had *unaffected* benthos. *Adversely affected* assemblages were found in Duwamish Waterway, Central Elliott Bay, and Smith Cove.

The area represented by *adversely affected* benthic assemblages is not significantly different than that found in the 1998 or 2007 surveys of the bay. The condition of the benthic assemblage at one site, just outside the East Waterway, deteriorated from a previous survey; all others remained unchanged or improved.

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 three types 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., 2014b). 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).

In 2013, the majority of the study area (70%) was classified as having *unimpacted* sediments (Figure 6). *Likely unimpacted* sediment quality was found at 11 sites, representing 18% of the study area. The remainder of the study area had *likely impacted* (1%) or *inconclusive* (11%) sediment quality, occurring at one site each. There were no *possibly impacted* or *clearly impacted* sediments found in the 2013 survey.

Comparison of the 2013 results to previous surveys shows statistically significant improvement in sediment quality as measured with the Triad Index. Most notably, the area with *unimpacted* sediment quality increased, with a concurrent decrease in areas with *possibly impacted* and *likely impacted* sediments, with respect to both the 1998 and the 2007 surveys.

Only one site, located in Smith Cove, indicated a decline in sediment quality from the 2007 survey; all other sites improved or stayed the same.

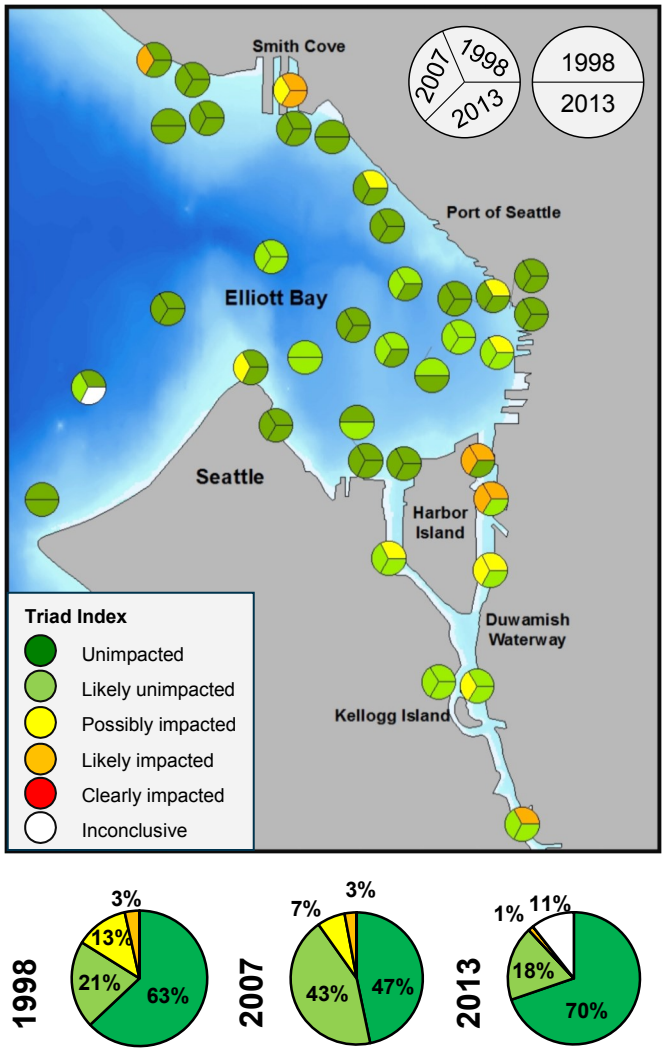
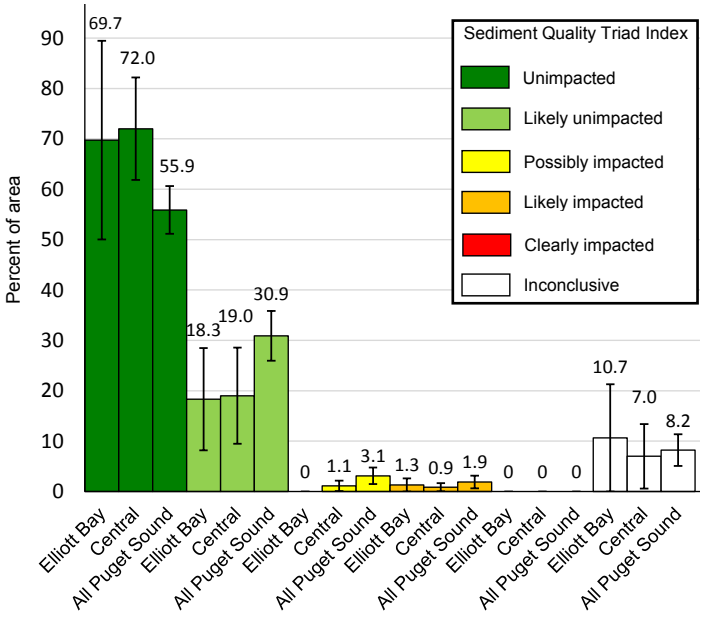


Figure 6. Triad Index categories calculated for Elliott Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.



Elliott Bay Compared to Central Puget Sound and all of Puget Sound

Sediment quality of Elliott Bay in 2013 was statistically similar to that of the encompassing Central Puget Sound region and the 2004-2014 Puget Sound Survey as a whole (Figure 7).

Figure 7. Percent of area for the Triad Index categories for Elliott Bay, compared to Central Puget Sound and to the entire Puget Sound.

Puget Sound Partnership "Vital Signs" Chemistry and Triad Indices

Ecology's Chemistry and Triad Indices, and also the percent of chemicals not meeting the Washington State 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. Weighted mean Chemistry and Triad Index values are compared to target values for highest quality. The indices are also compared between years of repeated sampling to determine changes over time, as well as among urban bays.

The weighted mean Chemistry Index value for Elliott Bay was below the 2020 target value of 93.3 (Figure 8). The Elliott Bay study area had the lowest index values compared to the other urban bays surveyed in Puget Sound. However, like Commencement Bay, the Elliott Bay chemistry index shows an improving trend from the first survey.

The percent of chemicals in Elliott Bay in 2013 exceeding SCO criteria did not meet the PSP target of zero (Figure 8). Although the target was not met, a decline in the number of chemicals not meeting the criteria was observed in the three Elliott Bay surveys.

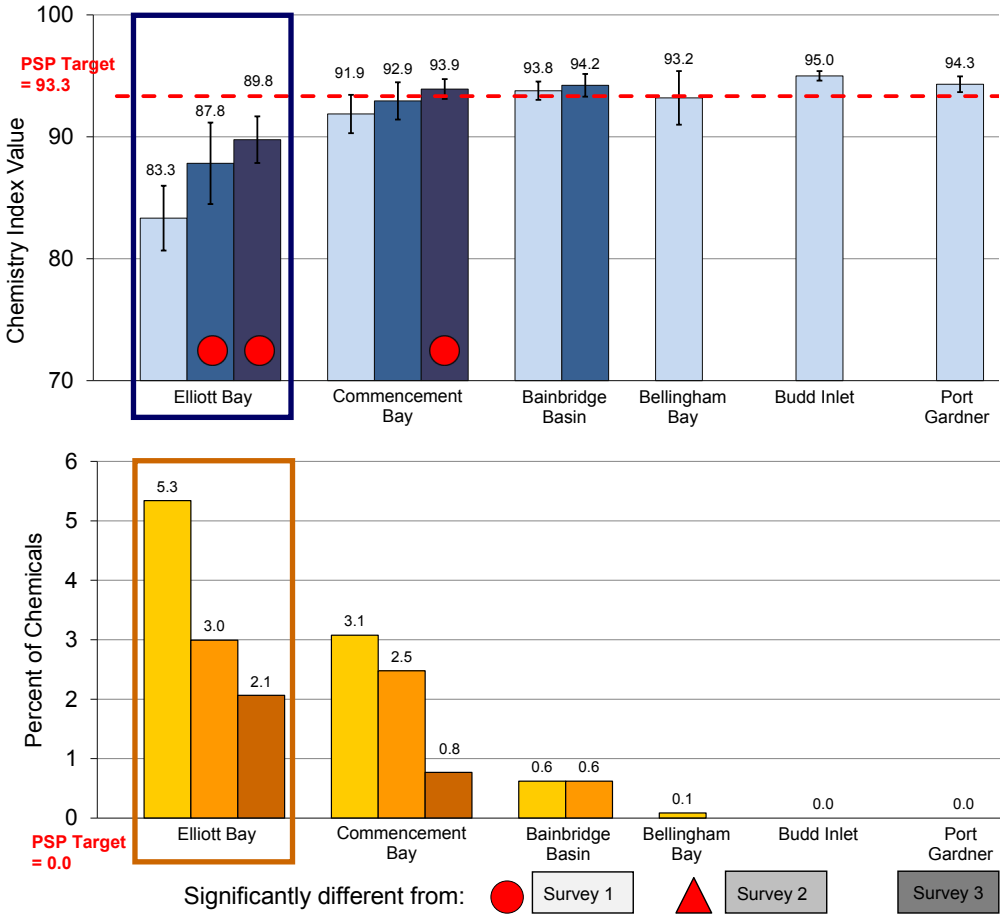


Figure 8. Change over time in Chemistry Index values (upper) and percent of chemicals not meeting Sediment Cleanup Objectives (lower) for urban bays in Puget Sound.

The weighted mean Triad Index value for the 2013 Elliott Bay survey was above the PSP target value of 81, and represented a statistically significant improvement in overall sediment quality from the previous two surveys of the bay (Figure 9). The PSP target value corresponds to the minimum value in the *unimpacted* Triad Index category.

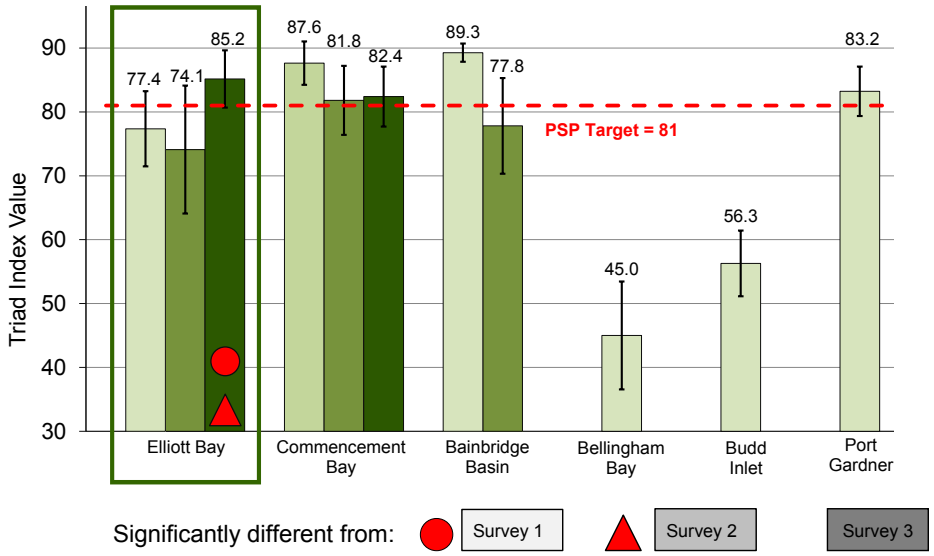


Figure 9. Change over time in weighted Triad Index values for urban bays in Puget Sound, with 95% confidence intervals.

Summary

Results from three surveys of Elliott Bay indicate that sediment quality in Elliott Bay has improved over time. The portions of the study area with *unimpacted* sediments has increased since 1998, and areas with *possibly* or *likely impacted* sediments have decreased to 0% and 1.3%, respectively. The overall Elliott Bay sediment quality in 2013 was statistically significantly higher than in the previous two surveys and met the Puget Sound Partnership target.

Overall, Elliott Bay benthic assemblages have stayed the same or slowly improved, with only one location showing signs of declining condition. Even though benthic assemblages have shown improvements, most locations monitored included several species known or suspected to be tolerant of stressful conditions.

Exposure to measured chemical contaminants and the presence of *adversely affected* benthic assemblages continue to be factors in degraded Elliott Bay sediment quality, whereas the significant responses of acute toxicity in laboratory tests are not a major contributor. Areas that are exposed to the measured chemical contaminants are not always sites where benthic assemblages are *adversely affected*, and no significant correlations between chemical and benthic measures could be established in these surveys. Additional parameters may need to be monitored to determine what is adversely affecting the benthic community.

It is important to distinguish between Ecology's ambient sediment monitoring activities, such as this Urban Bays study, and Ecology's Toxic Cleanup Program (TCP) Remedial Investigations and Feasibility Studies (RI/FS). This ambient study characterizes current conditions for large geographic areas rather than targeted locations. The TCP is concerned primarily with the toxic legacy from past industrial practices and how those practices have impacted Puget Sound. The RI/FS process examines sediment contamination in the biologically active zone, whereas this Urban Bays ambient study assesses the most recently deposited sediments. As a result, these differences in approach could potentially lead to differing conclusions, even at similar locations. Results from this publication are not intended to supersede, revise, or replace the State's regulatory criteria under the Sediment Management Standards.

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