Urban Bays Monitoring 2014: Sediment Quality in Commencement Bay, Tacoma WA

August 2016

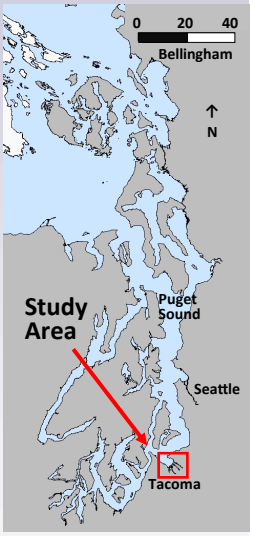
DEPARTMENT OF ECOLOGY
State of Washington

Monitoring Sediment Quality

As part of the Washington State Department of Ecology's Urban Bays monitoring program, Commencement Bay surface sediments were sampled in 1999, 2008, and again in 2014. Sediment condition was evaluated with calculated indices based on laboratory analyses, including:

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

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



Overall Results

Overall sediment quality, as measured with the Triad Index, in Commencement Bay has remained statistically unchanged over the three surveys (Figure 1). Since the 1999 survey, the Chemistry Index has shown a significant increase and meets the Puget Sound Partnership (PSP) recovery target value of 93.3. The Toxicity and Benthic Indices on the other hand, showed significant decreases since 1999. These decreases are reflected in the Triad Index, yet the PSP target value of 81 was still met.

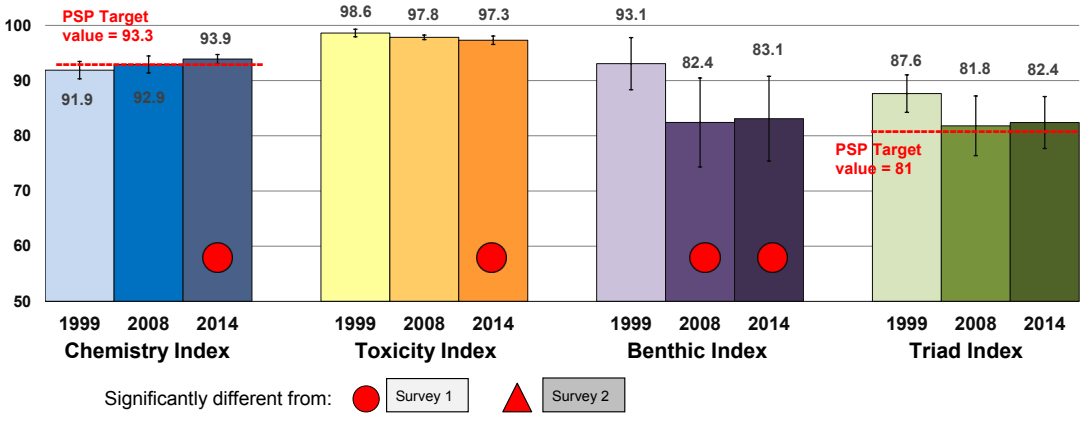


Figure 1. A comparison of weighted mean index values for Commencement Bay, with 95% confidence intervals. The PSP target values for the Chemistry and Triad Indices are shown in red. Numerical values of the indices range from 0 (poor) to 100 (high quality).

Findings

- Overall Sediment quality, as reflected in the Triad Index, did not change from previous surveys.
- The five most abundant invertebrate species were ones known to be or suspected to be tolerant of stressful conditions.
- Puget Sound Partnership Vital Sign target values were met.

Want more information?

This report covers only the primary results of the 2014 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, 2014a

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Physical Condition

Sampling depths ranged from 3 to 176 meters, with shallower stations in the Waterways and along the shoreline, and deeper stations in the center and outer portions of the bay. Commencement Bay sediments were predominantly composed of silty sand and mixed particle sizes.

Total organic carbon (TOC) content in 2014 ranged from 0.1% to 7.5%, with a median of 1.4%. Highest TOC concentrations were found in the Thea Foss Waterway. TOC was significantly higher in 2014 than in 2008 and was equal to 1999 levels.

Chemical Contamination

Many of the concentrations of individual chemicals were qualified as undetected at or below the sample quantitation limit. 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 5 locations, representing 3.7% of the study area. Heavily industrialized waterways were the only locations where the SCOs were not met and each waterway had a different chemical or suite of chemicals exceeding the SCOs:

- Hylebos Waterway - hexachlorobenzene
- Blair Waterway - phthalates
- Middle Waterway - mercury
- Thea Foss Waterway - PAHs and butylbenzylphthalate

When statistical comparisons were made to the previous surveys of the bay, low molecular weight PAH concentrations have remained the same or increased while high molecular weight PAHs remained the same or decreased. Metal concentrations fluctuated over time and showed no distinct patterns.

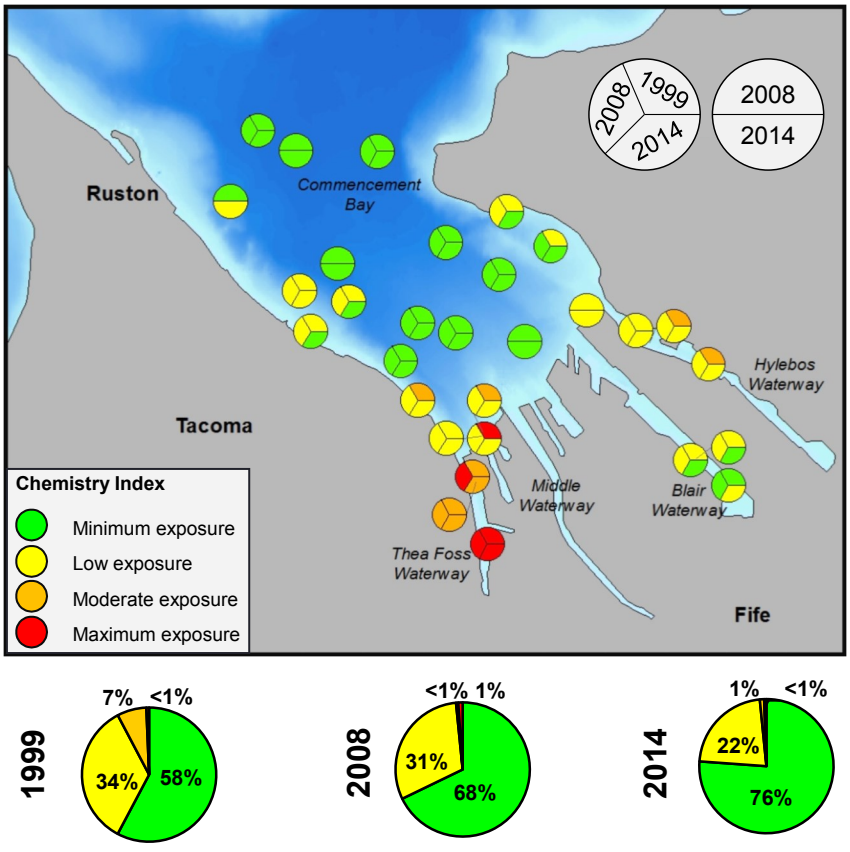


Figure 2. Chemistry Index categories calculated for Commencement Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

Chemistry Index

The Sediment Chemistry Index (Long et al., 2013) indicated that in 2014 most of Commencement Bay had *minimum exposure* (76%) or *low exposure* (22%) to 39 chemical contaminants for which the State of Washington has Sediment Management Standards (Figure 2). Only in the Thea Foss Waterway were sediments found with *moderate* and *maximum exposure,* representing 1% and 0.5% of the study area, respectively.

Compared to the 1999 and 2008 surveys of Commencement Bay, exposure to potentially harmful chemicals continued to decrease. All sites except two, one in Blair Waterway and one near Ruston, showed improvement or stayed the same.

Although individual sites showed improvement over time, the overall chemical exposure as measured with the Sediment Chemistry Index did not change significantly.

Toxicity Index

In the 2014 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.
(2) fertilization of sea urchin gametes exposed to sediment porewater.

Test results are characterized into four toxicity ranges, from non-toxic to high toxicity (Table 1).

The amphipod survival test results indicated 1% of the study area as having *low toxicity*. The urchin fertilization test, however, indicated *moderate toxicity* in 7% of the study area.

The test results were combined and characterized into the four toxicity categories as Ecology's Toxicity Index (Dutch et al., 2014b).

The Toxicity Index indicated that 92% of the study area in 2014 had *non-toxic* sediments. *Low toxicity* was found at five stations, representing 8% of the total study area (Figure 3). No *moderate* or *high toxicity* sediments were found in the 2014 survey.

Since 1999 there has been an increase in *low toxicity* in Commencement Bay. The small increase in *low toxicity* is not statistically significant. However, conditions measured by the Toxicity Index, at several stations in or near the Thea Foss Waterway and one site in the Hylebos Waterway, worsened from the previous surveys of the bay. One station in inner Blair Waterway and one in Thea Foss Waterway improved over time.

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

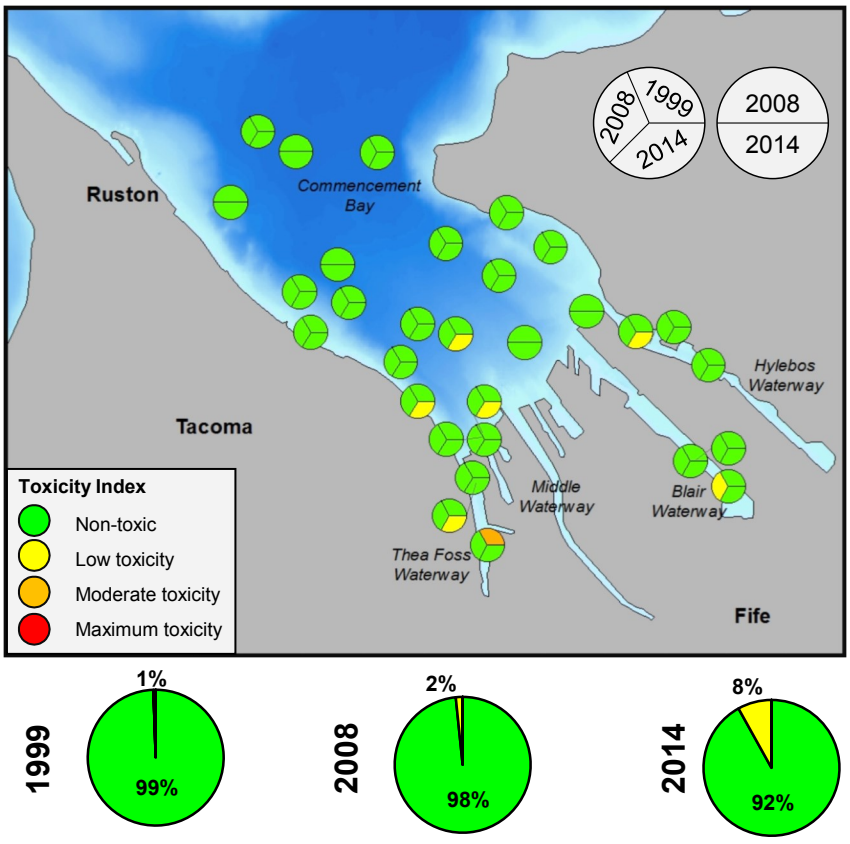


Figure 3. Toxicity Index categories calculated for Commencement Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

Benthic Invertebrates

Benthic invertebrate organisms (benthos) were identified and counted for all 30 locations sampled in 2014. Polychaetes (marine worms) were present at all sites and numerically dominant at 87% of the sites in the Commencement Bay study area. Molluscs occurred at 100% of the sites and were dominant at 10% of the sites. Arthropods occurred at 28 sites and, though dominant at one site, accounted for less than 8% of the overall total abundance. Miscellaneous taxa were found at 93% of the sites but contributed the least to the total abundance at those sites. Echinoderms were present least often - at 70% of the sites - and accounted for less than 3% of the overall total abundance.

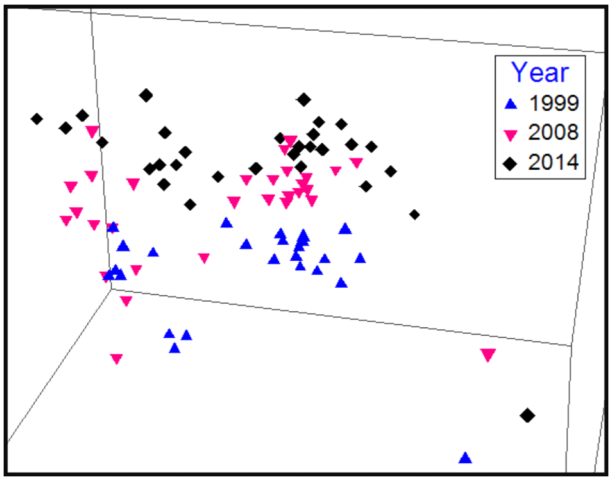
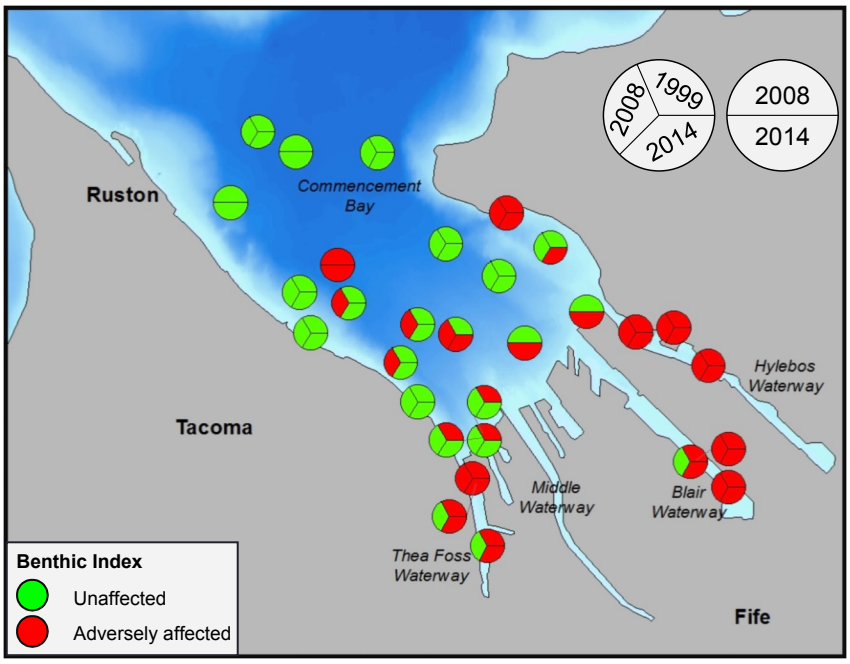


Figure 4. Non-metric multidimensional scaling (nMDS) map of benthic invertebrate assemblages in Commencement Bay, based on Bray-Curtis similarities of 4th-root-transformed species abundances. Degree of similarity or dissimilarity between assemblages is depicted by relative closeness or distance in this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

In all of the survey sites, the five most abundant species were ones known to be or suspected to be tolerant of stressful conditions. Seventy percent of the 2014 stations had a tolerant species as the most abundant species. Those found in highest abundance and frequency were several worms, including: *Aphelochaeta glandaria* Complex, *Dipolydora cardalia*, and *Scoletoma luti;* and one clam, *Parvilucina tenuisculpta*.

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. Several significant changes in calculated benthic community measures indicate that the benthic assemblages in Commencement Bay may be changing. Total abundance, as well as abundance of arthropods and molluscs, has declined over the three sampling events. Even though the overall abundance declined, species dominance and evenness increased over time, indicating that diversity in the communities increased and was less dominated by a few species.



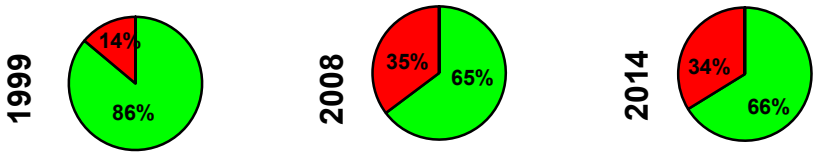


Figure 5. Benthic Index categories calculated for Commencement Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

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 invertebrate assemblages appear to be *adversely affected* or *unaffected* by any kind of stressor, natural and/or human-caused. 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 2014 Commencement Bay survey were judged to be *adversely affected* for 34% of the study area (Figure 5). The remainder of the study area had *unaffected* benthos.

The area represented by *adversely affected* benthic assemblages in 2014 is significantly greater than that found in the 1999 survey, but not significantly different from the 2008 area. The condition of the benthic assemblages along the eastern shoreline, the entrance of the Hylebos Waterway, and in Blair and Thea Foss Waterways have worsened over time. Conditions at stations near the Middle Waterway and along the southwestern shoreline have improved since the previous survey.

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., 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 2014, the majority of the area (66%) was classified as having *unimpacted* sediments (Figure 6). *Likely unimpacted* sediment quality was found at 10 sites, representing 28% of the study area. The remainder of the study area had *possibly impacted* (2%), *likely impacted* (1%), or *inconclusive* (3%) sediment quality. There were no *clearly impacted* sediments found in the 2014 survey.

Sediment of poorest overall quality was found in the Hylebos, Blair, and Thea Foss Waterways, whereas unimpacted sediments were found in the central and outer portions of the bay.

Comparison of the overall sediment quality for the three Commencement Bay surveys shows a statistically significant decline in the area with unimpacted sediment quality from 1999 to 2008 and no significant change from 2008 to 2014.

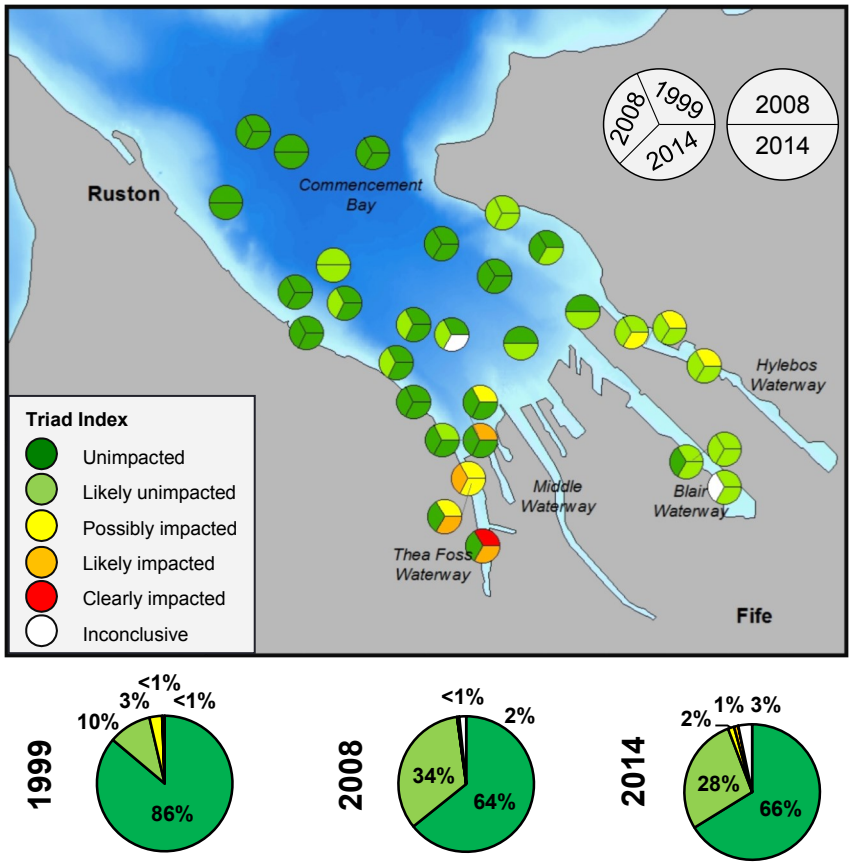
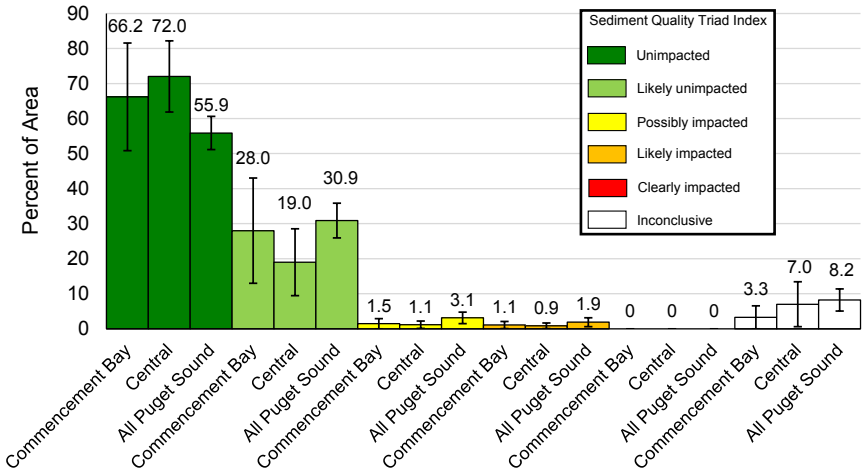


Figure 6. Triad Index categories calculated for Commencement Bay sediments. Spatial and temporal patterns shown on the map are summarized as percent area in the pie charts below the map.

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



Sediment quality of Commencement Bay in 2014 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 Commencement 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 exceeding (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 one of the "Vital Signs" indicators of the condition of Puget Sound (www.psp.wa. gov/vitalsigns/index.php). Weighted mean Chemistry and Triad Index values are compared to target values for highest quality sediment, 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 Commencement Bay was above the 2020 target value of 93.3 (Figure 8). The Commencement Bay study area was similar to the other recently surveyed urban bays except Elliott Bay, which was below the target.

The percent of chemicals in Commencement Bay in 2014 exceeding SCO chemical criteria did not meet the PSP target of zero (Figure 9).

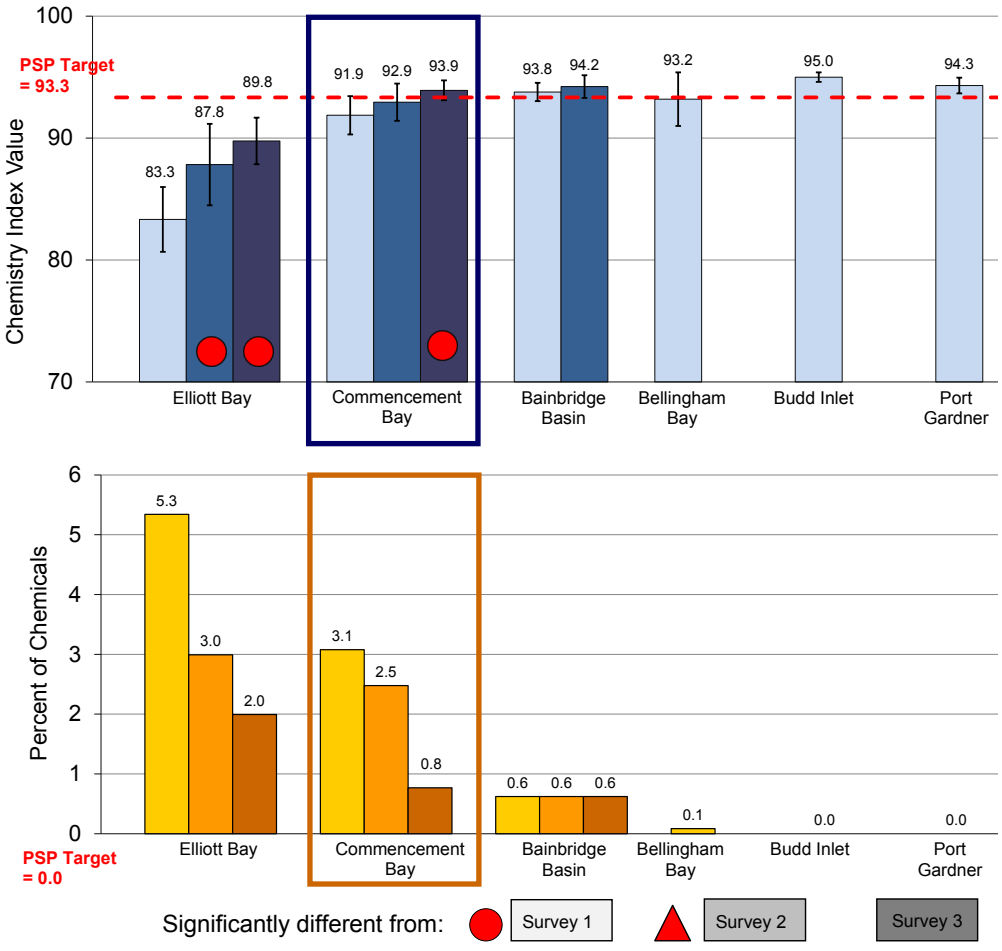


Figure 8. Change over time in Chemistry Index values (upper) and percent of chemicals not meeting Sediment Cleanup Objectives (lower) for urban bays in Puget Sound.

The weighted mean Triad Index value for the 2014 Commencement Bay survey met the PSP target value of 81 and was statistically similar to the previous surveys of the bay (Figure 9). The PSP target value corresponds to the minimum value in the *unimpacted* Triad Index category.

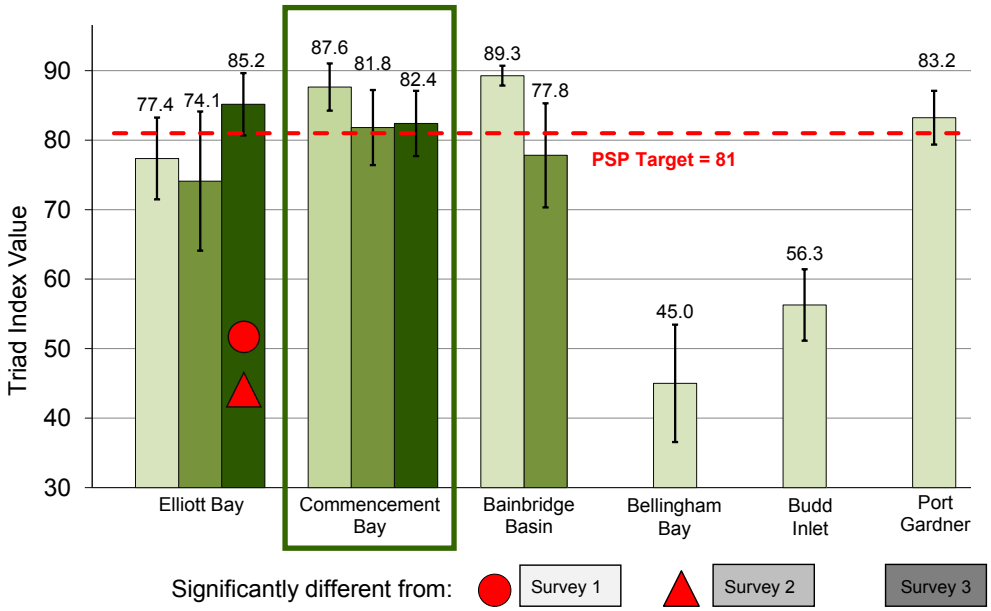


Figure 9. Change over time in weighted Triad Index values for urban bays in Puget Sound, with 95% confidence intervals.

Summary

The combined evidence from the triad measures of chemistry, toxicity, and benthos indicate that sediment quality in Commencement Bay has not changed significantly since the 1999 baseline survey. All three triad measures contributed in determining sediment quality for the bay, especially the benthic index, which identified 50% of the stations as having a potential problem. The majority of the bay had *unimpacted* or *likely unimpacted* sediment quality, and a relatively small portion (3%) of the bay had *impacted* sediments. For the bay as a whole, the Chemistry and Triad Indices met the target values adopted by the Puget Sound Partnership for those Vital Sign Indicators.

A spatial gradient of improving sediment quality from the waterways, particularly the Thea Foss Waterway, toward central and outer Commencement Bay, is evident. Although there was concordance among the three triad measures in determining this spatial pattern of sediment quality, no significant correlation among individual chemical parameters, responses in laboratory toxicity tests, and *adversely affected* benthic assemblages could be determined.

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 entire biologically active zone, whereas PSEMP assesses the most recently deposited sediments. The two programs use different sampling and analysis procedures.

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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Data for this project are available at Ecology's Environmental Information Management (EIM) website www.ecy.wa.gov/eim/index.htm. Search Study ID, UWI2014

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