Development and Evaluation of Biological Effects Criteria and Reference Area Performance Standards of the Sediment Management Standards Rule

TASK 3 REPORT: EVALUATION AND RECOMMENDATION OF REVISED SMS BENTHIC INFAUNAL SEDIMENT STANDARDS

Prepared for:
Washington Department of Ecology, Olympia, WA

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WESTON®
MANAGERS DESIGNERS/CONSULTANTS

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EVALUATION OF ANALYTICAL METHODS AND BENTHIC COMMUNITY ENDPOINTS FOR POTENTIAL INCLUSION IN THE SEDIMENT MANAGEMENT STANDARDS

1. INTRODUCTION

In August 1994, the Washington State Department of Ecology authorized Roy F. Weston (WESTON), under subcontract to Striplin Environmental Associates (SEA), to begin the second phase of the assessment of analytical techniques and indices for identifying impacted benthic infaunal communities under the Sediment Management (SMS) Rule. The scope of this phase of the project was based on selected recommendations made by the National Benthic Experts Workshop panel members and compiled in *Recommendations for Assessing Adverse Benthic Effects in Puget Sound* [PTI Environmental Services (PTI), 1993]. Specifically, the following recommendations were to be addressed by this phase of the project:

- The relative sensitivity among various benthic community indices should be tested using more than one case study
- Use of more than one benthic community index should be included in management decisions
- Benthic community indices should be based on the species-level data
- Alternative analytical techniques (nonparametric univariate statistics, multivariate techniques) should be considered
- Reference conditions should be defined for Puget Sound

To accomplish this scope, WESTON selected an existing benthic community data set from the Elliott Bay Urban Bay Action Program (EBAP) to statistically evaluate the performance of the following benthic indices relative to their ability to distinguish among natural, moderately impacted, and severely impacted communities:

- Richness
- Total abundance
- Major taxa abundance
- Major taxa richness

For this evaluation, major taxa are considered those that are defined under the Sediment Management Rule. Echinoderms and other infaunal phyla were present in the samples, but tended to be rare. Rare taxa are difficult to use in statistical analysis, because generally a much larger degree of replication is required than was used in the EBAP sampling design to support efficient and accurate statistical testing.

Semi-quantitative comparisons of the following indices were also used to develop a preponderance of evidence regarding degree of impact between Elliott Bay and Port Susan reference locations:

- Infaunal Trophic Index
- Shannon-Weiner diversity
- Swartz's dominance index (SDI)
- Evenness and dominance
- Community composition based on the top ten most numerically dominant taxa

Using the approach described in Appendix A: *Evaluation of Techniques for Assessing Benthic Endpoints for Use in Puget Sound Sediment Management Programs of the Recommendations for Assessing Adverse Benthic Effects in Puget Sound* (PTI 1993), statistical evaluations were based on pair-wise t-tests between Port Susan and Elliott Bay locations matched by similar grain size characteristics, as well as an analysis of variance (ANOVA) among all stations using *a posteriori* significance tests to identify differences among stations, including reference stations. Reference data were pooled to represent coarse- versus fine-grained habitats prior to statistical testing. Cluster and ordination techniques were used to further refine the evaluation of the accuracy of various indices to correctly identify differences between an impacted site and reference conditions.

As another part of this project, SEA created a comprehensive data set representing potential benthic reference conditions based on information reported in recent investigations conducted within Puget Sound over the last 15 years. Based on a preliminary screening of the sediment quality and physical characteristics, data representing four different habitat categories were compiled. Habitat categories were characterized based on a maximum bottom depth of 150 feet and four grain size categories:

- 0 to 20 percent fines
- 20 to 50 percent fines
- 50 to 80 percent fines
- greater than 80 percent fines

Benthic community indices were then calculated for each habitat category to represent Puget Sound-wide reference conditions. The results are published in *Development of Reference Value Ranges for Benthic Fauna Assessment Endpoints in Puget Sound* (SEA 1995).

As part of WESTON's scope of work, use of the Puget Sound-wide reference data was evaluated for potential inclusion in the Sediment Management Rule. Specifically, WESTON statistically compared the Elliott Bay data along with the previously evaluated Everett Harbor data (PTI 1993) to the Puget Sound reference data. The results of this evaluation were also compared to use of site-specific reference data divided into the four habitat categories described above.

This report presents the results of the evaluation of benthic indices and analytical techniques and WESTON's recommendations regarding revisions to the use of benthic community data in the Sediment Management Rule. The report is organized into three sections:

- Results of the Elliott Bay case study using the site-specific reference data.
- Comparison of the results of both the Elliott Bay and Everett Harbor case studies using the Puget Sound-wide reference data set.
- Recommendations regarding analytical techniques, inclusion of indices and use of Puget Sound reference habitat values in the SMS Rule.

2. CASE STUDY RESULTS—ELLIOTT BAY ACTION PROGRAM

One of the recommendations resulting from the National Benthic Experts Workshop was to test the efficacy of selected benthic indices in identifying adverse effects, using more than one test case. To address this recommendation, an additional Puget Sound data set was selected for statistical evaluation and regulatory interpretation following procedures described in PTI 1993. The data set chosen for this case study was from the 1985 Elliott Bay Action Program (EBAP) investigation (PTI and Tetra Tech, 1988). Species-level data from 16 stations throughout Elliott Bay (see Figure 1), including Alki Beach, the waterways surrounding Harbor Island, and the Seattle waterfront, were selected for evaluation. Reference area data collected from Port Susan during the EBAP study were used for comparison with the Elliott Bay stations.

2.1. Habitat Characteristics of the Case Study Locations

Because habitat attributes can affect benthic community structure, stations were grouped by their relative similarity in percent sediment fines for some of the subsequent analyses to help distinguish potential contaminant effects on the benthos. Stations were classified as either coarse- or fine-grained based on a general division of greater than or less than 50 percent fines (i.e., silt + clay). Habitat characteristics for all stations used in this case study are summarized in Table 1. As illustrated by these data, habitat characteristics within Elliott Bay, the Duwamish estuary, and the Port Susan reference area were not homogeneous. Elliott Bay stations EW-11, KG-01, NH-03, NH-08, NS-08, SS-04, SS-11, WW-09, WW-11, and WW-14 were classified as fine-grained, along with reference station PS-01. Coarse-grained sediments included Elliott Bay stations AB-01, EW-05, NH-01, NH-02, NH-04, and NS-03, and reference stations PS-02, PS-03, PS-04.

2.2. Sampling Efficiency and Power Analyses

An index of sampling efficiency based on the standard error as a percent of the mean was calculated for each station using total abundance, richness, and major taxonomic group abundance and richness data, and the results are presented in Table 2. According to Dauer et al. (1979) and Elliott (1977), values less than 20 to 30 percent indicate that the number of samples collected at each station are adequate to estimate total benthic population parameters. With few exceptions, the case study results indicated that the study design used was efficient for estimating population parameters.

Efficiency index values based on total abundance data ranged from 5 to 44 percent for all stations. Values greater than 30 percent were calculated for stations NS-08 (34 percent) and SS-04 (44 percent), possibly indicating that results for total abundance at these two fine-grained stations may be less reliable. Efficiency index values using richness ranged from 3 to 32 percent. For the major taxa groups, index values based on crustacean abundance ranged from 5 to 61 percent, with index values exceeding 30 percent calculated for stations AB-01, EW-05, NH-03, SS-04 and WW-09. Index values based on molluscan abundance ranged from 4 to 58 percent; values greater than 30 percent occurred at stations EW-05, NH-03, NH-04, NH-08, and SS-04. Index values based on polychaete abundance ranged from 2 to 41 percent, with the only two exceedances of the 30 percent sampling efficiency value occurring at stations PS-01 and NS-08. Using major taxa group richness data, only two exceedances of the 30 percent sampling efficiency value were calculated: crustacean richness (33 percent) and mollusc richness (53 percent) at Station NH-03. The ranges in sampling efficiency index values using the major taxa group data were as follows: 4 to 33 percent for crustacean richness; 4 to 53 percent for mollusc richness; and 2 to 21 percent for polychaete richness.

Power analyses were conducted to evaluate the ability to correctly detect differences among or between stations. Of particular interest was the ability to correctly identify, as significant, a 50 percent reduction of abundance measures relative to reference abundance indices. Thus, the power analysis was based on calculating the achievable minimum detectable difference (MDD) that would potentially yield a significant difference between groups or stations being compared. The power analysis was based on the approach developed by Scheffe (1959) and Cohn (1977) and found in the Ocean Data Evaluation System (Tetra Tech, 1987). Analyses were conducted using both transformed and original abundance data, in addition to original richness data. The estimate of the variance was derived from the mean square error term in the ANOVA results. Additional inputs to the analysis included a Type I error rate of 0.05 (5 percent) and a Type II error of 0.20 (20 percent). The MDD for declaring significant differences among any possible station pairs is presented in Table 3a. The MDD that would potentially result in a statistical significant outcome for tests between stations and the associated reference station(s) is presented in Table 3b.

Based on the EBAP sampling design (a total of twenty stations with five replicates each), the minimal detectable difference (MDD) for among stations comparisons, expressed as a percent of the mean, was 55 percent of the mean for richness. In other words, the mean richness at a single station would need to be reduced by more than 55 percent from the overall group mean to be declared significantly different. Non-transformed major taxa group richness MDDs ranged from 66 percent (polychaete richness) to 98 percent (crustacean richness) of the mean. Non-transformed abundance MDDs ranged from 114 percent (polychaete abundance) to 447 percent (crustacean abundance) of the mean for 5 replicates. Transformation of the data tended to lower the MDDs to within the range of the difference of concern (50 percent) under the Sediment Rule. As an example, MDDs for transformed abundance indices ranged from 21 percent (total abundance) to 52 percent (crustacean abundance).

The MDDs based on the evaluation of differences between stations and reference conditions by habitat type tend to be slightly higher than those for detecting among station differences for all station pairs. As an example, the MDDs for total abundance ranged from 13 percent (20 to 50 percent fines habitat category) to 27 percent (50 to 80 percent fines habitat category). This is likely due to the increased variability that occurs when only subsets of the data are examined in any one test. For most indices and habitat categories, the ability to detect at least a 50 percent difference was not achievable but was generally less than 100 percent of the mean.

2.3. Descriptive Biological Indices

Richness, total abundance, major taxa group abundance and richness, the infaunal trophic index (ITI), community composition based on numerically dominant taxa, and several measures of diversity were evaluated in the Elliott Bay case study. Station and sample characteristics based on these indices are described below.

2.3.1. Richness

Mean richness (number of taxa per 0.1 m^2) among Elliott Bay stations ranged from 6 taxa (Station NH-03) to 80 taxa (Station AB-01) (see Table 4). The mean number of taxa at seven of the Elliott Bay stations (EW-05, EW-11, KG-01, NH-03, NH-04, NH-08, and NS-08) fell below the range of values (44 to 59) reported for the Port Susan reference stations, while this range was exceeded at three other stations (AB-01, NH-02 and NS-03). Total pooled richness [the number of unique taxa across all replicate samples collected from a station (i.e., each new taxon is counted only once at a station)] among the Elliott Bay stations ranged from 23 taxa (Station NH-03) to 165 taxa (Station AB-01). At the reference stations, total pooled richness ranged from 85 taxa (Station PS-01) to 119 taxa (PS-04).

2.3.2. Abundance

Abundance (number of individuals) data for each sample collected from the 16 sampling stations in Elliott Bay and the four Port Susan (PS) reference stations are presented in Table 4. The mean abundance, expressed as the average number of individuals per 0.1 m^2, among stations located in Elliott Bay ranged from 32 individuals (Station NH-03) to 2,238 individuals (Station WW-14). Mean abundance at four stations (EW-05, NH-03, NH-08, and

NS-08) was lower than the range of values (503 to 723) reported for the reference stations in Port Susan. In contrast, the mean abundance of benthic organisms at nine Elliott Bay stations (AB-01, EW-11, KG-01, NH-04, NS-03, SS-04, WW-09, WW-11, and WW-14) exceeded the range of values reported for the Port Susan stations.

2.3.3. *Major Taxa Abundance*

Abundances of major taxonomic groups (crustaceans, molluscs, polychaetes, echinoderms and miscellaneous taxa) are summarized in Table 5. Polychaetes were generally the most abundant taxonomic group at the Elliott Bay stations, representing up to 97 percent of the total abundance at each of these stations, with values typically greater than 50 percent. The relative total abundance of polychaetes at 13 of the 16 Elliott Bay stations exceeded the maximum relative total abundance of polychaetes (43 percent) reported for any of the Port Susan reference stations.

Molluscs were the most abundant taxonomic group at three of the four Port Susan stations (PS-02, PS-03, and PS-04), with relative abundance values ranging from 39 to 45 percent. In contrast, molluscs accounted for less than 15 percent of the total abundance among all but three of the Elliott Bay stations (AB-01, NS-03, and SS-11). The relative abundance of crustaceans was typically more variable among both the Elliott Bay and Port Susan stations. Crustaceans were the most abundant taxonomic group at reference station PS-01, representing 36 percent of the total abundance. This value was exceeded only by stations WW-11 (48 percent) and SS-04 (64 percent) in Elliott Bay. Crustaceans were the least abundant taxonomic group at two of the four reference stations (PS-02 and PS-03), and at 6 of the 16 stations in Elliott Bay (AB-01, EW-05, EW-11, KG-01, NH-08 and NS-08).

Echinoderms were the least abundant major taxonomic group and were absent from several stations throughout Elliott Bay and Port Susan. Miscellaneous taxa represented less than one percent of the total abundance at all stations except NH-02 (approximately 5 percent).

2.3.4. *Major Taxa Richness*

The number of taxa represented by three of the five major taxonomic groups (i.e., crustaceans, molluscs, and polychaetes) is summarized in Table 6. Richness data for echinoderms and miscellaneous taxa were not evaluated because these taxonomic groups generally represented less than one percent of the total abundance among all stations.

At all Elliott Bay and Port Susan stations, highest mean richness values were observed for polychaetes. Mean polychaete richness at four Elliott Bay stations (AB-01, NH-01, NH-02 and NS-03) exceeded the range of richness values (22 to 34 taxa) reported for the Port Susan stations, while mean polychaete richness at five stations (EW-05, KG-01, NH-03, NH-04 and NS-08) fell below this range of reference values. The mean number of mollusc taxa did not exceed 10 taxa at over 80 percent of the Elliott Bay stations; mollusc richness at the Port Susan reference stations ranged from 11 to 14 taxa/0.1 m^2. Crustaceans generally represented the second-highest number of taxa present at the Elliott Bay stations. Mean crustacean richness at three stations in Elliott Bay (AB-01, NS-03 and SS-11) exceeded the range (8 to 12 taxa) reported for the reference stations sampled in Port Susan, while mean crustacean richness at five stations (EW-05, KG-01, NH-03, NH-08, and NS-08) fell below the reference values.

2.3.5. *Infaunal Trophic Index*

Infaunal trophic index (ITI) values are presented in Table 7. ITI values calculated using the Elliott Bay data ranged from 9 (Station NH-03) to 68 (stations KG-01, NH-08 and SS-11), with all falling below the range of ITI values (71 to 74) calculated using the Port Susan reference station data. In general, ITI values less than 65 are indicative of benthic communities composed of transitional or pollution-tolerant taxa. ITI values of less than 35 occurred at stations EW-05, NH-03, and NS-08, indicating communities composed predominantly of surface or subsurface deposit feeders. ITI values at all other Elliott Bay stations were greater than 60, indicating surface or suspended detrital-feeding communities.

2.3.6. *Diversity*

Various indices of the distribution of individuals among species (i.e., diversity) are presented in Table 7, including Shannon-Weiner, Swartz's dominance, and Pielou's evenness and dominance. Shannon-Weiner diversity index (H′) values among the Elliott Bay stations ranged from 0.35 (stations NH-03 and NH-04) to 1.53 (Station NH-02). Values of H′ calculated for the Elliott Bay stations were typically lower than the range of values (1.09 to 1.18) for the Port Susan reference stations, with the exception of stations AB-01, NH-01, NH-02, NS-03, and SS-11, where diversity indices exceeded reference values.

A similar pattern was observed for the Swartz's dominance index (SDI) values, with Elliott Bay stations typically characterized by SDI values lower than the reference station values. The same stations at which H′ values exceeded reference had SDI values within or above the range reported for the reference stations. However, nine of the remaining Elliott Bay stations had SDI values less than 5.0, suggesting that the communities at these stations were stressed. Among these nine stations, two (EW-05 and NH-03) were numerically dominated by *Capitella capitata*, three (EW-11, KG-01, and NS-08) were dominated by *Tharyx multifilis*, two (NH-04 and WW-14) were dominated by *Cirratulus cirratus*, and two (SS-04 and WW-11) were dominated by *Leptochelia dubia*.

Evenness (J) values for the Elliott Bay stations ranged from 0.24 (Station NH-04) to 0.73 (stations NH-01 and NH-02), while Port Susan stations ranged from 0.63 to 0.69. Higher evenness values indicate that individual organisms are more homogeneously distributed among taxa. As the complement of evenness, dominance (D) values among Elliott Bay stations ranged from 0.27 (stations NH-01 and NH-02) to 0.76 (Stations NH-04). Communities dominated by one or two relatively abundant taxa are reflected in dominance values approaching 1.0. Dominance values for 10 of the 16 stations in Elliott Bay were higher than those reported for the Port Susan reference stations, which ranged from 0.31 to 0.37.

2.3.7. Community Composition Based on Numerically Abundant Taxa

Compilation of the top ten numerically abundant taxa at each station resulted in a matrix represented by a total of 63 species (see Table 8). Among the Elliott Bay stations, 53 species represented the top ten numerically abundant taxa. Ten of the 19 taxa that composed the top ten dominant array at the Port Susan reference stations were also among the top ten numerically abundant taxa at the Elliott Bay stations.

Tharyx multifilis, *Axinopsida serricata*, *Euphilomedes carcharodonta*, *Lumbrineris* spp., *Cirratulus* spp., *Capitella capitata*, *Leptochelia dubia*, and *Prionospio steenstrupi*, *Notomastus tenuis* were the most frequently occurring dominant taxa among the Elliott Bay stations. Of these species, the polychaete *Tharyx multifilis* was the most abundant taxon at stations EW-11, KG-01, NH-02, NH-08, NS-08, SS-11 and WW-09, and was second-highest in abundance at stations SS-04 and WW-11. The predatory tanaid crustacean *Leptochelia dubia*, was among the top one or two dominant taxa at NH-01, NH-02, WW-09, and WW-11. The opportunistic polychaetes *Capitella capitata* and several Cirratulidae species were among the top three dominant taxa at stations EW-05, NH-03, NH-08, NS-08 and WW-14. *Axinopsida serricata* and *Euphilomedes carcharodonta* were among the top three dominant taxa at stations AB-01, NS-03, and SS-11. Among the reference stations, *Axinopsida serricata*, *Euphilomedes carcharodonta*, *E. producta*, and *Psephidia lordi* were among the most abundant species at each station. Of these species, *Axinopsida serricata* was the most abundant taxon at Station PS-02, and *Psephidia lordi* was numerically dominant at stations PS-03 and PS-04. The most abundant taxon at Station PS-01, *Protomedia prudens*, was not among the top ten numerically abundant taxa at any other Port Susan or Elliott Bay station. PS-01 was also the only fine-grained reference station sampled during EBAP.

2.4. Differences Among Stations Using Port Susan as Reference

Relationships among stations based on richness, total abundance, major taxa abundance, and major taxa richness were examined using analysis of variance techniques. Analysis of variance (ANOVA) tests were conducted to determine whether significant differences existed among all stations. Tests were run using three groups of data to identify differences among: (1) all Elliott Bay stations; (2) all fine-grained stations including fine-grained reference stations; and (3) all coarse-grained stations including coarse-grained reference stations. Log-transformed data were used in the ANOVA to satisfy the normality assumptions required by this method. As part of the ANOVA procedure, Tukey's honestly significant difference (HSD) *a posteriori* pair-wise contrasts (as applied in SYSTAT; described in Sokal and Rohlf, 1981) were calculated for all possible station pairs to identify significant differences.

Independent t-tests were also conducted for two-sample comparisons (i.e., Elliott Bay stations versus reference stations) to determine whether statistically significant differences existed between site and reference stations. Use of the t-test follows the current guidance promulgated in the SMS Rule. The independent t-test procedure applied in this case study is based upon the assumption that the data are approximately normally distributed, but does not assume that the samples have equal variances. To satisfy the normality assumption, log-transformed data were used. Because the t-test is most appropriately applied to a single two-sample comparison, the experiment-wise error rate was lowered to 0.001 to reduce the probability of making a Type I error. This type of error (i.e., saying a community is impacted when it is not) increases dramatically when t-tests are applied to multiple sample pairs. It should be noted that Tukey's *a posteriori* pair-wise test conducted as part of the ANOVA adjusts for the experiment-wise error rate resulting from multiple comparisons as part of the procedures. Table 9 illustrates the increase in a Type I error rate that occurs with increasing number of comparisons. Use of such a conservative alpha level as 0.001 also tends to increase the Type II error rate (i.e., saying a community is the same as a reference community when it is not).

2.4.1. Analysis of Variance Results

The ANOVA using abundance and richness data for the Elliott Bay and reference stations indicated that there were significant differences among stations in richness, total abundance, and major taxonomic group abundance and richness. ANOVA results are summarized in Tables 10 to 17. Results of the ANOVAs using richness and total abundance indicated that 10 of the 16 Elliott Bay stations were not significantly different from their "matching" reference stations [reference data were pooled by grain size (i.e., coarse and fine-grained stations)]. Only two fine-grained (KG-01 and NS-08) and two coarse-grained (EW-05 and NH-04) Elliott Bay stations had significantly fewer taxa than their respective pooled reference stations, and a total of three stations (EW-05, NH-03 and NS-08) had significantly fewer individuals than reference.

Results of the ANOVAs using major taxonomic group abundance and group richness indicated that molluscs had the most frequently reduced abundance and richness when compared to the pooled reference stations, and that these reductions were measured at both fine- and coarse-grained stations. Significantly lower values for at least one of the six major taxa indices occurred at six fine-grained (EW-11, KG-01, NH-03, NS-08, WW-09, and WW-11) and four coarse-grained stations (EW-05, NH-01, NH-02, and NH-04). Crustacean abundance was significantly depressed compared to pooled reference stations at four fine-grained (KG-01, NH-03, NH-08, and NS-08) and two coarse-grained (EW-05 and NH-04) stations in Elliott Bay. In contrast, polychaete abundance was significantly reduced at only two stations (EW-05 and NH-03). Results of ANOVA using richness data for crustaceans and polychaetes often did not indicate significant differences from reference, with the exception of stations EW-05 and NH-03, which had significantly reduced values for both crustacean and polychaete richness, and stations NH-04 and NH-08, which had significantly lower polychaete richness than pooled reference.

Similar results were reported for the t-tests, with few exceptions (see Tables 18 through 25). A lack of agreement between the ANOVA and t-test results was observed for all indices tested, for a total of 15 occurrences. In ten of these cases, the t-test failed to detect a difference declared as significant by the ANOVA. In the remaining five cases, the t-test suggested a station was different from reference when the ANOVA results suggested it was not. It is highly likely that the t-test results were impacted by a higher Type II error rate which thus contributed to the lack of agreement between the ANOVA and t-test results.

2.4.2. Classification Analyses Results

Classification (cluster) analyses were conducted using the Bray-Curtis proportional similarity index with a group-averaging clustering algorithm. Before the classification analysis was conducted, the data matrix was reduced to 214 taxa by dropping any taxa with less than 5 individuals in the entire data set to meet software matrix size requirements. Data were log-transformed to minimize the effect of numerically dominant taxa. Results of the classification analyses are presented in Table 26 and Figure 2.

The degree of similarity among stations tended to be relatively high; several stations or station groups were linked at greater than 60 percent similarity, and the majority of the remaining station groups were linked at between 50 and 60 percent similarity. However, most importantly, the reference stations typically formed clusters separate from the Elliott Bay stations. This result reflects the differences in community composition between reference and potentially impacted stations in Elliott Bay that may be due, in part, to geographic variability in species distributions. As an example, several Elliott Bay stations represented relatively unimpacted communities based on the abundance and richness indices (e.g., Station AB-01), yet did not have a high degree of similarity with Port Susan communities. Of the 53 taxa comprising the numerically dominant array for the Elliott Bay stations, only 10 were shared with the Port Susan reference stations.

All Elliott Bay stations were linked at greater than 49 percent similarity, with the exception of stations NH-03, NH-04, EW-05, and NS-08, which were the least similar to all other Elliott Bay stations. Using all taxa with more than four individuals in the entire data set, two distinct clusters of Elliott Bay stations were formed at 60 percent or greater similarity: (1) stations AB-01, SS-11, and NS-03 formed a cluster with a similarity of 63 percent among members (2) stations NH-01 and NH-02 formed another cluster with stations WW-09, WW-11 and WW-14 that exhibited about 60 percent similarity or greater among members. Station SS-04 was linked with this cluster, but at lower level of similarity. Station EW-11, KG-01, and NH-08 formed a group with between 50 to 60 percent similarity among members.

Separate clusters were formed using the reference stations: PS-03 and PS-04 clustered at 74 percent similarity; PS-01 and PS-02 clustered at 63 percent similarity; and these two clusters grouped together at a similarity of 55 percent. The cluster formed by the reference stations grouped with most of the Elliott Bay stations at less than 33 percent similarity.

The stations forming the first cluster of Elliott Bay stations (i.e., AB-01, SS-11 and NS-03) are located along the outer portions of the bay (near Alki Beach and along the northern portion of the Seattle waterfront). Sediment at these stations was coarse-grained with the exception of SS-11, which was characterized by 68 percent fines (silt+clay). The benthic communities at these stations shared dominant taxa including the mollusc *Axinopsida serricata* and crustacean *Euphilomedes carcharodonta*, along with the molluscs *Macoma carlottensis* and *Odostomia* spp.

Stations NH-01 and NH-02 are located along the northern shoreline of Harbor Island. These stations were classified as coarse-grained, with percent fines of 19 and 31 percent, respectively. Numerically dominant taxa shared between these two stations included the crustacean *Leptochelia dubia*, the polychaetes *Tharyx multifilis*, *Notomastus tenuis*, *Mediomastus californiensis*, *Prionospio steenstrupi*, and *P. cirrifera*, and the crustacean *Euphilomedes carcharodonta*. Stations WW-09, WW-11 and WW-14 are all located within the West Waterway in the Duwamish River estuary. The sediment at these stations was composed primarily of fine sand, silts and clays, ranging from 62 to 72 percent fine-grained material. The benthic communities at these three stations were dominated by *Leptochelia dubia*, *Tharyx multifilis*, *Lumbrineris* spp., *Notomastus tenuis*, and *Photis brevipes*. *Odostomia* spp., *P. steenstrupi*, and *P. cirrifera* were also abundant at several of the West Waterway stations. Station SS-04 is located along the south Seattle waterfront and was characterized as a fine-grained habitat with a high percent TOC (6.8 percent). However, this station shared many of the same taxa that were dominant at the north Harbor Island and West Waterway stations, including *Leptochelia dubia* and *Tharyx multifilis*.

Substrate composition at the reference stations, which together clustered at 55 percent similarity, ranged from 11 to 88 percent fines. The benthic community at stations PS-03 and PS-04, which clustered with a higher degree of similarity than stations PS-01 and PS-02, was numerically dominated by the mollusc *Psephidia lordi* and two species of the crustacean *Euphilomedes* (*E. carcharodonta* and *E. producta*). Stations PS-01 and PS-02 were also characterized by the numerically abundant mollusc (*Psephidia lordi*), as well as the polychaete *Terebellides stroemi*. Except for *Euphilomedes carcharodonta*, these species were not typically among the numerically dominant taxa at the Elliott Bay stations, which contributed to the overall low percent similarity between the reference and Elliott Bay stations.

2.4.3. Ordination Results

Relationships among stations based on community composition was also examined using a principal coordinates (PCOR) analysis. Procedures were provided in the Community Analysis System documentation (CAS; version 5.0) published by Ecological Data Consultants (1994). Although the software can handle a large number of taxa, rare taxa were dropped from the analyses because PCOR is highly sensitive to the presence of taxa with only a few individuals. Relationships among stations tend to be difficult to discern graphically with the "noise" caused by the presence of rare taxa. Therefore, all taxa representing more than a total of seven individuals (summed across all samples) were used in this analysis. Abundance data were log-transformed [ln(x+1)] and standardized prior to generation of a dissimilarity matrix. Gower's Distance Index was used as a measure of (dis)similarity.

Results for the initial analysis are presented in Figure 3. Stations are displayed in three-dimensional space based on the community structure attributes (in this case species). Distance among stations or groups of stations is indicative of the degree of similarity among them. Each of the axes present represent species that "explain" or result in the greatest amount of separation among stations. These first three factors shown in the plot as Principal Axes I, II, and III, accounted for about 45 percent of the variance among stations. The difference between reference stations and Elliott Bay stations is very apparent. Only stations AB-01, NS-03, and SS-11 (which also grouped together in the cluster analysis) fall within the proximity of any reference station. All other Elliott Bay stations grouped tightly together, with the exception of NH-02, which was spatially separated from all other stations.

Using techniques available as part of CAS, a 95 percent confidence envelope was calculated and projected into three-dimensional space around the reference stations for each of the possible pairings among the axes (Figures 4a, b, and c). If an Elliott Bay station plotted within this space, it was interpreted as being not statistically different from reference. Conversely, if a station occurred outside of this space, it was considered significantly different from reference. For this analysis, each of the possible combinations was tested separately. Based on these analyses, Elliott Bay stations were not considered similar to reference conditions.

2.5. Summary of the Case Study Results and Evaluation of Statistical Methods

All statistical methods and indices used to evaluate differences among stations appeared to be adequate in detecting differences between highly stressed communities versus unstressed communities, but some techniques provided more objective measures of community health for moderately stressed benthic communities. Comparisons of results using different indices are presented in Table 27 and are discussed below with regard to the results of the Elliott Bay case study.

Using the current SMS data evaluation approach, benthic communities at four stations (i.e., EW-05, NH-03, NH-04, and NS-08) did not meet the SMS Cleanup Screening Level (CSL) criteria, by having greater than 50 percent depressions in abundance for at least two major taxa groups relative to the Port Susan reference areas. Stations KG-01, NH-01, NH-02, and NH-08 exhibited statistically significant depressions in abundance for only one major taxa group, and thus did not meet the Sediment Quality Standards (SQS) biological criteria. The remaining stations (AB-01, EW-11, NS-03, SS-04, SS-11, WW-09, WW-11, and WW-14) did not exceed either standard, using the SMS endpoints. The failures of the CSL and SQS criteria were initially considered as the thresholds for identifying highly stressed and moderately impacted communities. Consideration of other indices and evaluation techniques was used to refine the identification of highly impacted and moderately impacted stations.

The identification of the benthic communities at stations EW-05, NH-03, and NS-08 as highly impacted relative to other Elliott Bay and reference stations was apparent based on all indices and statistical methods, including the SMS approach, used to evaluate the data. Communities at these three stations were characterized by extremely low total abundances, all of which were significantly lower than mean reference abundance based on the results of the ANOVAs and t-tests ($P<0.05$ and $P<0.001$, respectively). The ANOVA results also indicated that the mean total abundance at Station NH-03 was significantly lower than all other Elliott Bay stations. In addition, abundances of the three major taxonomic groups (i.e., crustaceans, molluscs and polychaetes) were depressed at Station NH-03, with abundances less than 50 percent of reference area abundances and significantly lower. Similar results were observed at stations EW-05 and NS-08, which were characterized by significantly lower abundances of crustaceans and molluscs compared to reference.

Measures of diversity at stations EW-05, NH-03 and NS-08 also indicated that the benthic communities were highly stressed. Mean richness values for stations EW-05 and NS-08 were significantly lower than reference based on both ANOVA and t-test results. The ANOVA and t-test results using major taxonomic group richness also indicated that mean richness values for all three taxa groups at stations EW-05 and NH-03 were significantly lower than reference area taxa group richness. At Station NS-08, significantly depressed richness values for molluscs and polychaetes were also observed. Values of Shannon-Weiner diversity, Swartz's dominance index, and evenness were substantially lower than those measured at the reference area, providing additional evidence of adverse impacts to the benthic communities at these stations.

The communities at stations EW-05 and NH-03 were numerically dominated by the pollution-tolerant polychaete *Capitella capitata*. This polychaete, in conjunction with another pollution-tolerant species (*Tharyx multifilis*), numerically dominated the community at Station NS-08. The dominance of these taxa was reflected in the high relative abundances of polychaetes (greater than 80 percent of the total abundance) and the low ITI values that were indicative of communities represented by surface deposit feeders at these stations. In addition, results of the classification and ordination analyses indicated that stations EW-05, NH-03, and NS-08 were dissimilar from reference stations and tended to represent outliers (most dissimilar from reference and all other Elliott Bay stations).

Depressions in major taxa abundance for stations KG-01 and NH-04 were also indicative of highly stressed benthic communities, although Station KG-01 would not have been declared impacted using the SMS approach, because the greater than 50 percent reduction in mollusc abundance at this station was not statistically significant. However, examination of measures of diversity and community composition supported the designation of these stations as adversely impacted.

Stations KG-01 and NH-04 were both characterized by reductions in total richness values, as well as depressions in mean abundances of crustaceans and molluscs compared to reference values. Reductions were statistically significant in all cases, except mollusc abundance at KG-01, where the power was insufficient to detect a 50 percent difference from the within-habitat reference as significant. Values of H′, J and SDI were substantially lower than reference at both stations. However, the ITI values were within the range reported for many of the other Elliott Bay samples, and therefore did not distinguish these stations.

Unlike the benthic communities at the first group of stations considered to be highly stressed (EW-05, NH-03, and NS-08), these two station exhibited increased total abundance and polychaete abundance that exceeded the range reported for the reference values. The high total abundance measures for stations KG-01 and NH-04 reflected the domination of these communities by polychaetes. Review of the species level data for stations KG-01 and NH-04 indicated that both stations were numerically dominated by pollution-tolerant polychaetes: *Tharyx multifilis* accounted for nearly 75 percent of the total abundance at Station KG-01, and *Cirratulus cirratus* represented 85 percent of the total infaunal abundance at Station NH-04. Results of the classification analyses indicated that overall community composition at both stations were relatively dissimilar from reference, and NH-04 was one of the stations identified as an outlier in the cluster dendrogram.

The need for comparing several different measures of benthic community structure to evaluate the relative health of benthic communities was most apparent in evaluating data from remaining stations that initially were considered to be moderately stressed or unstressed. The mean total abundance of organisms collected from all these stations fell within or above the range of values reported for the reference area. Richness values also fell within or above the range reported for the Port Susan stations, with the exception of stations EW-11 and NH-08, which had values slightly (but not significantly) lower than reference. ITI results for all of these stations were indicative of relatively unstressed communities. However, further review of major taxa group abundance and richness data, as well as species-level data, indicated that these benthic stations formed two groups that were substantially different, with one group exhibiting moderate stress (EW-11, NH-01, NH-02, NH-08, WW-09, WW-11, and WW-14), while the other did not (AB-01, NS-03, SS-04, and SS-11).

Abundance of at least one of the three major taxa groups was substantially lower (< 50 percent) than reference at all stations identified as moderately stressed, except for Station WW-11 (other indices lead to the inclusion of this station in the moderately stressed category). However, in several cases (mollusc abundance at WW-09 and WW-14), the ANOVA results were not statistically significant. This lack of significance is a reflection of inadequate power to detect a 50 percent change in abundance; for this study the change would need to be greater than 69 percent of the reference mean in order to be declared significant (see Table 3b). As with several highly stressed stations, significantly higher polychaete abundances relative to reference were also observed at EW-11, NH-02, WW-09, WW-11, and WW-14. In the case of EW-11 and WW-14, polychaetes represented greater than 90 percent of the total number of individuals present. No significant depressions or enhancements in major taxa group abundances were observed for those stations identified as unstressed, with the exception of AB-01 where polychaete abundance was greater than reference. Mean mollusc richness at stations EW-11, NH-01, WW-09, and WW-11 was lower than reference. Similar reductions in richness indices were not obtained using data collected from the apparently unstressed stations.

Evaluation of diversity indices also suggested that some of the stations were impacted. Shannon-Weiner diversity, evenness, and dominance were less than the reference range for stations EW-11, SS-04, WW-11 and WW-14. Swartz's dominance index was depressed relative to reference at stations EW-11, NH-08, SS-04, WW-09, WW-11, and WW-14.

Review of species-level data indicated that at all but one (Station NH-01) of the moderately stressed stations were characterized by the pollution-tolerant polychaete *Tharyx multifilis* among the top ten dominant taxa. Station NH-01 did not share the presence of *Tharyx multifilis* among the abundant taxa, rather it was dominated by *Leptochelia dubia*, an opportunistic tanaid that typically colonizes recently disturbed sediment. This species was also abundant at several of the moderately stressed stations, but only exhibited a similar dominance rank at Station WW-11 and SS-04. One or more lumbrinerid polychaetes were also characteristic of some of the moderately stressed stations (EW-11 and NH-08). In contrast, two detrital-feeding species, the mollusc *Axinopsida serricata* and the crustacean *Euphilomedes carcharodonta*, were numerically dominant at stations AB-01, NS-03 and SS-11. These two species represented less than 6 percent of the total abundance at the moderately stressed stations, but accounted for up to 30 percent of the total abundances among the reference stations.

The results of the cluster analysis tended to support differentiation between the moderately impacted and unimpacted stations. Stations NH-01, NH-02, WW-09, WW-11, and WW-14 formed a group with a high degree of similarity in community composition among members, while AB-01, NS-04, and SS-11 formed another group with a high degree of internal similarity. Station SS-04 appeared to be most similar to the first group, but at less than 60 percent similarity in species present. Both groups were dissimilar to the group formed by the reference stations.

Inclusion of multivariate results, and abundance and diversity indices in addition to major taxa abundance, and use of a numerical reduction without statistical significance in light of inadequate statistical power resulted in the following changes in station designation when compared to the current SMS approach:

- Station KG-01 became a highly stressed station based on the reduction of two major taxa group abundances relative to reference, without relying upon the statistical significance result.

- Stations EW-11, WW-09, WW-11, and WW-14 were classified as moderately stressed based on use of a numerical reduction in a single major taxa group abundance (without associated statistical significance), reduced diversity indices, depressed Swartz's Dominance Index, and a shared membership in the same cluster group among the West Waterway stations.

Station NH-01 was retained as a moderately stressed station, because of its shared membership in the cluster with NH-02, and the West Waterway stations. Some consideration was given to dropping this designation, because the reduced molluscan abundance and richness may be been due to the dominance of the tanaid, *Leptochelia dubia*, at this station. This tanaid builds dense tube mats and is highly predatory, which effectively excludes many other infaunal organisms from settling and thriving at the same location. Development and use of an "indicator" taxa list may have allowed a clearer determination of the status of this location.

Stations EW-11 and NH-08 might have also been highly stressed. Both these stations were dominated by polychaetes, which made up between 80 and 90 percent of the sample community. The SDI was also extremely low, and crustaceans (often representing more sensitive taxa) represented a very small percentage of the community. In addition, these stations shared community characteristics displayed by the highly stressed station, KG-01). However, only one major taxa group was reduced in abundance at each of these stations so the moderate designation was retained. All other station designations remained the same, as indicated in the SMS evaluation.

3. COMPARISON OF RESULTS USING PUGET SOUND REFERENCE VALUES VERSUS SITE-SPECIFIC REFERENCE VALUES

Statistical testing of all benthic indices reported in this case study and previously reported in the Everett Harbor case study were conducted using the Puget Sound reference data sets as a replacement for site-specific reference data. Benthic indices representing reference conditions are summarized in Table 28. Reference values exhibited a range of variability, with the maximum variability reported for the finer-grained habitats. The minimum value for some indices in the finer-grained habitat categories was zero (crustacean richness and abundance, and mollusc abundance). Puget Sound reference values were compared to the results of the Elliott Bay, Everett Harbor and Port Susan benthic analyses using the four grain size categories for the depth range from 0 to 150 feet as habitat categories. A summary of the station means, site-specific reference (i.e., Port Susan) means, and proposed Puget Sound reference means for each benthic index by each of the four habitat categories is presented in Tables 29 through 36. In general, the mean Puget Sound reference values were higher for the coarser-grained habitats and lower for the finer-grained habitats, compared to the site-specific means.

Results of both ANOVA and pair-wise testing procedures using both the Puget Sound reference values and the site-specific reference values by grain size category are summarized in Tables 37 through 48. For this comparison, only the outcome of the ANOVAs will be discussed. In the case where the Port Susan data did not allow calculation of a reference value for a specific grain size class (i.e., 50 to 80 percent fine), the performance of the Puget Sound reference values was compared to the original use of fine-grained (i.e., greater than 50 percent fines) reference value. The reevaluation of ITI, SDI, diversity and evenness for Everett Harbor stations were not included in this comparison; in the original case study these indices were not subjected to statistical testing, therefore these results were not available for inclusion here.

In general, there was broad agreement between the results of statistical comparisons using site-specific and Puget Sound reference data sets, although significance levels varied. However, use of the Puget Sound reference data sets resulted in identification of fewer Elliott Bay and Everett Harbor stations as being different compared to reference conditions than use of site-specific reference data. Discrepancies in declaring a station as similar or dissimilar to a reference value occurred among all benthic indices and habitat categories, with the exception of the coarsest-grained habitat (i.e., 0 to 20 percent fines). This absence of disagreement in results may be a function of the size of the data set representing the coarsest habitat category in this case study (only two stations fall in this category).

The greatest frequency of disagreement occurred among the results for total abundance, mollusc abundance and polychaete abundance. The greatest agreement occurred among the results for crustacean richness, Shannon-Weiner diversity, Swartz's dominance index and evenness. Using the ANOVA results representing comparisons to Port Susan reference data as the basis, the number and types of reversals in the outcome of the tests using Puget Sound reference data are summarized in Table 49. It should be noted that about half of the differences in declarations of significance versus non-significance of a given test would not have changed the outcome of any management decision, because the site index value was higher than either reference value. When these disagreements were examined in light of declaring a station impacted or not, use of primarily mollusc abundance and mollusc richness would have led to a different management decision.

4. RECOMMENDATIONS

The following recommendations are based on the case study results and the comparisons of different data sets representing reference conditions.

4.1. Analytical Techniques

WESTON strongly recommends that the Rule be modified to replace the t-test with ANOVA procedures. A Dunnett's *a posteriori* pair-wise test is then recommended to establish which samples are significantly different from reference. Dunnett's procedure allows the identification of samples representing control or reference, so that samples are only compared to the reference set and not all other stations. This statistical approach most closely reflects the hypothesis and sampling design most often used in benthic community investigations for sediment management purposes. According to Zar, use of a two-sample test (i.e., a t-test) to test a multi-sample hypothesis is invalid (1984; page 162). As illustrated in Table 9, the Type I error increases dramatically with an increase of only a few comparisons. As an example, selection of an alpha level of 0.05 (i.e., a Type I error rate of 5 percent) to test 10 samples against the same reference sample results in an actual error rate of 23 percent (i.e., 23 percent of the time, the analyst would say a sample was different from the reference when it was not). To compensate, the analyst can select a smaller alpha level, but use of an overly conservative alpha level then negatively impacts the Type II error rate (i.e., the rate of erroneously declaring a sample as being no different from reference when it is, increases). The approach recommended above addresses all of the short-comings inherent in the use of the t-test.

As a further modification to the approach to statistical evaluations in the Rule, WESTON recommends that statistical power be determined for each investigation or project design, as part of the data evaluation phase. This would allow managers to understand how reliable the outcome of a statistical test is, prior to finalizing decisions. As an example, if two major taxa group abundances were found to be less than 50 percent of a reference value at a location being considered for inclusion in a cleanup area, but were not statistically different from reference, the potential exists for deciding to exclude this location from the final cleanup area. However, if an earlier evaluation of the achievable minimum detectable difference for the specific sampling design suggested that a 70 percent difference would be needed to declare the difference significant, then the evaluator could make the decision to include this location in the cleanup area based on the assessment of the reliability of the significance test for the decision endpoint of interest.

WESTON also recommends that Ecology and other sediment management programs consider the use of multivariate techniques (including use of cluster analysis, at a minimum) that allow statistical testing based on a more complete representation of community structure. This approach would take full advantage of the information available from collecting species level data. Being able to evaluate the entire community membership at stations gives a manager the greatest ability to discern if shifts in community indices are of ecological significance. When descriptive characteristics (e.g., grain size, TOC, diversity indices, top few dominant taxa, chemicals exceeding criteria) are overlain on groupings of stations formed based on overall community composition, physical and chemical factors that are influencing the structure often become more apparent. Many multivariate statistical procedures allow incorporation of the non-biological factors in the test, to facilitate this type of interpretation. Use of multivariate statistics may also address the issue of reference area failures for benthic comparisons. For example, station clustering patterns may be related to gradients in chemical concentrations and thus may be used to identify relatively umimpacted locations within the area to be investigated. Pair-wise comparisons could proceed following this type of examination, based on the least impacted stations representing local reference area conditions. As an example, in the EBAP study, stations AB-01, NS-03, and SS-11 could be considered relatively unimpacted, and be used as the basis for comparisons with other Elliott Bay stations.

Use of multivariate techniques has been most recently demonstrated as part of the evaluation of the benthic communities at the St. Paul habitat restoration site [see Parametrix (1994) for approach]. Multivariate techniques have been applied successfully to the evaluation of benthic communities along the Southern California Bight for a number of years. The majority of the panel members participating in the National Benthic Experts Workshop recommended inclusion of multivariate techniques in the approach to evaluating benthic communities. However, use of these procedures will be most powerful if the community structure of each reference habitat is clearly defined in terms of species (or taxa) composition and abundance. To address this issue, sampling multiple reference stations or increased replication at reference stations may provide advantages, if they are representative of habitat conditions and potential communities at a site.

4.2. Benthic Indices

All of the benthic indices were able to distinguish between severely impacted benthic communities and unimpacted communities. However, these same indices exhibited mixed abilities in identifying moderately impacted communities in Elliott Bay. Use of mollusc abundance and mollusc richness, crustacean abundance, SDI, Shannon-Weiner diversity, and evenness assisted in clarifying which stations may have had moderately impacted benthic communities. Conversely, depressions in total abundance, polychaete abundance, crustacean richness, polychaete richness, and the ITI did not contribute to the ability to identify moderately impacted stations. None of these indices were able to suggest a possible mechanism (e.g., physical disturbance, toxic chemicals, organic enrichment) for the impacts observed. To begin to predict causal factors, examination of the species composition and habitat characteristics was necessary. For example, the dominant species present suggested that one of the stations (NH-01) that was identified as moderately impacted based on reduced molluscan abundance may have been responding to the presence of a colonizing, predatory tanaid crustacean, rather than environmental contaminants. The dominance of *Capitella capitata* at Station EW-05 may have been due, in part, to the high TOC (7.4 percent) that characterized this location. This species complex has long been considered an indicator of organic enrichment. WESTON recommends that Puget Sound sediment management programs pursue development of an indicator species list that includes keystone species (those having a disproportionate effect on community structure), taxa that are highly sensitive to specific contaminant groups, and opportunistic or pollution-tolerant taxa to assist in the determination of the ecological health and degree of impact at sites being addressed in Puget Sound.

Based on the results of this study, WESTON recommends reliance on total richness, major taxa abundance (with modifications to the use of polychaete abundance; see below), diversity, and Swartz's dominance index (SDI) for sediment management decisions. At this time, there does not appear to be strong evidence that the major taxa richness indices (with the possible exception of mollusc richness) will perform substantially better than the total richness or abundance indices, so only the abundance suite and total richness is included in the recommendation. Ecology and other sediment management agencies may want to request that regulated parties include major taxa richness in their investigations for the purpose of evaluating the ability of these indices to support management decisions. However, based on the power analysis results for major taxa richness in this study, (see Tables 3a and b), an increased level of replication will be necessary to be able to detect an ecologically significant difference from reference.

Diversity and evenness are not included in the recommended list, in part, because the ability to identify moderately impacted stations was shared with Swartz's dominance index, a simpler index to calculate and interpret. For the Elliott Bay data set, the ITI was unable to identify moderately impacted stations. This performance is contrary to that observed in the Everett Harbor case study and in other investigations in Puget Sound. WESTON reserves its recommendations regarding the inclusion of the ITI as an evaluation tool at this time. Modifications to the ITI as proposed by Word (1990) should be examined and may improve the performance of this index.

It is also recommended that the criteria for abundance measures currently promulgated in the Sediment Management Standards be modified to include a numerical reduction in abundance that exceeds 50 percent of the reference value, without paired statistical significance, if a power analysis suggests that this difference would not be recognized as significant within the test. The requirement for a statistically significant result could be retained where adequate power was achieved. WESTON further recommends that the criteria for richness measures be based on a statistically significant reduction from reference (i.e., no paired numerical requirement).

As an additional modification, WESTON suggests sediment management programs consider enhancements of polychaete abundance relative to other major taxa groups as an indicator of impacts. As demonstrated in this report, highly stressed communities are typically indicated by a number of indices and are easily identifiable. In each case where polychaete abundance was less than 50 percent of reference, other major taxa groups were also significantly reduced. For the polychaete abundance index, the decision endpoint could be either when polychaetes are greater than 85 or 90 percent of the total abundance or when polychaetes are significantly greater than reference, based on statistical tests.

The SDI is also recommended and can be applied in a statistical test or treated as a simple numerical comparison (i.e., is the index above or below 5.0). Based on the performance of the Shannon-Weiner index in this report, sediment management programs may want to include this index, even though it was not recommended by the Benthic Expert Panel members. Comparisons to reference could be made either on a numerical (diversity less than reference could be used as the endpoint) or statistical basis using a significantly lower diversity as an indicator of impacts.

4.3. Representation and Use of Reference Habitat Data

WESTON recommends that the existing approach of developing site-specific reference conditions for a given project be maintained in sediment management programs, with one exception, as discussed below. The Puget Sound reference data set, in its current version, contains values that may be indicative of impacted communities, and may therefore be unacceptable for characterizing reference habitats. For example, reference ranges for the SDI span from 2 to 37 for coarse-grained habitats. Typically, values less than 5 indicate that a community is severely stressed (i.e., 5 taxa contribute 75 percent of the abundance in a sample). The minimum crustacean richness and crustacean abundance values reported for reference conditions for the finer-grained habitats were zero. Absence of crustaceans has often been used as an indication of an impacted benthic community. Molluscs were also rare or absent in some of the reference samples. WESTON suggests that the reference data set be reevaluated to determine the appropriateness of inclusion of some of the potentially impacted samples.

Initial statistical evaluations by SEA suggest that there may be a degree of geographic variability in representation of reference conditions. Although multivariate analytical results apparently did not confirm any geographic trends, this phenomena has been recorded by a number of marine biologists and oceanographers in their work in Puget Sound. The differences in the distribution of taxa in Puget Sound is strongly affected by the hydrography of the three Puget Sound basins and their relative distance from the Strait of Juan de Fuca (and thus the Pacific Ocean) as a source of infaunal larval recruits. As an example, several of the Elliott Bay stations (AB-01, SS-11, and NS-03) were considered unstressed, yet different statistical approaches suggested that they were different from either the Port Susan or Puget Sound reference. This differences may have been more a function of the geographic variability in community composition than an ecological impact because the reference stations were not associated with Elliott Bay/Central Puget Sound faunal distributions. It is strongly recommended that the Puget Sound reference data sets be evaluated using several different techniques to determine the geographic influence on reference area characteristics. In particular, similarity in community composition should be used as a criterion in combining data to describe habitat categories.

Examination of the community composition at the reference stations would be an appropriate next "step" in the evaluation of the data to refine reference area characterizations. Invaluable information about whether or not the data set for each habitat type was homogeneous or actually represented a number of diverse community types could be gained by examining numerically dominant taxa, at a minimum. If different communities appear to be present within each Puget Sound habitat category, the criteria for identifying habitats should be expanded. In *A Marine and Estuarine Habitat Classification System for Washington State* (Dethier 1990), several other characteristics are used to define subtidal habitats including salinity, the amount of energy in the system (primarily currents), and amount of organic debris (particularly large plant debris, including wood chips). These characteristics should be compiled, to the degree possible, for the existing data set to assist in identifying possible refinements to the reference data sets.

Another possible reference value modification recommended by WESTON is combining some of the reference categories. An examination of reference value indices (see Table 28) suggested that there may be little difference between the two coarsest habitat categories. The two finer-grained habitat categories also appear fairly similar for most indices. Following the refinements discussed above, statistical comparisons among habitat categories could be conducted to determine if any categories should be combined.

Ecology may want to consider use of the Puget Sound reference data sets on a case-by-case basis where reference sample performance failed or where project size and potential impacts are minimal. In these cases, comparisons to the Puget Sound reference data (following the above mentioned refinements) could be used to screen for concerns at the site.

4.4. Sampling Design Considerations

As part of the potential modifications of the Rule, Ecology and other sediment management programs may want to consider incorporation of guidance for sampling program design to improve the effectiveness of benthic indicators in management decisions. Benthic community indices provide regulators with a "picture" of site conditions that incorporates effects on multiple phyla and life stages based on long-term exposures that cannot be achieved in laboratory testing.

Guidance should primarily address the initial planning stages of the investigative process. Without appropriate planning and clear identification of the questions to be answered by the study, no amount of after-the-fact data manipulation or interpretation can be successful if the sampling design did not collect the needed data. Issues that could be addressed in this guidance are briefly discussed below.

Selection of the number of samples and their locations as part of the design process should incorporate as much site knowledge as possible. The level of replication at a station should support sufficient power to detect the desired degree of difference from reference conditions. Historical data from the same area or similar sites within Puget Sound could be used to estimate the parameters for conducting a power analysis, prior to finalizing the sampling design. Reference station locations need to control for effects that are not important to the investigation (e.g., TOC, grain size, depth, presence of wood debris, etc.). Serious consideration should be given to selection of reference stations within the same geographic area as the study site, because of potential geographic variability in faunal distributions. In addition, Ecology and other agencies may want to revisit the use of local background or stations that represent the area associated with lowest concentration of a gradient in the parameters under investigation as the reference comparison for determining the impacted area of a site.

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FIGURES

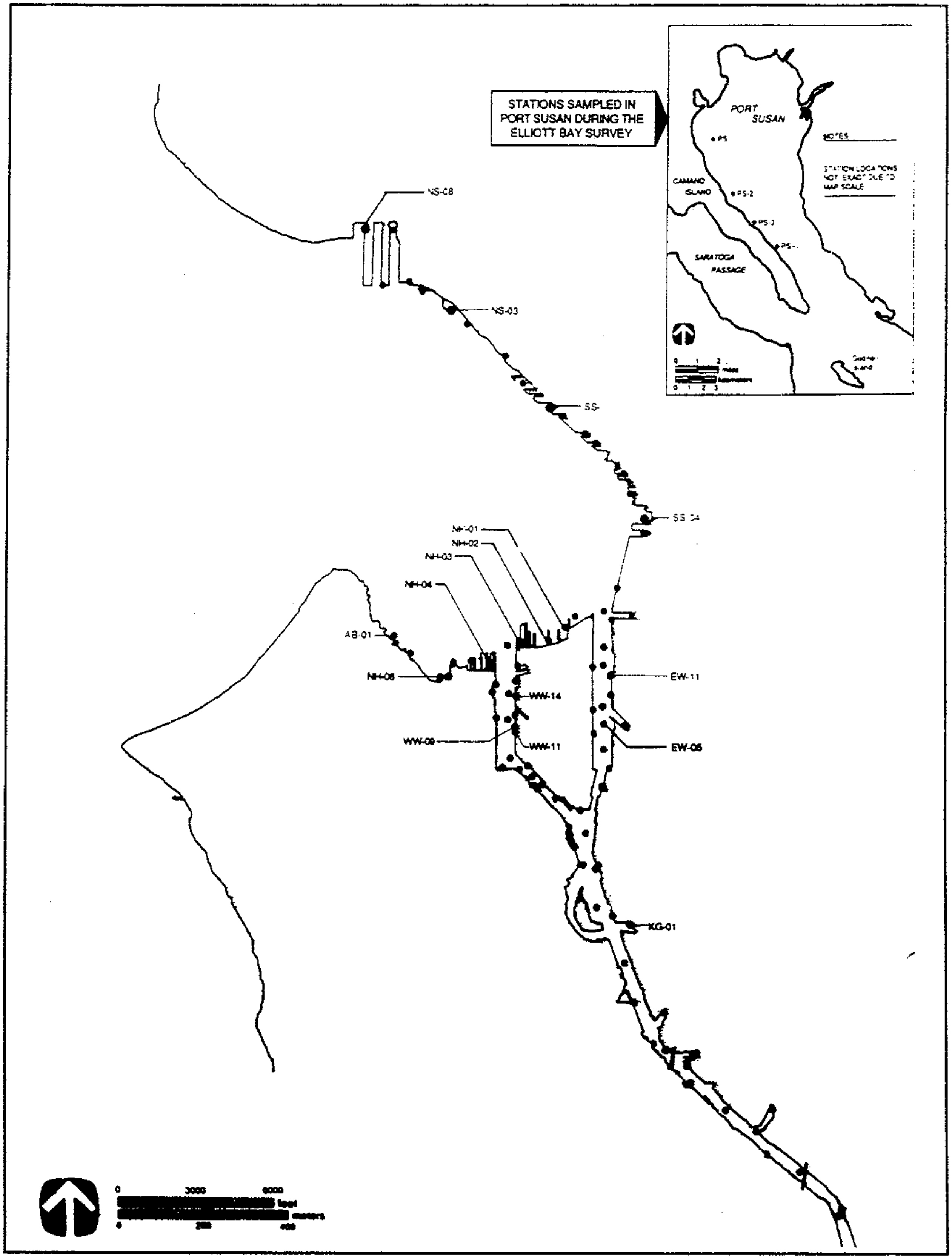

Figure 1. Elliott Bay Action Program (EBAP) Benthic Community Station Locations

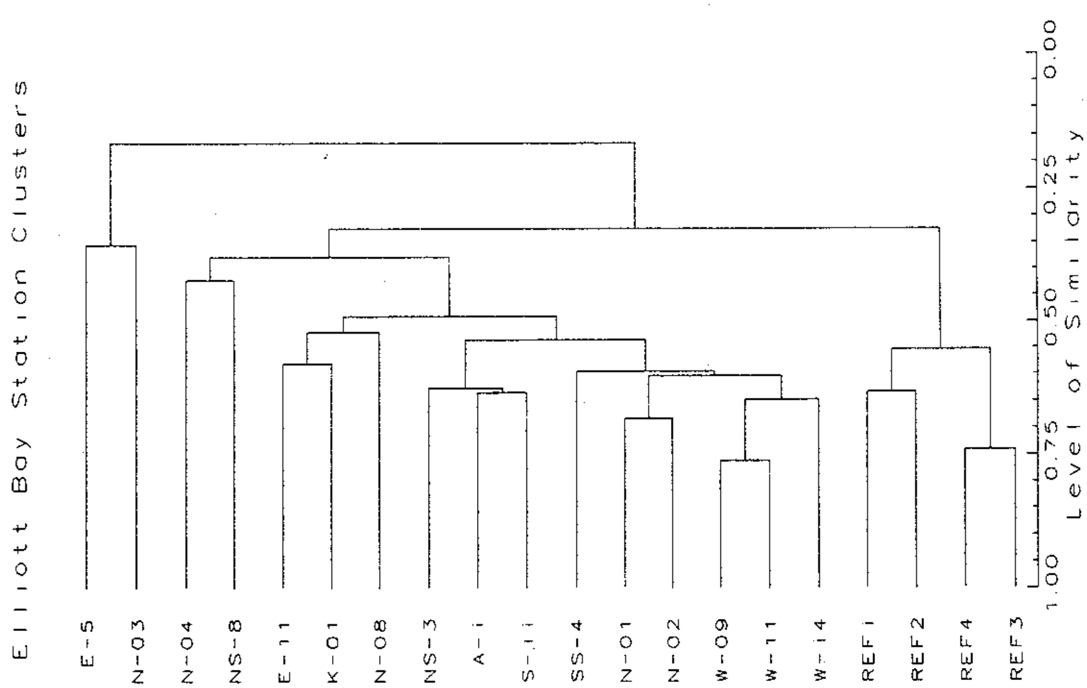

Figure 2. Dendrogram Representing Similarities in Benthic Community Structure Among Elliott Bay and Port Susan EBAP Stations

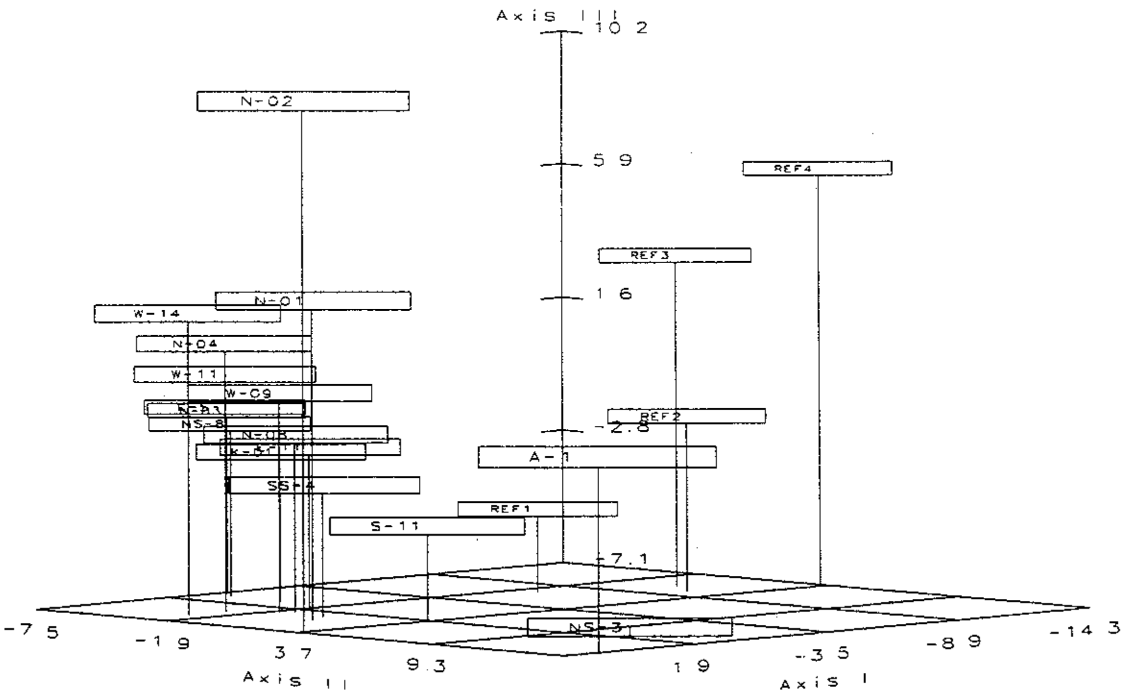

Figure 3. Principal Coordinates Analyses of Benthic Community Structure at Sixteen Locations in Elliott Bay and Four Locations in Port Susan

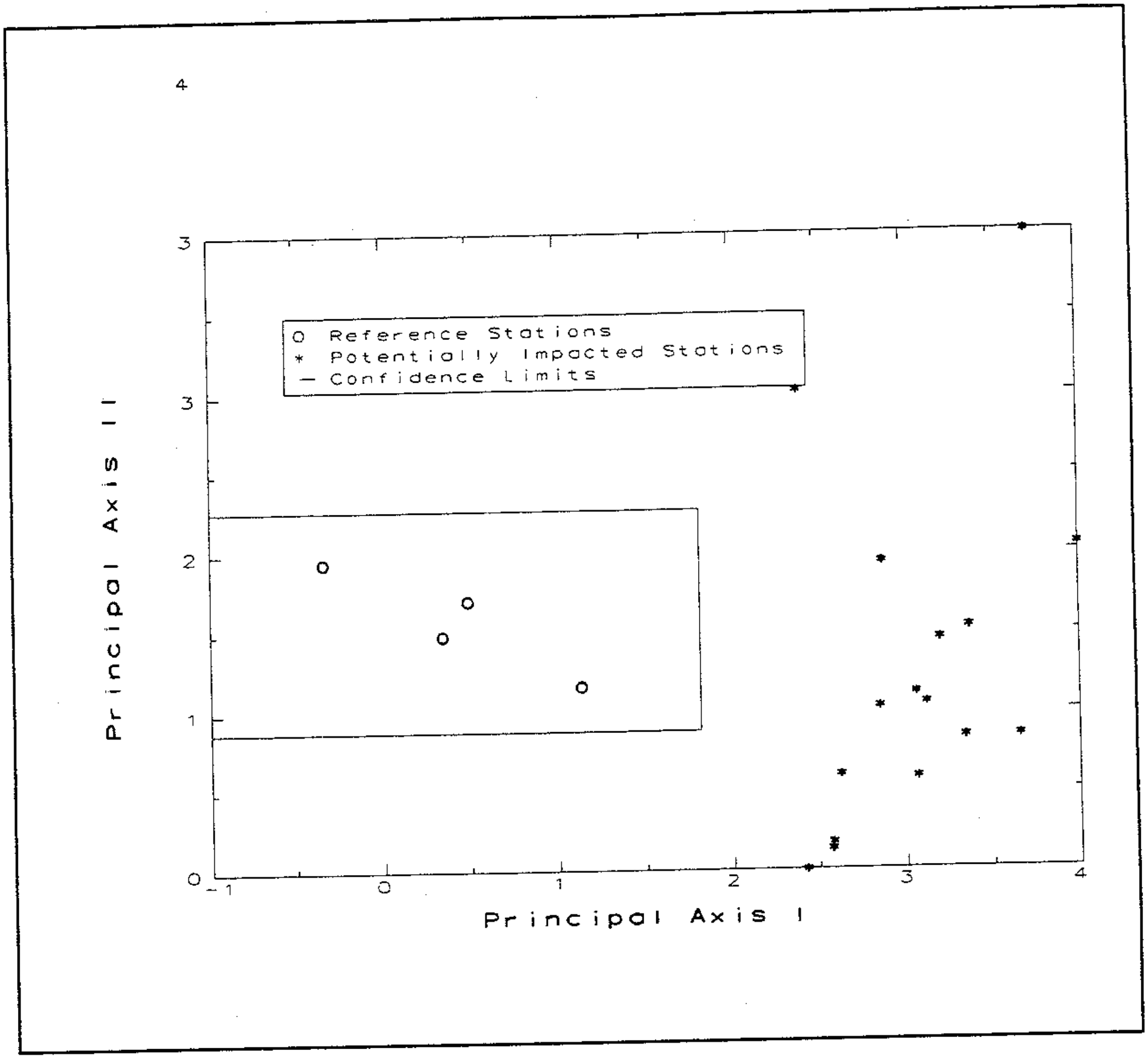

Figure 4a. Results of Statistical Evaluation of Similarities Between Elliott Bay and Port Susan Reference Areas Based on Axes I and II from the Principal Coordinates Analysis

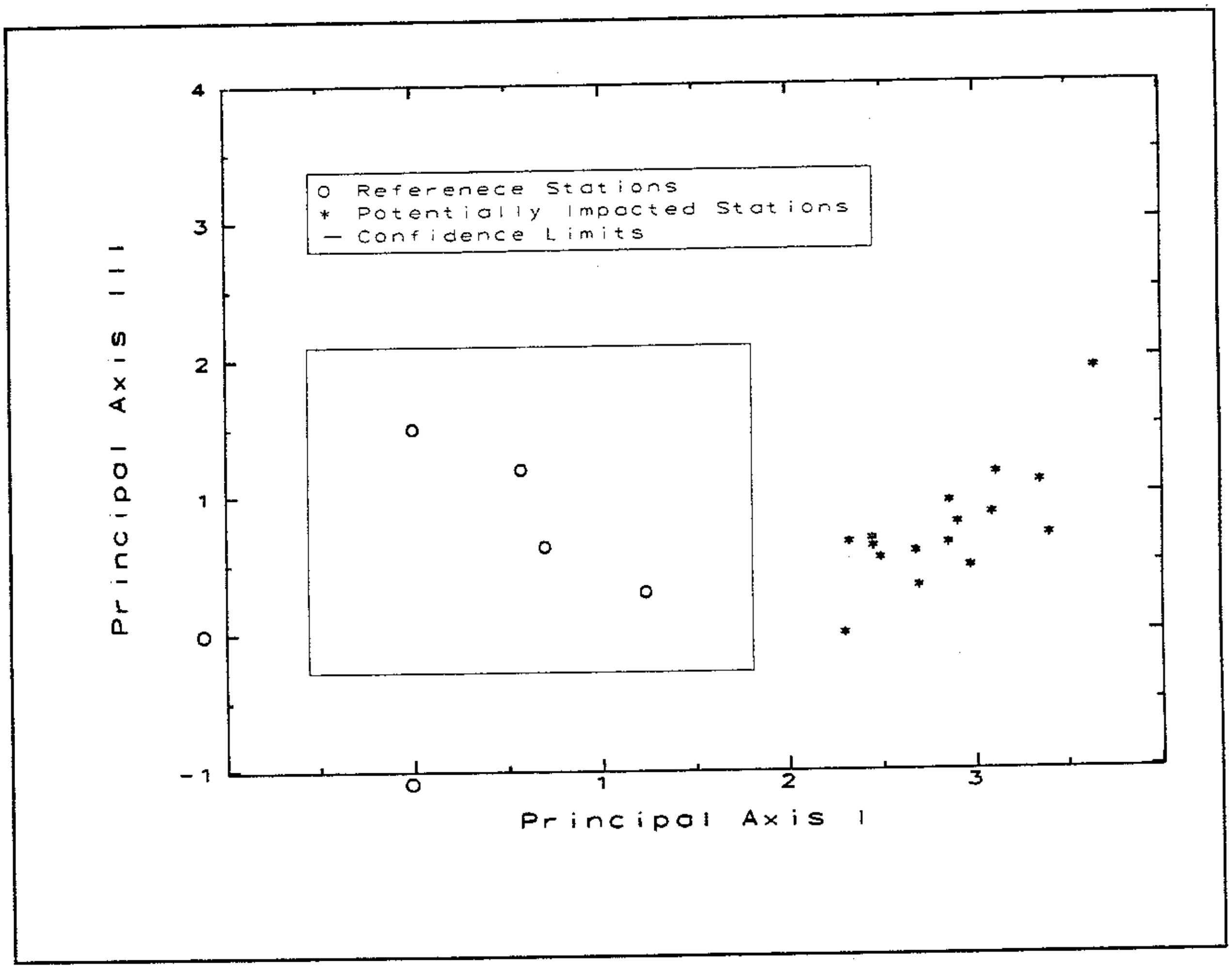

Figure 4b. Results of Statistical Evaluation of Similarities Between Elliott Bay and Port Susan Reference Areas Based on Axes I and III from the Principal Coordinates Analysis

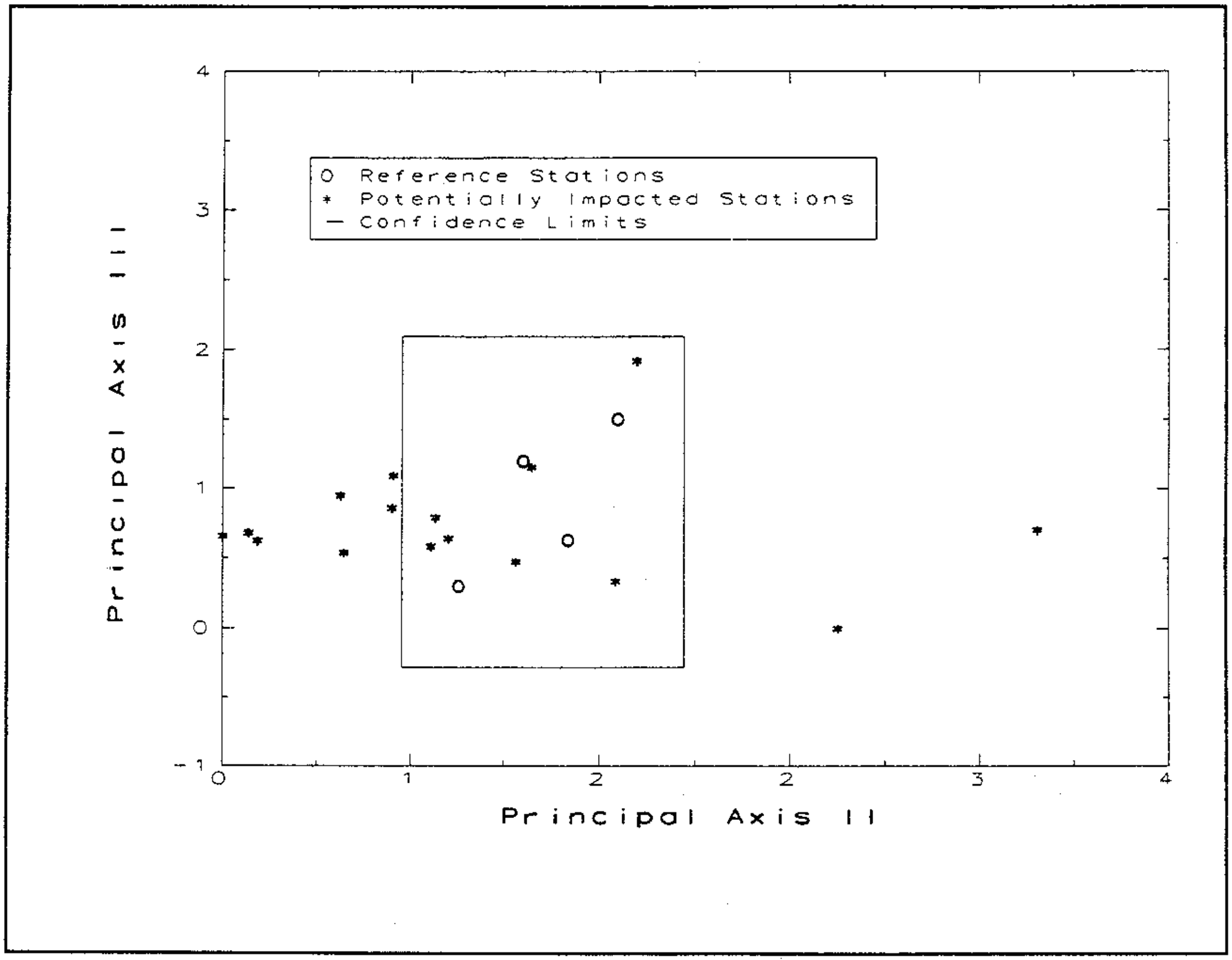

Figure 4c. Results of Statistical Evaluation of Similarities Between Elliott Bay and Port Susan Reference Areas Based on Axes II and III from the Principal Coordinates Analysis

TABLES

Table 1—Habitat characteristics of the stations selected for the case study.

Station	Depth (m)	Sediment Fines (% Silt + Clay)	Total Organic Carbon (%)
AB-01	11.7	29	1.5
EW-05	12.8	40	7.4
EW-11	11.3	74	3.4
KG-01	7.6	95	3.1
NH-01	8.8	19	1.0
NH-02	9.2	31	1.8
NH-03	12.2	74	3.0
NH-04	11.9	46	2.0
NH-08	9.4	53	2.0
NS-03	12.3	24	0.7
NS-08	8.0	84	1.3
SS-04	9.4	84	6.8
SS-11	9.4	68	5.1
WW-09	7.6	76	2.8
WW-11	7.3	72	5.2
WW-14	7.5	62	2.5
PS-01	9.6	88	1.5
PS-02	9.2	24	0.8
PS-03	8.9	12	0.4
PS-04	8.6	11	0.4

Table 2—Sampling Efficiency (SE/mean) Based On Total Abundance, Richness, and Major Taxonomic Group Abundance for 16 Stations in Elliott Bay and 4 Reference Stations in Port Susan

Station	Sampling Efficiency (%)				
	Total Abundance	Richness	Crustacean Abundance	Mollusc Abundance	Polychaete Abundance
AB-01	8	4	33	18	11
EW-05	17	18	31	36	19
EW-11	12	9	29	12	13
KG-01	13	10	15	13	13
NH-01	20	8	28	17	16
NH-02	10	4	23	13	9
NH-03	29	32	43	58	27
NH-04	16	12	23	34	17
NH-08	28	15	21	35	28
NS-03	7	3	10	9	7
NS-08	34	7	26	19	41
SS-04	44	12	61	34	16
SS-11	14	6	29	19	9
WW-09	15	7	33	28	11
WW-11	10	4	21	23	2
WW-14	5	4	21	13	5
PS-01	15	8	11	8	35
PS-02	7	5	9	4	12
PS-03	7	7	11	5	9
PS-04	7	11	5	16	22

Values < 20 to 30 percent indicate sufficient power to compare and contrast data

Table 3a—Minimum Detectable Difference (as a percent of the mean) for Analysis of Variance by Station[a]

Major Taxa Group	Minimum Detectable Difference (as percent of mean)	
	Raw Data	[Log(x+1)]
Total Abundance	129	21
Total Richness	55	N/A
Crustacean Abundance	447	52
Mollusc Abundance	115	38
Polychaete Abundance	114	23
Crustacean Richness	98	N/A
Mollusc Richness	77	N/A
Polychaete Richness	66	N/A

a—Statistical design evaluated differences among all station pairs
N/A—Not calculated; data approximately normally distributed

Table 3b—Minimum Detectable Difference (as a percent of the mean) for Analysis of Variance by Reference Habitat Category[a]

Major Taxa Group	Puget Sound Reference Category			
	<20 % Fines	20 to 50 % Fines	50 to 80 % Fines	>80 % Fines
Total Abundance [log(x+1)]	16	13	27	20
Total Richness	63	51	64	62
Crustacean Abundance [log(x=1)]	38	56	85	71
Mollusc Abundance [log(x=1)]	28	38	69	44
Polychaete Abundance [log(x=1)]	28	21	32	38
Crustacean Richness	76	103	121	86
Mollusc Richness	56	67	89	83
Polychaete Richness	78	67	542	94

a—Statistical design evaluated differences based on comparison to reference only within habitat category

Table 4—Richness and abundance of benthic infaunal organisms at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

Station	RICHNESS (# taxa/0.1 m^2)							ABUNDANCE (# individuals/0.1 m^2)						
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Mean	Total	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Mean	Total
AB-01	81	89	76	72	82	80	165	958	873	970	609	807	843	4,217
EW-05	4	15	10	15	11	11	27	51	111	83	160	111	103	516
EW-11	37	54	37	35	37	40	92	2,389	2,650	1,829	1,470	1,564	1,980	9,902
KG-01	32	21	29	21	21	25	53	1,345	843	1,695	1,297	924	1,221	6,104
NH-01	57	49	66	43	50	53	113	421	550	905	319	418	523	2,613
NH-02	58	54	60	68	61	60	123	585	431	479	776	597	574	2,868
NH-03	5	14	5	5	3	6	23	15	63	41	25	15	32	159
NH-04	42	33	36	21	26	32	80	1,322	849	798	442	1,070	896	4,481
NH-08	61	43	24	38	37	41	87	922	669	145	299	428	493	2,463
NS-03	61	64	73	63	66	65	124	753	689	1,034	871	880	845	4,227
NS-08	24	18	19	25	18	21	49	139	103	133	433	115	185	923
SS-04	34	60	32	46	48	44	100	291	2,946	272	924	1,068	1,100	5,501
SS-11	66	49	59	50	66	58	107	705	366	710	914	544	648	3,239
WW-09	44	44	59	50	39	47	97	689	758	1,179	697	473	759	3,796
WW-11	47	41	52	48	44	46	87	1,905	1,527	2,033	1,262	1,241	1,593	7,968
WW-14	52	52	52	43	50	50	87	1,964	2,643	2,233	2,067	2,285	2,238	11,192
PS-01	55	48	34	41	43	44	85	770	581	342	350	536	516	2,579
PS-02	48	61	47	50	55	52	95	614	855	680	632	832	723	3,613
PS-03	67	50	51	48	47	53	100	545	418	430	556	566	503	2,515
PS-04	51	39	61	73	70	59	119	635	443	663	522	610	575	2,873

Table 5—Average total abundance (# individuals/m^2) and relative total abundance of major taxonomic groups at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

Station	Average Total Abundance (# individuals/0.1 m^2)					Relative Total Abundance (%)				
	Crustaceans	Molluscs	Polychaetes	Echinoderms	Misc. Taxa	Crustaceans	Molluscs	Polychaetes	Echinoderms	Misc. Taxa
AB-01	170	259	411	1	2	20	31	49	<1	<1
EW-05	3	7	93	0	0	2.5	7.0	91	0	0
EW-11	49	156	1,774	<1	<1	2.5	7.9	90	<1	<1
KG-01	10	72	1,138	0	<1	<1	5.9	93	0	<1
NH-01	183	28	311	0	1	35	5.3	59	0	<1
NH-02	112	59	374	1	27	19	10	65	<1	4.8
NH-03	3	2	28	0	0	13	5.0	87	0	0
NH-04	19	12	865	0	<1	2.1	1.3	97	0	<1
NH-08	15	65	411	0	2	3.1	13	83	0	<1
NS-03	272	425	148	<1	<1	32	50	17	<1	<1
NS-08	9	28	147	<1	<1	4.8	15	80	<1	<1
SS-04	706	66	328	<1	<1	64	6.0	30	<1	<1
SS-11	228	195	223	0	2	35	30	34	0	<1
WW-09	181	54	522	<1	2	24	7.1	69	<1	<1
WW-11	762	67	762	1	1	48	4.2	48	<1	<1
WW-14	93	59	2,080	0	6	4.2	2.6	93	0	<1
PS-01	184	154	177	0	1	36	30	34	0	<1
PS-02	80	326	312	0	4	11	45	43	0	<1
PS-03	100	279	120	<1	4	20	55	24	<1	<1
PS-04	176	222	173	0	4	31	39	30	0	<1

Table 6—Average total richness (# taxa/0.1 m^2) of major taxonomic groups at 16 stations in Elliott Bay and at 4 reference stations in Port Susan

Station	Average Total Richness (# taxa/0.1 m^2)		
	Crustaceans	Molluscs	Polychaetes
AB-01	16	14	47
EW-05	2	1	7
EW-11	8	7	24
KG-01	4	6	15
NH-01	9	7	36
NH-02	11	9	36
NH-03	2	1	3
NH-04	11	4	17
NH-08	5	10	25
NS-03	13	15	37
NS-08	5	7	8
SS-04	11	8	25
SS-11	16	13	29
WW-09	11	8	27
WW-11	10	6	28
WW-14	9	8	31
PS-01	9	12	22
PS-02	12	11	27
PS-03	8	14	27
PS-04	12	12	34

Table 7—Average benthic community infaunal trophic index values and diversity indices at 16 stations in Elliott Bay and at 4 reference area stations in Port Susan.

Station	ITI	Diversity Indices			
		H′	J	D	SDI
AB-01	66	1.35	0.71	0.29	11.6
EW-05	27	0.54	0.54	0.46	1.8
EW-11	66	0.56	0.35	0.65	1.6
KG-01	68	0.48	0.35	0.65	1.6
NH-01	62	1.25	0.73	0.27	9.6
NH-02	61	1.53	0.73	0.27	11.5
NH-03	9	0.35	0.45	0.55	1.6
NH-04	63	0.35	0.24	0.76	1.0
NH-08	68	1.01	0.64	0.36	6.6
NS-03	62	1.22	0.67	0.33	8.2
NS-08	34	0.86	0.51	0.49	1.6
SS-04	64	0.83	0.52	0.48	4.2
SS-11	68	1.26	0.71	0.29	9.2
WW-09	66	1.03	0.62	0.38	6.0
WW-11	65	0.79	0.47	0.53	3.0
WW-14	66	0.60	0.35	0.65	1.8
PS-01	71	1.13	0.69	0.31	7.6
PS-02	71	1.18	0.69	0.31	8.8
PS-03	71	1.09	0.63	0.37	7.2
PS-04	74	1.18	0.67	0.33	9.6

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

	Station															
Species	AB01	EW05	EW11	KG01	NH01	NH02	NH03	NH04	NH08	NS03	NS08	SS04	SS11	WW09	WW11	WW14
Ampharete acutifrons																
Armandia brevis			8								10					
Aoroides columbiae			9													
Aoroides inermis							16									
Aoroides spinosus							16									
Axinopsida serricata	i		4	5	10		3		5	2	8.5	6	2			9
Capitella capitata		1		7	9	5	1	2			2			10		
Caprella alaskana							6									
Caprella spp.							16									
Caulleriella hamata								5	10							
Chaetozone spp		13							8.5							
Chone spp.							16									
Cirratulidae		3					16									
Cirratulus cirratus		13		8				i							7	i
Cirratulus spectabilis							2	7								
Clinocardium californiense																
Corophium acherusicum							6									7
Diastylis alaskensis							16									
Eteone longa		13														
Euchone limnicola		2		2										6		8
Eudorella pacifica							6									
Euphilomedes carcharodonta	2	9	7		5	3	16		8.5	i		4	3			
Euphilomedes producta										5						
Eusyllis blomstrandi							16									
Exogone lourei		13			4							3			8	
Heteromastus filobranchus												10				
Heterophoxus oculatus													5			
Leitoscoloplos elongatus																
Leptochelia dubia		8			i	7				8		i	4	2	i	

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

	Station															
	AB01	EW05	EW11	KG01	NH01	NH02	NH03	NH04	NH08	NS03	NS08	SS04	SS11	WW09	WW11	WW14
Lumbrineris cruzensis									2							
Lumbrineris luti		13	2	6												
Lumbrineris spp.	7		3	3	8			9.5	3			5	7.5	5	5	4
Macoma carlottensis	6	4	5	4			6	9.5		3	4	8	7.5			
Macoma elimata										10						
Maldanidae																
Mediomastus californiensis	4				3	6										2
Megacrenella columbiana										7						
Mysella tumida											7					
Nephtys ferruginea		13														
Nicolea zostericola																
Notomastus tenuis	3				2	10				9				9	9.5	5
Nucula tenuis							16									
Odostomia spp.	5		6	9		4	16	6	6	4	5	7	6	8	4	
Paraprionospio pinnata							6									
Pholis brevipes											6			4	3	6
Platynereis bicanaliculata			10				16	8			3					10
Polycirrus spp.									4							
Polydora cardalia		6														
Praxillella affinis																
Praxillella gracilis																
Prionospio cirrifera					7	9								7	9.5	
Prionospio steenstrupi	9				6	2		3				9	9	3	6	
Protomedia prudens																
Psephidia lordi	10			10			16			6	8.5		10			
Rhachotropis oculata							16									
Rhodine bitorquata							16									
Rutiderma lomae																
Spiochaetopterus costarum		13							7							
Tectidrilus diversus						8										

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

	Station															
	AB01	EW05	EW11	KG01	NH01	NH02	NH03	NH04	NH08	NS03	NS08	SS04	SS11	WW09	WW11	WW14
Terebellides stroemi																
Tharyx multifilis	8	5	1	1		1		4	1		1	2	1	1	2	3
Vitrinella columbiana		7														
Westwoodilla caecula							16									

Taxa are ranked from highest (1) to lowest abundance.

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

Species	Station			
	PS-01	PS-02	PS-03	PS-04
Ampharete acutifrons				5
Armandia brevis				
Aoroides columbiae				
Aoroides inermis				
Aoroides spinosus				
Axinopsida serricata	10	1	5	4
Capitella capitata				
Caprella alaskana				
Caprella spp.				
Caulleriella hamata				
Chaetozone spp.				
Chone spp.				
Cirratulidae				
Cirratulus cirratus				
Cirratulus spectabilis				
Clinocardium californiense			6	
Corophium acherusicum				
Diastylis alaskensis				
Eteone longa				
Euchone limnicola				
Eudorella pacifica				
Euphilomedes carcharodonta		7	2	2
Euphilomedes producta	4	9	3	3
Eusyllis blomstrandi				
Exogone lourei				
Heteromastus filobranchus				
Heterophoxus oculatus	8			

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

	Station			
	PS-01	PS-02	PS-03	PS-04
Leitoscoloplos elongatus			7	
Leptochelia dubia				
Lumbrineris cruzensis				
Lumbrineris luti	6	4	4	7
Lumbrineris spp.	5	5		
Macoma carlottensis	9	10		
Macoma elimata				
Maldanidae		6		6
Mediomastus californiensis				
Megacrenella columbiana				
Mysella tumida				
Nephtys ferruginea				
Nicolea zostericola			9	
Notomastus tenuis				
Nucula tenuis				
Odostomia spp.	7		8	9
Paraprionospio pinnata				
Pholis brevipes				
Platynereis bicanaliculata				
Polycirrus spp.				
Polydora cardalia				
Prexillella affinis			10	
Prexillella gracilis		8		
Prionospio cirrifera				
Prionospio steenstrupi				
Protomedia prudens	1			
Psephidia lordi	2	3	1	1
Rhachotropis oculata				
Rhodine bilorquata				

Table 8—Top 10 taxa ranked by total pooled abundance (# individuals/0.5 m^2) at 16 stations in Elliott Bay and at 4 references area stations in Port Susan.

	Station			
	PS-01	PS-02	PS-03	PS-04
Rutiderma lomae				8
Spiochaetopterus costarum				
Tectidrilus diversus				
Terebellides stroemi	3	2		10
Tharyx multifilis				
Vitrinella columbiana				
Westwoodilla caecula				

Taxa are ranked from highest (1) to lowest abundance.

Table 9—Probability of Committing a Type 1 Error by Using Multiple t-tests to Detect Differences Between All Station Pairs

Number of comparisons	Level of Significance Used in the t-test					
	0.20	0.10	0.05	0.02	0.01	0.001
2	0.20	0.10	0.05	0.02	0.01	0.001
3	0.41	0.23	0.13	0.05	0.03	0.003
4	0.58	0.36	0.21	0.09	0.05	0.006
5	0.71	0.47	0.23	0.13	0.07	0.009
10	0.96	0.83	0.63	0.37	0.23	0.034
20	1.00	0.98	0.92	0.71	0.52	0.109

Table 10—Probability of significant differences among station pairs based of mean total abundance at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

ANOVA Using Mean Total Abundance																
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																NS[b]
EW-05	<0.001															<0.001[b]
EW-11	NS	<0.001														<0.004[a]
KG-01	NS	<0.001	NS													NS[a]
NH-01	NS	<0.001	<0.001	NS												NS[b]
NH-02	NS	<0.001	<0.005	NS	NS											NS[b]
NH-03	<0.001	<0.005	<0.001	<0.001	<0.001	<0.001										<0.001[a]
NH-04	NS	<0.001	NS	NS	NS	NS	<0.001									NS[b]
NH-08	NS	<0.001	<0.001	<0.034	NS	NS	<0.001	NS								NS[a]
NS-03	NS	<0.001	NS	NS	NS	NS	<0.001	NS	NS							NS[b]
NS-08	<0.001	NS	<0.001	<0.001	<0.016	<0.003	<0.001	<0.001	NS	<0.001						<0.030[a]
SS-04	NS	<0.001	NS	NS	NS	NS	<0.001	NS	NS	NS	<0.001					NS[a]
SS-11	NS	<0.001	<0.015	NS	NS	NS	<0.001	NS	NS	NS	<0.001	NS				NS[a]
WW-09	NS	<0.001	NS	NS	NS	NS	<0.001	NS	NS	NS	<0.001	NS	NS			NS[a]
WW-11	NS	<0.001	NS	NS	<0.012	<0.049	<0.001	NS	<0.002	NS	<0.001	NS	NS	NS		<0.027[a]
WW-14	NS	<0.001	NS	NS	<0.001	<0.001	<0.001	NS	<0.001	NS	<0.001	<0.024	<0.003	<0.018	NS	<0.001[a]

aFine-grained (>50 percent fines) pooled reference represented by Station PS-01.
bCoarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04
NS: Differences between stations not significant at P<0.05.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 11—Probability of significant differences among station pairs based on mean richness at 16 stations in Elliott Bay and at 4 reference stations in Puget Sound.

	ANOVA Using Mean Richness															
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																<0.001[b]
EW-05	<0.001															<0.001[b]
EW-11	<0.001	<0.001														NS[a]
KG-01	<0.001	NS	NS													<0.012[a]
NH-01	<0.001	<0.001	NS	<0.001												NS[b]
NH-02	<0.013	<0.001	<0.003	<0.001	NS											NS[b]
NH-03	<0.001	NS	<0.001	<0.020	<0.001	<0.001										<0.001[a]
NH-04	<0.001	<0.003	NS	NS	<0.002	<0.001	<0.001									<0.001[b]
NH-08	<0.001	<0.001	NS	NS	NS	<0.004	<0.001	NS								NS[a]
NS-03	NS	<0.001	<0.001	<0.001	NS	NS	<0.001	<0.001	<0.001							NS[b]
NS-08	<0.001	NS	<0.017	NS	<0.001	<0.001	NS	NS	<0.013	<0.001						<0.002[a]
SS-04	<0.001	<0.001	NS	<0.010	NS	<0.037	<0.001	NS	NS	<0.002	<0.001					NS[a]
SS-11	<0.001	<0.001	<0.025	<0.001	NS	NS	<0.001	<0.001	<0.033	NS	<0.001	NS				NS[a]
WW-09	<0.001	<0.001	NS	<0.001	NS	NS	<0.001	NS	NS	<0.025	<0.001	NS	NS			NS[a]
WW-11	<0.001	<0.001	NS	<0.001	NS	NS	<0.001	NS	NS	<0.015	<0.001	NS	NS	NS		NS[a]
WW-14	<0.001	<0.001	NS	<0.001	NS	NS	<0.001	<0.017	NS	NS	<0.001	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant
Probabilities based on Tukey's *a posteriori* contrasts.

Table 12—Probability of significant differences among station pairs based on mean crustacean abundance at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

	ANOVA Using Mean Crustacean Abundance															
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																NS[b]
EW-05	<0.001															<0.001[b]
EW-11	NS	<0.001														NS[a]
KG-01	<0.001	NS	NS													<0.001[a]
NH-01	NS	<0.001	NS	<0.001												NS[b]
NH-02	NS	<0.001	NS	<0.001	NS											NS[b]
NH-03	<0.001	NS	<0.001	NS	<0.001	<0.001										<0.001[a]
NH-04	<0.005	<0.037	NS	NS	<0.002	<0.036	<0.037									<0.001[b]
NH-08	<0.002	NS	NS	NS	<0.001	<0.013	NS	NS								<0.001[a]
NS-03	NS	<0.001	<0.022	<0.001	NS	NS	<0.001	<0.001	<0.001							<0.028[b]
NS-08	<0.001	NS	NS	NS	<0.001	<0.001	NS	NS	NS	<0.001						<0.001[a]
SS-04	NS	<0.001	NS	<0.001	NS	NS	<0.001	<0.001	<0.001	NS	<0.001					NS[a]
SS-11	NS	<0.001	NS	<0.001	NS	NS	<0.001	<0.001	<0.001	NS	<0.001	NS				NS[a]
WW-09	NS	<0.001	NS	<0.001	NS	NS	<0.001	<0.005	<0.002	NS	<0.001	NS	NS			NS[a]
WW-11	NS	<0.001	<0.001	<0.001	NS	<0.013	<0.001	<0.001	<0.001	NS	<0.001	NS	NS	NS		NS[a]
WW-14	NS	<0.001	NS	<0.004	NS	NS	<0.001	NS	<0.037	NS	<0.001	NS	NS	NS	<0.004	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03, PS-04
NS: Differences between stations not significant at P<0.05
Probabilities based on Tukey's *a posteriori* contrasts.

Table 13—Probability of significant differences among station pairs based on mean mollusc abundance at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

ANOVA Using Mean Mollusc Abundance																
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																NS[b]
EW-05	<0.001															<0.001[b]
EW-11	NS	<0.001														NS[a]
KG-01	NS	<0.001	NS													NS[a]
NH-01	<0.001	<0.018	<0.001	NS												<0.001[b]
NH-02	<0.018	<0.001	NS	NS	NS											<0.001[b]
NH-03	<0.001	NS	<0.001	<0.001	<0.001	<0.001										<0.001[a]
NH-04	<0.001	NS	<0.001	<0.001	NS	<0.001	<0.003									<0.001[b]
NH-08	<0.006	<0.001	NS	NS	NS	NS	<0.001	<0.002								NS[a]
NS-03	NS	<0.001	NS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001							NS[b]
NS-08	<0.001	<0.016	<0.001	NS	NS	NS	<0.001	NS	NS	<0.001						<0.001[a]
SS-04	<0.005	<0.001	NS	NS	NS	NS	<0.001	<0.002	NS	<0.001	NS					NS[a]
SS-11	NS	<0.001	NS	NS	<0.001	NS	<0.001	<0.001	NS	NS	<0.001	<0.050				NS[a]
WW-09	<0.004	<0.001	NS	NS	NS	NS	<0.001	<0.003	NS	<0.001	NS	NS	<0.040			NS[a]
WW-11	<0.023	<0.001	NS	NS	NS	NS	<0.001	<0.001	NS	<0.001	NS	NS	NS	NS		NS[a]
WW-14	<0.017	<0.001	NS	NS	NS	NS	<0.001	<0.001	NS	<0.001	NS	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at P<0.05.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 14—Probability of significant differences among station pairs based on mean polychaete abundance at 16 stations in Elliott Bay and at 4 reference stations in Port Susan.

	ANOVA Using Mean Polychaete Abundance															Comparisons Between Elliott Bay and Reference Stations
	Among Station Comparisons Using Only Elliott Bay Stations															
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																<0.009[b]
EW-05	<0.001															<0.037[b]
EW-11	<0.001	<0.001														<0.001[a]
KG-01	<0.010	<0.001	NS													<0.001[a]
NH-01	NS	<0.001	<0.001	<0.001												NS[b]
NH-02	NS	<0.001	<0.001	<0.003	NS											<0.025[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001										<0.001[a]
NH-04	NS	<0.001	NS	NS	<0.010	NS	<0.001									<0.001[b]
NH-08	NS	<0.001	<0.001	<0.001	NS	NS	<0.001	NS								NS[a]
NS-03	<0.010	NS	<0.001	<0.001	NS	<0.029	<0.001	<0.001	NS							NS[b]
NS-08	<0.001	NS	<0.001	<0.001	<0.022	<0.001	<0.001	<0.001	<0.004	NS						NS[a]
SS-04	NS	<0.001	<0.001	<0.001	NS	NS	<0.001	<0.018	NS	NS	<0.012					NS[a]
SS-11	NS	<0.029	<0.001	<0.001	NS	NS	<0.001	<0.001	NS	NS	NS	NS				NS[a]
WW-09	NS	<0.001	<0.001	NS	NS	NS	<0.001	NS	NS	<0.001	<0.001	NS	NS			<0.003[a]
WW-11	NS	<0.001	NS	NS	<0.022	NS	<0.001	NS	NS	<0.001	<0.001	<0.038	<0.001	NS		<0.001[a]
WW-14	<0.001	<0.001	NS	NS	<0.001	<0.001	<0.001	<0.023	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.011	<0.001[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at P<0.05.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 15—Probability of significant differences among station pairs based on mean crustacean richness at 16 stations in Elliott Bay and at 4 reference stations in Puget Sound.

	ANOVA Using Mean Crustacean Richness															
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																<0.014[b]
EW-05	<0.001															<0.001[b]
EW-11	<0.001	NS														NS[a]
KG-01	<0.001	NS	NS													NS[a]
NH-01	<0.005	NS	NS	NS												NS[b]
NH-02	NS	<0.001	NS	<0.010	NS											NS[b]
NH-03	<0.001	NS	NS	NS	NS	<0.001										<0.010[a]
NH-04	NS	<0.001	NS	<0.014	NS	NS	<0.001									NS[b]
NH-08	<0.001	NS	NS	NS	NS	NS	NS	NS								NS[a]
NS-03	NS	<0.001	NS	<0.001	NS	NS	<0.001	NS	<0.010							NS[b]
NS-08	<0.001	NS	NS	NS	NS	NS	NS	NS	NS	<0.005						NS[a]
SS-04	NS	<0.002	NS	<0.028	NS	NS	<0.002	NS	NS	NS	NS					NS[a]
SS-11	NS	<0.001	<0.002	<0.001	<0.014	NS	<0.001	NS	<0.001	NS	<0.001	NS				<0.010[a]
WW-09	NS	<0.002	NS	<0.028	NS	NS	<0.002	NS	NS	NS	NS	NS	NS			NS[a]
WW-11	NS	<0.005	NS	NS	NS	NS	<0.005	NS	NS	NS	NS	NS	NS	NS		NS[a]
WW-14	<0.005	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	<0.014	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P<0.05$.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 16—Probability of significant differences among station pairs based on mean mollusc richness at 16 stations in Elliott Bay and at 4 reference stations in Puget Sound.

	ANOVA Using Mean Mollusc Richness															
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																NS[b]
EW-05	<0.001															<0.001[b]
EW-11	<0.001	<0.010														<0.021[a]
KG-01	<0.001	NS	NS													<0.001[a]
NH-01	<0.001	<0.006	NS	NS												<0.002[b]
NH-02	NS	<0.001	NS	NS	NS											NS[b]
NH-03	<0.001	NS	<0.010	NS	<0.006	<0.001										<0.001[a]
NH-04	<0.001	NS	NS	NS	NS	<0.015	NS									<0.001[b]
NH-08	NS	<0.001	NS	NS	NS	NS	<0.001	<0.006								NS[a]
NS-03	NS	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	<0.001	<0.024							NS[b]
NS-08	<0.001	<0.015	NS	NS	NS	NS	<0.015	NS	NS	<0.001						<0.014[a]
SS-04	<0.003	<0.003	NS	NS	NS	NS	<0.003	NS	NS	<0.001	NS					NS[a]
SS-11	NS	<0.001	<0.024	<0.001	<0.036	NS	<0.001	<0.001	NS	NS	<0.015	NS				NS[a]
WW-09	<0.002	<0.004	NS	NS	NS	NS	<0.004	NS	NS	<0.001	NS	NS	NS			<0.045[a]
WW-11	<0.001	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	NS	NS	<0.003	NS		<0.002[a]
WW-14	<0.003	<0.003	NS	NS	NS	NS	<0.003	NS	NS	<0.001	NS	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at P<0.05.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 17—Probability of signficant differences among station pairs based on mean polychaete richness at 16 stations in Elliott Bay and at 4 reference stations in Puget Sound.

ANOVA Using Mean Polychaete Richness																
	Among Station Comparisons Using Only Elliott Bay Stations															Comparisons Between Elliott Bay and Reference Stations
Station	AB-01	EW-05	EW-11	KG-01	NH-01	NH-02	NH-03	NH-04	NH-08	NS-03	NS-08	SS-04	SS-11	WW-09	WW-11	Pooled Reference
AB-01																<0.001[b]
EW-05	<0.001															<0.001[b]
EW-11	<0.001	<0.001														NS[a]
KG-01	<0.001	NS	NS													NS[a]
NH-01	NS	<0.001	<0.024	<0.001												NS[b]
NH-02	NS	<0.001	<0.020	<0.001	NS											NS[b]
NH-03	<0.001	NS	<0.001	<0.024	<0.001	<0.001										<0.001[a]
NH-04	<0.001	NS	NS	NS	<0.001	<0.001	<0.004									<0.001[b]
NH-08	<0.001	<0.001	NS	NS	<0.042	<0.035	<0.001	NS								NS[a]
NS-03	NS	<0.001	<0.009	<0.001	NS	NS	<0.001	<0.001	<0.017							NS[b]
NS-08	<0.001	NS	<0.001	NS	<0.001	<0.001	NS	NS	<0.001	<0.001						<0.008[a]
SS-04	<0.001	<0.001	NS	NS	<0.050	<0.042	<0.001	NS	NS	<0.020	<0.001					NS[a]
SS-11	<0.001	<0.001	NS	<0.003	NS	NS	<0.001	<0.020	NS	NS	<0.001	NS				NS[a]
WW-09	<0.001	<0.001	NS	<0.020	NS	NS	<0.001	NS	NS	NS	<0.001	NS	NS			NS[a]
WW-11	<0.001	<0.001	NS	<0.008	NS	NS	<0.001	<0.042	NS	NS	<0.001	NS	NS	NS		NS[a]
WW-14	<0.001	<0.001	NS	<0.001	NS	NS	<0.001	<0.002	NS	NS	<0.001	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at P<0.05.
Probabilities based on Tukey's *a posteriori* contrasts.

Table 18—Probability of Significant Differences Between Station Pairs Based on Mean Total Abundance at 16 Stations in Elliott Bay and at 4 Stations in Port Susan

T-test Using Mean Total Abundance					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	NS	NS	NS[b]
EW-05	<0.001	<0.001	<0.001	<0.001	<0.001[b]
EW-11	<0.001	<0.001	<0.001	<0.001	<0.001[a]
KG-01	NS	NS	<0.001	NS	NS[a]
NH-01	NS	NS	NS	NS	NS[a]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-04	NS	NS	NS	NS	NS[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	NS	<0.001	NS	NS[b]
NS-08	NS	NS	NS	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	NS	NS	NS	NS[a]
WW-11	<0.001	<0.001	<0.001	<0.001	<0.001[a]
WW-14	<0.001	<0.001	<0.001	<0.001	<0.001[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.001$.

Table 19—Probability of Significant Differences Between Station Pairs Based on Mean Richness at 16 stations in Elliott Bay and at 4 Stations in Port Susan

T-test Using Mean Richness					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	<0.001	<0.001	<0.001	NS	<0.001[b]
EW-05	<0.001	<0.001	<0.001	<0.001	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	NS	<0.001	<0.001	NS	NS[a]
NH-01	NS	NS	NS	NS	NS[b]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-04	NS	NS	NS	NS	<0.001[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	NS	NS	NS	NS[b]
NS-08	NS	<0.001	<0.001	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	NS	NS	NS	NS[a]
WW-11	NS	NS	NS	NS	NS[a]
WW-14	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.001$.

Table 20—Probability of Significant Differences Between Station Pairs Based on Mean Crustacean Abundance at 16 stations in Elliott Bay and at 4 Stations in Port Susan

T-test Using Mean Crustacean Abundance					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	NS	NS	NS[b]
EW-05	<0.001	<0.001	<0.001	<0.001	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-01	NS	NS	NS	NS	NS[b]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-04	<0.001	NS	<0.001	<0.001	<0.001[b]
NH-08	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NS-03	NS	<0.001	<0.001	NS	<0.001[b]
NS-08	<0.001	<0.001	<0.001	<0.001	<0.001[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	NS	NS	NS	NS[a]
WW-11	NS	<0.001	<0.001	NS	NS[a]
WW-14	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.001$.

Table 21—Probability of Significant Differences Between Station Pairs Based on Mean Mollusc Abundance at 16 Stations in Elliott Bay and at 4 Stations in Port Susan

T-test Using Mean Mollusc Abundance					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	NS	NS	NS[b]
EW-05	<0.001	<0.001	<0.001	<0.001	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-01	<0.001	<0.001	<0.001	<0.001	<0.001[b]
NH-02	<0.001	<0.001	<0.001	<0.001	<0.001[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-04	NS	<0.001	<0.001	<0.001	<0.001[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	<0.001	NS	NS	NS	NS[b]
NS-08	<0.001	<0.001	<0.001	<0.001	<0.001[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	<0.001	<0.001	<0.001	NS[a]
WW-11	NS	NS	NS	NS	NS[a]
WW-14	<0.001	<0.001	<0.001	<0.001	<0.001[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.001$.

Table 22—Probability of Significant Differences Between Station Pairs Based on Mean Polychaete Abundance at 16 Stations in Elliott Bay and At 4 Stations in Port Susan

T-test Using Mean Polychaete Abundance					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	<0.001	NS	<0.001[b]
EW-05	NS	<0.001	NS	NS	NS[b]
EW-11	<0.001	<0.001	<0.001	<0.001	<0.001[a]
KG-01	NS	<0.001	<0.001	<0.001	NS[a]
NH-01	NS	NS	<0.001	NS	NS[b]
NH-02	NS	NS	<0.001	NS	<0.001[b]
NH-03	NS	<0.001	NS	<0.001	NS[a]
NH-04	NS	<0.003	<0.001	<0.001	<0.001[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	<0.002	NS	NS	NS[b]
NS-08	NS	NS	NS	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	<0.001	NS	NS[a]
WW-09	NS	NS	<0.001	NS	NS[a]
WW-11	NS	<0.001	<0.001	<0.004	NS[a]
WW-14	<0.001	<0.001	<0.001	<0.001	<0.001[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.001$.

Table 23—Probability of Significant Differences Between Station Pairs Based on Mean Crustacean Richness at 16 Stations in Elliott Bay and At 4 Stations in Port Susan

T-test Using Mean Crustacean Richness					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	NS	NS	NS[b]
EW-05	<0.001	NS	NS	<0.001	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	NS	NS	NS	NS	NS[a]
NH-01	NS	NS	NS	NS	NS[b]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	<0.001	NS	NS	<0.001	<0.001[a]
NH-04	NS	NS	NS	NS	NS[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	NS	NS	NS	NS[b]
NS-08	NS	NS	NS	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	<0.001	NS	NS	NS	<0.001[a]
WW-09	NS	NS	NS	NS	NS[a]
WW-11	NS	NS	NS	NS	NS[a]
WW-14	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.01$.

Table 24—Probability of Significant Differences Between Station Pairs Based on Mean Mollusc Richness at 16 Stations in Elliott Bay and At 4 Stations in Port Susan

T-test Using Mean Mollusc Richness					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	NS	NS	NS	NS	NS[b]
EW-05	<0.001	<0.001	<0.001	<0.001	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-01	NS	NS	<0.001	NS	<0.001[b]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	<0.001	<0.001	<0.001	<0.001	<0.001[a]
NH-04	<0.001	<0.001	<0.001	<0.001	<0.001[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	NS	NS	NS	NS[b]
NS-08	NS	NS	<0.001	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	NS	<0.001	NS	NS[a]
WW-11	<0.001	<0.001	<0.001	<0.001	<0.001[a]
WW-14	NS	NS	<0.001	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.01$.

Table 25—Probability of Significant Differences Between Station Pairs Based on Mean Polychaete Richness at 16 Stations in Elliott Bay and At 4 Stations in Port Susan

T-test Using Mean Polychaete Richness					
Station	PS-01	PS-02	PS-03	PS-04	Pooled Reference
AB-01	<0.001	<0.001	<0.001	NS	<0.001[b]
EW-05	NS	<0.001	<0.001	NS	<0.001[b]
EW-11	NS	NS	NS	NS	NS[a]
KG-01	NS	NS	NS	NS	NS[a]
NH-01	NS	NS	NS	NS	NS[b]
NH-02	NS	NS	NS	NS	NS[b]
NH-03	NS	<0.001	<0.001	NS	NS[a]
NH-04	NS	NS	NS	NS	<0.001[b]
NH-08	NS	NS	NS	NS	NS[a]
NS-03	NS	<0.001	NS	NS	<0.001[b]
NS-08	NS	<0.001	<0.001	NS	NS[a]
SS-04	NS	NS	NS	NS	NS[a]
SS-11	NS	NS	NS	NS	NS[a]
WW-09	NS	NS	NS	NS	NS[a]
WW-11	NS	NS	NS	NS	NS[a]
WW-14	NS	NS	NS	NS	NS[a]

[a]Fine-grained (>50 percent fines) pooled reference represented by Station PS-01.
[b]Coarse-grained (<50 percent fines) pooled reference represented by Stations PS-02, PS-03 and PS-04.
NS: Differences between stations not significant at $P \leq 0.01$.

Table 26—Percent Similarities Among Benthic Communities From Cluster Analysis Based on Total Taxa Abundance (n>4) at 16 Stations in Elliott Bay and at 4 Reference Stations in Port Susan

Clusters Linked (Stations)		Percent Similarity
WW11	WW09	76.1
PS03	PS04	74.4
NH02	NH01	68.3
WW14	WW11	64.8
SS11	AB01	63.4
PS02	PS01	63.4
SS11	NS03	62.6
WW14	NH02	60.4
WW14	SS04	59 4
KG01	EW11	57.9
PS03	PS02	55.4
WW14	SS11	53.5
NH08	KG01	52.1
WW14	NH08	49
NS08	NH04	42.1
WW14	NS08	37.9
NH03	EW05	35.5
PS03	WW14	32.6
PS03	NH03	17.0

Table 27—Comparison of Test Results in Identifying Adverse Benthic Impacts

Station	Conclusion Based on Numerical Criterion/Statistical Test								Conclusion Based on Best Professional Judgement			
	Total Abundance	Crustacean Abundance	Mollusc Abundance	Polychaete Abundance	Total Richness	Crustacean Richness	Mollusc Richness	Polychaete Richness	H'	J and D	SDI	ITI
AB-01	NS	NS	NS	*	*	*	NS	*	unstressed	unstressed	unstressed	unstressed
EW-05	<50%**	<50%**	<50%**	<50%**	**	**	**	**	stressed	moderately stressed	stressed	stressed
EW-11	*	<50%	NS	*	NS	NS	**	NS	stressed	stressed	stressed	unstressed
KG-01	NS	<50%**	<50%	*	**	NS	**	NS	stressed	stressed	stressed	unstressed
NH-01	NS	NS	<50%**	NS	NS	NS	**	NS	unstressed	unstressed	unstressed	unstressed
NH-02	NS	NS	<50%**	*	NS	NS	NS	NS	unstressed	unstressed	unstressed	unstressed
NH-03	<50%**	<50%**	<50%**	<50%**	**	**	**	**	stressed	stressed	stressed	stressed
NH-04	NS	<50%**	<50%**	*	**	NS	**	**	stressed	stressed	stressed	unstressed
NH-08	NS	<50%**	NS	NS	NS	NS	NS	NS	moderately stressed	unstressed	moderately stressed	unstressed
NS-03	NS	*	NS	NS	NS	NS	NS	NS	unstressed	unstressed	unstressed	unstressed
NS-08	<50%**	<50%**	<50%**	NS	**	NS	**	**	moderately stressed	moderately stressed	stressed	stressed
SS-04	NS	NS	NS	NS	NS	NS	NS	NS	moderately stressed	moderately stressed	stressed	unstressed
SS-11	NS	NS	NS	NS	NS	*	NS	NS	unstressed	unstressed	unstressed	unstressed
WW-09	NS	NS	<50%	*	NS	NS	**	NS	moderately stressed	unstressed	moderately stressed	unstressed
WW-11	*	NS	NS	*	NS	NS	**	NS	moderately stressed	stressed	stressed	unstressed
WW-14	*	NS	<50%	*	NS	NS	NS	NS	stressed	stressed	stressed	unstressed

*Significantly higher compared to reference.
**Significantly lower compared to reference.
NS: Not significantly different compared to reference.
<50%: Less than 50 percent of the reference abundance.

Table 28—Summary Statistics for the Puget Sound Reference Data

Habitat Category	0 to 20 % fines				20 to 50 % fines				50 to 80 % fines				80 to 100 % fines			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Total Abundance	57	994	491	197	192	864	494	18	43	894	343	187	90	644	307	129
Crustacean Abundance	6	298	120	78	2	222	103	8	0	250	51	53	0	252	76	72
Crustacean Richness	2	23	12	5	1	24	11	1	0	13	7	3	0	10	5	2
Mollusc Abundance	18	318	88	62	16	346	110	10	0	503	111	120	5	171	64	40
Mollusc Richness	3	26	16	5	5	21	13	1	2	24	13	5	3	16	9	3
Polychaete Abundance	10	610	197	125	62	449	224	98	16	287	147	68	11	266	88	57
Polychaete Richness	6	65	34	13	19	65	39	11	9	44	28	8	5	30	16	6
Total Richness	25	115	69	22	30	89	64	14	19	80	52	14	18	52	33	8
Infaunal Trophic Index	60	88	74	7	66	84	72	6	52	84	70	7	54	96	77	10
Swartz's Dominance Index	2	37	14	7	2	24	14	5	4	22	11	5	2	12	7	3
Diversity (H')	0.73	1.79	1.34	0.23	0.62	1.59	1.31	0.22	0.83	1.64	1.23	0.22	0.68	1.33	1.06	0.18
Eveness (J)	0.53	0.91	0.74	0.09	0.42	0.88	0.72	0.10	0.40	0.92	0.72	0.13	0.48	0.89	0.71	0.11

Table 29—Comparisons of Mean Total Abundance by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	523	539	491
Everett Harbor			
EW-12	1,296	425	491
20 to 50% Fines			
Elliott Bay			
AB-01	843	723	494
EW-05	103	723	494
NH-02	574	723	494
NH-04	896	723	494
NS-03	845	723	494
Everett Harbor			
EW-14	488	425[b]	494
50 to 80% Fines			
Elliott Bay			
EW-11	1,980	516[b]	343
NH-03	32	516[b]	343
NH-08	493	516[b]	343
SS-11	648	516[b]	343
WW-09	759	516[b]	343
WW-11	1,593	516[b]	343
WW-14	2,238	516[b]	343
Everett Harbor			
EW-01	54	516[b]	343
EW-04	1,610	516[b]	343
EW-07	54	516[b]	343
EW-10	1,207	516[b]	343
> 80% Fines			
Elliott Bay			
KG-01	1,221	516	307
NS-08	185	516	307
SS-04	1,100	516	307

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 30—Comparisons of Mean Richness by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	53	56	69
Everett Harbor			
EW-12	52	55	69
20 to 50% Fines			
Elliott Bay			
AB-01	80	52	64
EW-05	11	52	64
NH-02	60	52	64
NH-04	32	52	64
NS-03	65	52	64
Everett Harbor			
EW-14	59	55[b]	64
50 to 80% Fines			
Elliott Bay			
EW-11	40	44[b]	52
NH-03	6	44[b]	52
NH-08	41	44[b]	52
SS-11	58	44[b]	52
WW-09	47	44[b]	52
WW-11	46	44[b]	52
WW-14	50	44[b]	52
Everett Harbor			
EW-01	3	44[b]	52
EW-04	15	44[b]	52
EW-07	15	44[b]	52
EW-10	30	44[b]	52
> 80% Fines			
Elliott Bay			
KG-01	25	44	33
NS-08	21	44	33
SS-04	44	44	33

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 31—Comparisons of Mean Crustacean Abundance by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	183	138	120
Everett Harbor			
EW-12	1,064	100	120
20 to 50% Fines			
Elliott Bay			
AB-01	170	80	103
EW-05	3	80	103
NH-02	112	80	103
NH-04	19	80	103
NS-03	272	80	103
Everett Harbor			
EW-14	250	100[b]	103
50 to 80% Fines			
Elliott Bay			
EW-11	49	184[b]	51
NH-03	3	184[b]	51
NH-08	15	184[b]	51
SS-11	228	184[b]	51
WW-09	181	184[b]	51
WW-11	762	184[b]	51
WW-14	93	184[b]	51
Everett Harbor			
EW-01	6	184[b]	51
EW-04	156	184[b]	51
EW-07	26	184[b]	51
EW-10	345	184[b]	51
> 80% Fines			
Elliott Bay			
KG-01	10	184	76
NS-08	9	184	76
SS-04	706	184	76

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 32—Comparisons of Mean Mollusc Abundance by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	28	250	88
Everett Harbor			
EW-12	140	161	88
20 to 50% Fines			
Elliott Bay			
AB-01	259	326	110
EW-05	7	326	110
NH-02	59	326	110
NH-04	12	326	110
NS-03	425	326	110
Everett Harbor			
EW-14	70	161[b]	110
50 to 80% Fines			
Elliott Bay			
EW-11	156	154[b]	111
NH-03	2	154[b]	111
NH-08	65	154[b]	111
SS-11	195	154[b]	111
WW-09	54	154[b]	111
WW-11	67	154[b]	111
WW-14	59	154[b]	111
Everett Harbor			
EW-01	<1	154[b]	111
EW-04	4	154[b]	111
EW-07	6	154[b]	111
EW-10	38	154[b]	111
> 80% Fines			
Elliott Bay			
KG-01	72	154	64
NS-08	28	154	64
SS-04	66	154	64

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 33—Comparisons of Mean Polychaete Abundance by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	311	146	197
Everett Harbor			
EW-12	88	157	197
20 to 50% Fines			
Elliott Bay			
AB-01	411	312	224
EW-05	93	312	224
NH-02	374	312	224
NH-04	865	312	224
NS-03	148	312	224
Everett Harbor			
EW-14	158	157[b]	224
50 to 80% Fines			
Elliott Bay			
EW-11	1,774	177[b]	147
NH-03	28	177[b]	147
NH-08	411	177[b]	147
SS-11	223	177[b]	147
WW-09	522	177[b]	147
WW-11	762	177[b]	147
WW-14	2,080	177[b]	147
Everett Harbor			
EW-01	48	177[b]	147
EW-04	1,446	177[b]	147
EW-07	22	177[b]	147
EW-10	823	177[b]	147
> 80% Fines			
Elliott Bay			
KG-01	1,138	177	88
NS-08	147	177	88
SS-04	328	177	88

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 34—Comparisons of Mean Crustacean Richness by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	9	10	12
Everett Harbor			
EW-12	21	9	12
20 to 50% Fines			
Elliott Bay			
AB-01	16	12	11
EW-05	2	12	11
NH-02	11	12	11
NH-04	11	12	11
NS-03	13	12	11
Everett Harbor			
EW-14	18	9[b]	11
50 to 80% Fines			
Elliott Bay			
EW-11	8	9[b]	7
NH-03	2	9[b]	7
NH-08	5	9[b]	7
SS-11	16	9[b]	7
WW-09	11	9[b]	7
WW-11	10	9[b]	7
WW-14	9	9[b]	7
Everett Harbor			
EW-01	1	9[b]	7
EW-04	5	9[b]	7
EW-07	7	9[b]	7
EW-10	15	9[b]	7
> 80% Fines			
Elliott Bay			
KG-01	4	9	5
NS-08	5	9	5
SS-04	11	9	5

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 35—Comparisons of Mean Mollusc Richness by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	7	13	16
Everett Harbor			
EW-12	11	15	16
20 to 50% Fines			
Elliott Bay			
AB-01	14	11	13
EW-05	1	11	13
NH-02	9	11	13
NH-04	4	11	13
NS-03	15	11	13
Everett Harbor			
EW-14	11	15[b]	13
50 to 80% Fines			
Elliott Bay			
EW-11	7	12[b]	13
NH-03	1	12[b]	13
NH-08	10	12[b]	13
SS-11	13	12[b]	13
WW-09	8	12[b]	13
WW-11	6	12[b]	13
WW-14	8	12[b]	13
Everett Harbor			
EW-01	<1	12[b]	13
EW-04	2	12[b]	13
EW-07	3	12[b]	13
EW-10	4	12[b]	13
> 80% Fines			
Elliott Bay			
KG-01	6	12	9
NS-08	7	12	9
SS-04	8	12	9

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 36—Comparisons of Mean Polychaete Richness by Puget Sound Habitat Category

Station	Station Mean	Site-Specific Reference Mean[a]	Proposed Reference Set Mean
< 20% Fines			
Elliott Bay			
NH-01	36	31	34
Everett Harbor			
EW-12	17	28	34
20 to 50% Fines			
Elliott Bay			
AB-01	47	27	39
EW-05	7	27	39
NH-02	36	27	39
NH-04	17	27	39
NS-03	37	27	39
Everett Harbor			
EW-14	27	28[b]	39
50 to 80% Fines			
Elliott Bay			
EW-11	24	22[b]	30
NH-03	3	22[b]	30
NH-08	25	22[b]	30
SS-11	29	22[b]	30
WW-09	27	22[b]	30
WW-11	28	22[b]	30
WW-14	31	22[b]	30
Everett Harbor			
EW-01	1	22[b]	30
EW-04	7	22[b]	30
EW-07	5	22[b]	30
EW-10	10	22[b]	30
> 80% Fines			
Elliott Bay			
KG-01	15	22	16
NS-08	8	22	16
SS-04	25	22	16

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).

Table 37—Comparisons of ANOVA Results For Total Abundance Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.96)	<0.003
EW-05	<0.001	<0.001
EW-11	<0.004[b]	<0.001
KG-01	NS (<0.15)	<0.001
NH-01	NS (<0.56)	NS (<0.67)
NH-02	NS (<0.76)	NS (<0.84)
NH-03	<0.001[b]	<0.001
NH-04	NS (<0.94)	<0.003
NH-08	NS (<1.0)[b]	NS (<0.91)
NS-03	NS (<0.95)	<0.003
NS-08	<0.045	<0.043
SS-04	NS (<0.72)	<0.001
SS-11	NS (<1.0)[b]	NS (<0.10)
WW-09	NS (<0.98)[b]	<0.020
WW-11	<0.027[b]	<0.001
WW-14	<0.001[b]	<0.001
Everett Harbor		
EW-01	<0.001[b]	<0.001
EW-04	<0.005[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	NS (<0.07)[b]	<0.001
EW-12	<0.001	<0.001
EW-14	NS (<0.99)[b]	NS (<0.59)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 38—Comparisons of ANOVA Results for Richness Using Site-Specific and Puget Sound Reference Data

Station	ANOVA	
	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	<0.001	NS (<0.11)
EW-05	<0.001	<0.001
EW-11	NS (<1.0)[b]	NS (<0.46)
KG-01	<0.005	NS (<0.17)
NH-01	NS (<0.68)	NS (<0.11)
NH-02	NS (<0.20)	NS (<0.98)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<1.0)[b]	NS (<0.53)
NS-03	<0.021	NS (<1.0)
NS-08	<0.001	<0.014
SS-04	NS (<1.0)	<0.032
SS-11	NS (<0.20)[b]	NS (<0.96)
WW-09	NS (<1.0)[b]	NS (<0.99)
WW-11	NS (<1.0)[b]	NS (<0.98)
WW-14	NS (<0.97)[b]	NS (<1.0)
Everett Harbor		
EW-01	<0.001[b]	<0.001
EW-04	<0.001[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	<0.001[b]	<0.003
EW-12	NS (<0.46)	NS (<0.08)
EW-14	NS (<0.80)[b]	NS (<0.40)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 39—Comparisons of ANOVA Results For Crustacean Abundance Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.55)	NS (<0.70)
EW-05	<0.001	<0.001
EW-11	NS (<0.19)[b]	NS (<1.0)
KG-01	<0.004	<0.035
NH-01	NS (<0.42)	NS (<0.15)
NH-02	NS (<0.97)	NS (<0.98)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.020
NH-08	<0.001[b]	NS (<0.86)
NS-03	<0.013	<0.048
NS-08	<0.002	<0.010
SS-04	NS (<0.99)	<0.020
SS-11	NS (<1.0)[b]	<0.006
WW-09	NS (<1.0)[b]	NS (<0.051)
WW-11	NS (<0.27)[b]	<0.001
WW-14	NS (<0.93)[b]	NS (<0.41)
Everett Harbor		
EW-01	<0.001[b]	<0.003
EW-04	NS (<0.81)[b]	NS (<0.21)
EW-07	<0.006[b]	NS (<0.90)
EW-10	NS (<0.93)[b]	<0.001
EW-12	<0.001	<0.001
EW-14	<0.006[b]	<0.027

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 40—Comparisons of ANOVA Results For Mollusc Abundance Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.92)	<0.022
EW-05	<0.001	<0.001
EW-11	NS (<1.0)[b]	NS (<0.67)
KG-01	NS (<0.12)	NS (<0.79)
NH-01	<0.001	<0.001
NH-02	<0.001	NS (<0.80)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<0.09)[b]	NS (<1.0)
NS-03	NS (<0.97)	<0.001
NS-08	<0.001	NS (<0.25)
SS-04	<0.016	NS (<1.0)
SS-11	NS (<1.0)[b]	NS (<0.44)
WW-09	NS (<0.06)[b]	NS (<1.0)
WW-11	NS (<0.22)[b]	NS (<1.0)
WW-14	NS (<0.18)[b]	NS (<1.0)
Everett Harbor		
EW-01	<0.001[b]	<0.001
EW-04	<0.001[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	<0.002[b]	NS (<0.71)
EW-12	NS (<0.65)	NS (<0.06)
EW-14	<0.026[b]	NS (<0.32)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 41—Comparisons of ANOVA Results For Polychaete Abundance Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.70)	<0.015
EW-05	<0.001	<0.001
EW-11	<0.001[b]	<0.001
KG-01	<0.001	<0.001
NH-01	<0.004	NS (<0.051)
NH-02	NS (<0.91)	<0.048
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<0.12)[b]	<0.007
NS-03	<0.011	NS (<0.60)
NS-08	NS (<0.95)	NS (<0.41)
SS-04	NS (<0.16)	<0.001
SS-11	NS (<0.90)[b]	NS (<0.44)
WW-09	<0.003[b]	<0.001
WW-11	<0.001[b]	<0.001
WW-14	<0.001[b]	<0.001
Everett Harbor		
EW-01	<0.009[b]	<0.001
EW-04	<0.001[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	<0.001[b]	<0.001
EW-12	<0.009	NS (<0.06)
EW-14	NS (<0.94)[b]	NS (<0.08)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 42—Comparisons of ANOVA Results For Crustacean Richness Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.25)	NS (<0.14)
EW-05	<0.002	<0.001
EW-11	NS (<1.0)[b]	NS (<1.0)
KG-01	<0.001	NS (<0.54)
NH-01	NS (<0.36)	NS (<0.09)
NH-02	NS (<1.0)	NS (<1.0)
NH-03	<0.010[b]	<0.031
NH-04	NS (<1.0)	NS (<1.0)
NH-08	NS (<0.57)[b]	NS (<0.97)
NS-03	NS (<0.99)	NS (<0.97)
NS-08	<0.009	NS (<1.0)
SS-04	NS (<0.47)	<0.001
SS-11	<0.010[b]	<0.001
WW-09	NS (<1.0)[b]	NS (<0.18)
WW-11	NS (<1.0)[b]	NS (<0.39)
WW-14	NS (<1.0)[b]	NS (<0.94)
Everett Harbor		
EW-01	<0.003[b]	<0.002
EW-04	NS (<0.15)[b]	NS (<0.59)
EW-07	NS (<0.65)[b]	NS (<1.0)
EW-10	<0.025[b]	<0.001
EW-12	<0.001	<0.001
EW-14	<0.001[b]	<0.002

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 43—Comparisons of ANOVA Results For Mollusc Richness Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	NS (<0.41)	NS (<0.98)
EW-05	<0.001	<0.001
EW-11	<0.021[b]	NS (<0.09)
KG-01	<0.003	NS (<0.10)
NH-01	<0.001	<0.001
NH-02	NS (<0.66)	NS (<0.17)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<0.69)[b]	NS (<0.72)
NS-03	NS (<0.17)	NS (<0.83)
NS-08	<0.015	NS (<0.42)
SS-04	<0.044	NS (<0.75)
SS-11	NS (<1.0)[b]	NS (<1.0)
WW-09	<0.045[b]	NS (<0.15)
WW-11	<0.002[b]	<0.023
WW-14	NS (<0.07)[b]	NS (<0.18)
Everett Harbor		
EW-01	<0.001[b]	<0.001
EW-04	<0.001[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	<0.001[b]	<0.001
EW-12	<0.018	<0.018
EW-14	<0.007[b]	NS (<0.15)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 44—Comparisons of ANOVA Results For Polychaete Richness Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
Elliott Bay		
AB-01	<0.001	NS (<0.64)
EW-05	<0.001	<0.001
EW-11	NS (<1.0)[b]	NS (<0.95)
KG-01	NS (<0.27)	NS (<0.99)
NH-01	NS (<0.23)	NS (<0.71)
NH-02	<0.013	NS (<0.99)
NH-03	<0.001[b]	<0.001
NH-04	<0.004	<0.001
NH-08	NS (<1.0)[b]	NS (<0.98)
NS-03	<0.006	NS (<1.0)
NS-08	<0.012	NS (<0.06)
SS-04	NS (<0.86)	<0.008
SS-11	NS (<0.62)[b]	NS (<1.0)
WW-09	NS (<0.91)[b]	NS (<1.0)
WW-11	NS (<0.77)[b]	NS (<1.0)
WW-14	NS (<0.21)[b]	NS (<0.98)
Everett Harbor		
EW-01	<0.001[b]	<0.001
EW-04	<0.001[b]	<0.001
EW-07	<0.001[b]	<0.001
EW-10	<0.001[b]	<0.001
EW-12	<0.001	<0.004
EW-14	<0.003[b]	<0.016

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines)
NS: Not significant at P<0.05

Table 45—Comparisons of ANOVA Results for the Infaunal Trophic Index Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
AB-01	NS (<0.91)	NS (<0.41)
EW-05	<0.001	<0.001
EW-11	NS (<0.95)[b]	NS (<0.78)
KG-01	NS (<0.93)	NS (<0.16)
NH-01	<0.001	<0.001
NH-02	NS (<0.38)	<0.011
NH-03	<0.001[b]	<0.001
NH-04	NS (<0.56)	<0.041
NH-08	NS (<1.0)[b]	NS (<1.0)
NS-03	NS (<0.48)	<0.023
NS-08	<0.001	<0.001
SS-04	NS (<0.63)	<0.024
SS-11	NS (<1.0)[b]	NS (<0.99)
WW-09	NS (<0.96)[b]	NS (<0.82)
WW-11	NS (<0.92)[b]	NS (<0.69)
WW-14	NS (<0.97)[b]	NS (<0.85)

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 46—Comparisons of ANOVA Results For Swartz's Dominance Index Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
AB-01	<0.047	NS (<0.93)
EW-05	<0.001	<0.001
EW-11	<0.001[b]	<0.001
KG-01	<0.001	<0.001
NH-01	NS (0.51)	NS (<0.17)
NH-02	<0.002	NS (<1.0)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<0.95)[b]	NS (<0.48)
NS-03	NS (<0.98)	NS (<0.14)
NS-08	<0.001	<0.011
SS-04	<0.003	NS (<0.10)
SS-11	NS (<0.53)[b]	NS (<0.99)
WW-09	NS (<0.53)[b]	NS (<0.31)
WW-11	<0.001[b]	<0.009
WW-14	<0.001[b]	<0.002

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05
–: One variable had no associated variance.

Table 47—Comparisons of ANOVA Results For Shannon-Weiner Diversity Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
AB-01	<0.029	NS (<1.0)
EW-05	<0.001	<0.001
EW-11	<0.001[b]	<0.001
KG-01	<0.001	<0.001
NH-01	NS (<0.22)	NS (<0.38)
NH-02	<0.008	NS (<0.99)
NH-03	<0.001[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<0.85)[b]	NS (<0.22)
NS-03	NS (<0.97)	NS (<0.91)
NS-08	<0.002	<0.001
SS-04	<0.015	<0.027
SS-11	NS (<0.79)[b]	NS (<1.0)
WW-09	NS (<0.95)[b]	NS (<0.33)
WW-11	<0.001[b]	<0.001
WW-14	<0.001[b]	<0.001

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines)
NS: Not significant at P<0.05

Table 48—Comparisons of ANOVA Results For Evenness Using Site-Specific and Puget Sound Reference Data

	ANOVA	
Station	Site-Specific Reference[a]	Proposed Reference Set
AB-01	NS (<0.98)	NS (<1.0)
EW-05	<0.001	<0.001
EW-11	<0.001[b]	<0.001
KG-01	<0.001	<0.001
NH-01	NS (<0.07)	NS (<0.81)
NH-02	NS (<0.10)	NS (<0.88)
NH-03	<0.002[b]	<0.001
NH-04	<0.001	<0.001
NH-08	NS (<1.0)[b]	NS (<0.79)
NS-03	NS (<0.99)	NS (<0.80)
NS-08	NS (<0.32)	<0.031
SS-04	NS (<0.10)	<0.002
SS-11	NS (<1.0)[b]	NS (<1.0)
WW-09	NS (<0.94)[b]	NS (<0.50)
WW-11	<0.007[b]	<0.001
WW-14	<0.001[b]	<0.001

[a]Site-specific reference grouped by grain size class (SEA) unless otherwise noted.
[b]Grain size class comparison not available based on site-specific reference data set; comparison made using site-specific reference data pooled by "fines" (>50% fines) or "coarse" (<50% fines).
NS: Not significant at P<0.05

Table 49—Outcome of the Statistical Comparisons using Puget Sound Reference Values versus Site-Specific Reference Values Using Elliott Bay and Everett Harbor Stations

Index	No net change in result[a]	Results become significant with use of Puget Sound reference	Results become non-significant with use of Puget Sound reference
Total abundance	15	7	0
Crustacean abundance	16	4	2
Mollusc abundance	16	2	4
Polychaete abundance	19	2	1
Total richness	19	1	2
Crustacean richness	20	1	1
Mollusc richness	17	0	5
Polychaete richness	20	0	2
ITI[b]	12	4	0
SDI[b]	13	0	3
H'[b]	14	0	2
J[b]	14	2	0
Total number of reversals		23	22

a Based on ANOVA results using Tukey's *a posteriori* pair-wise test
b Evaluated for Elliott Bay Stations only