Chapter 13
Case Studies

In conjunction with the drafting of this guidance manual, the USEPA Biocriteria Program has also supported or assisted in the support of projects around the country to evaluate estuarine and coastal marine survey methods and to develop metrics appropriate for use in different settings. These studies were conducted prior to the creation of this guidance document. Each case study exemplifies a section within the guidance. This chapter summarizes studies conducted in the Pacific Northwest, Gulf of Mexico, and along the Middle and South Atlantic coasts.

Some of the material presented here also appears in the body of this text and the information which follows expands on that discussion. Further, the principal investigators or other contact in each instance are listed with their addresses and phone numbers should the reader desire to comment or request more information.

13.1 Puget Sound - *Development of Trawl-Based Tools For the Assessment of Demersal Fauna (Macroinvertebrates and Fishes): A Puget Sound Pilot Study*

The relationship between pollution and the health and status of marine benthos are being studied in the Puget Sound region of Washington state (Figure 13-1). Detailed sediment data, including information on chemistry, toxicity and infaunal populations, are being collected for the Puget Sound Ambient Monitoring Program (PSAMP) as well as for various urban bay, dredge disposal, and Superfund action programs. The PSAMP has quantitatively defined population patterns of demersal fishes, but has not defined those patterns for other demersal fauna such as macroinvertebrates. Nor has any program developed data to explain how the fauna are responding to the environmental stresses associated with a contaminated substrate.

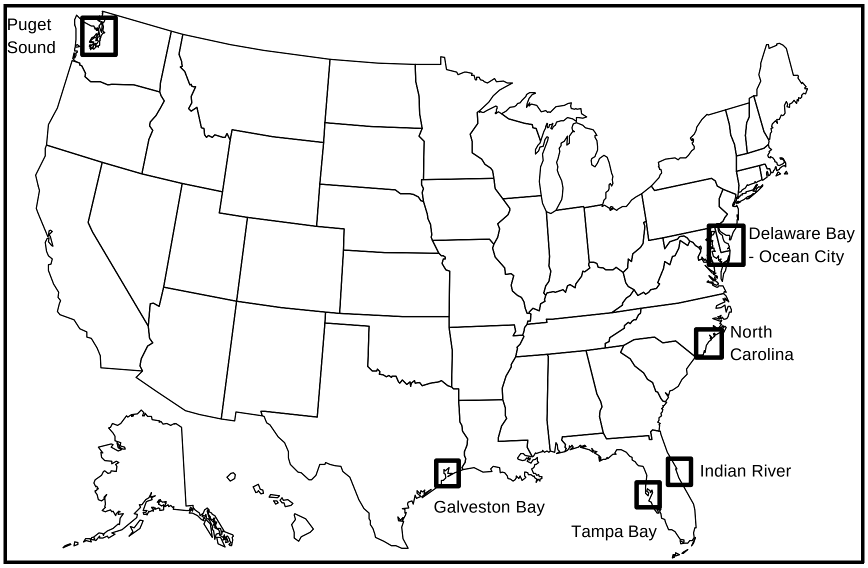
13.1.1 Study Objectives

The Puget Sound study (Eaton and Dinnel 1993, Eaton 1994, 1995) was initiated in 1993 to document demersal populations in their entirety, and to attempt to relate the resulting biological information to sediment chemistry, toxicity, and infauna. The pilot study, funded by USEPA, began by assessing the utility of using two different trawls to quantitatively define demersal populations at a given point in time. Using the resulting documented population patterns and comparisons between reference and contaminated areas, the study objectives were ultimately to:

- Gain a greater understanding of how demersal populations are being affected by pollution and habitat degradation;
- Determine which patterns reflect environmental stress;
- Develop metrics (biological measures) which would help to build a biological index for the rapid

Figure 13-1

General location of the case studies.



and economical assessment of stress in subtidal biotic marine communities.

13.1.2 Study Methods

Beam and otter trawls were used to sample Puget Sound demersal fauna in 1993 and 1994. A 3-m beam trawl (with a tickler chain attached in front of the net) towed at 1.5 knots proved to be very effective for sampling most demersal invertebrates and small or juvenile fishes. A 7.6-m Southern California Coastal Water Research Project otter trawl, towed at 2.5 knots, was best suited for sampling larger and more mobile marine fishes and invertebrates. All trawl catches were held in tubs of running seawater following capture, and fauna were subsequently sorted, identified, counted, measured and weighed. All organisms were released on station.

In the first year of the pilot study (1993) sampling focused on two of the Tacoma Waterways, the contaminated Hylebos Waterway (a Superfund site) and the adjacent, less-impacted Blair Waterway. Sampling in 1994 compared another Tacoma Waterway and Superfund site, Thea Foss (City) Waterway, with a cleaner and more natural reference condition (six miles to the north) in Quartermaster Harbor on Vashon Island. Bottom depth, sediment grain-size analysis (either historical information or wet-sieving technique for percent fines), bottom temperature, and salinity data were recorded for all stations to insure meaningful pairing of sites.

Spatial coverage of the study area was determined using a stratified random design. The Hylebos and Blair Waterways were divided into four strata, the Thea Foss into three strata, and Quartermaster Harbor into two. One station was located in each stratum, except in mid-Quartermaster Harbor with two stations one being an historical sediment monitoring station. A second station was placed in the mid-Quartermaster Harbor stratum to compare the variability in results between two stations of close proximity with similar depth and sediment grain-size.

Evaluation of ten consecutive and seven non-consecutive otter trawl replications in 1993 led to the conclusion that four or five otter trawl replications were needed to quantitatively define the demersal fish community at a given station, and that the replications should not recur in less than four hours. The 1994 sampling design incorporated these recommendations, utilizing a sampling effort of five otter trawl and three beam trawl replications per station.

The extensive data set resulting from the trawl surveys was entered into computer spreadsheets as catch files, and was sorted and statistically analyzed for patterns and relationships. The null hypothesis for the pilot study was that the contaminated and non-contaminated sites were not significantly different for the parameters measured (i.e., fish abundance, biomass, mean individual weights, diversity and evenness). Data comparisons were tested for statistical significance using either a parametric test (i.e., Student's two-tailed, two-sample t-test either paired or independent) or a non-parametric test (i.e., two-sample Kolmogorov-Smirnov Test) depending on the outcome of the test for normality (i.e., one-sample Kolmogorov-Smirnov normality test). Species diversity was calculated using the Shannon-Wiener Index (H') with the natural logarithm, although simple species richness measurements proved to be more statistically significant. Species evenness was measured with Pielou's evenness index (J) and number of species $\geq$90% of total abundance. Dominance was measured using the dominance ratio, N_{max} / N, where N_{max} = number of individuals of the most abundant species, and N is the total catch.

13.1.3 Study Results

Pilot study results focused on a comparison of the reference and contaminated stations which showed the best match of environmental parameters. Reference station QMH1 in upper Quartermaster Harbor and contaminated station TF1 in the upper end of the Thea Foss Waterway proved to be very similar in depth, sediment grain size, bottom temperature and salinity. A comparison of catch data for the two stations indicated that fish abundance in the reference area was actually lower compared to that found at the contaminated Superfund site (Figure 13-2a), whereas fish biomass was significantly greater at the reference site (Figure 13-2b). This finding indicated that the individual fishes at the reference site must be considerably larger than those found at the contaminated site, and/or that sensitive fish species found at the reference site but not at the contaminated site tended to be much larger than the other fish. Both factors contributed to the differences. Eight of the thirteen fish and invertebrate species common to both sites showed significantly greater mean individual weights at the reference stations, and of the remaining five, only one species was consistently larger at the contaminated sites (Figure 13-2c). Also the cartilaginous fishes (i.e. spiny dogfish, spotted ratfish, and the skates), tentatively classified as sensitive species, were only rarely encountered in the contaminated waterways and were very large compared to the bony fishes.

A preliminary list of tolerant and sensitive fish and invertebrate species was generated for the Tacoma waterways and Quartermaster Harbor fauna based on the pilot study results (Table 13-1). Tolerant species were defined as those whose relative abundance at contaminated sites is significantly greater than or indistinguishable from those species found at comparable reference sites (i.e., site of comparable depth, salinity, dissolved oxygen, sediment grain-size, slope, and density of structures such as eelgrass). Sensitive (intolerant) species, on the other hand, were defined as those species whose relative abundance is

Figure 13-2a

Bony fish abundance and total fish abundance for reference and contaminated sites.

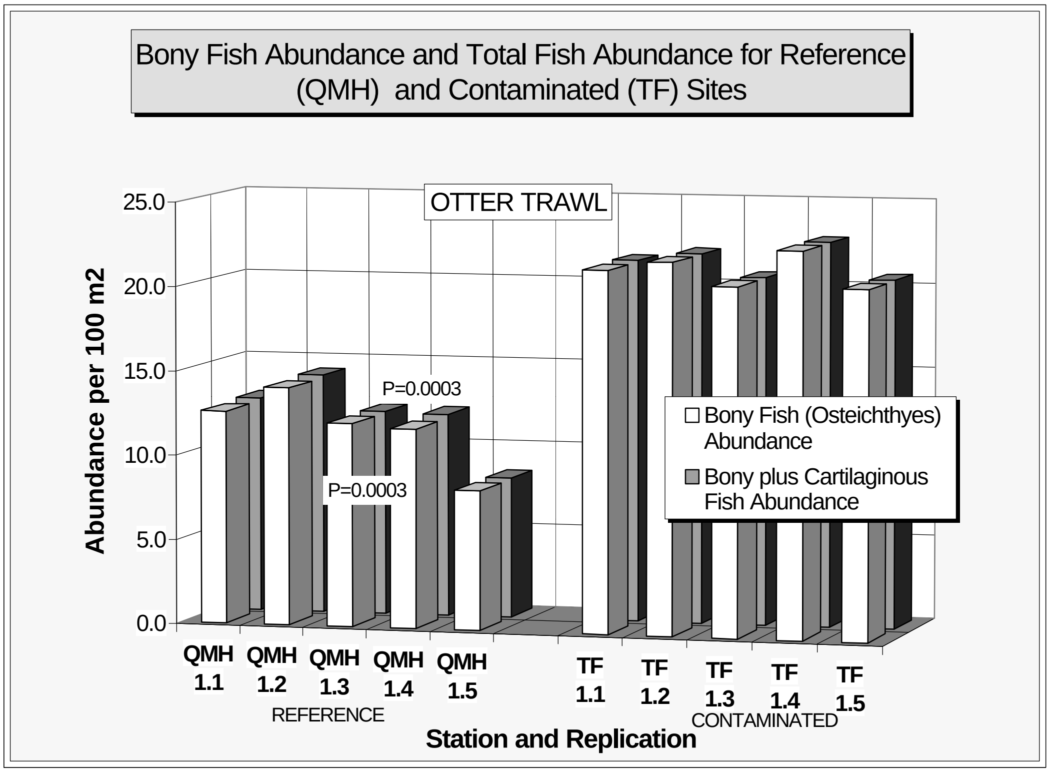
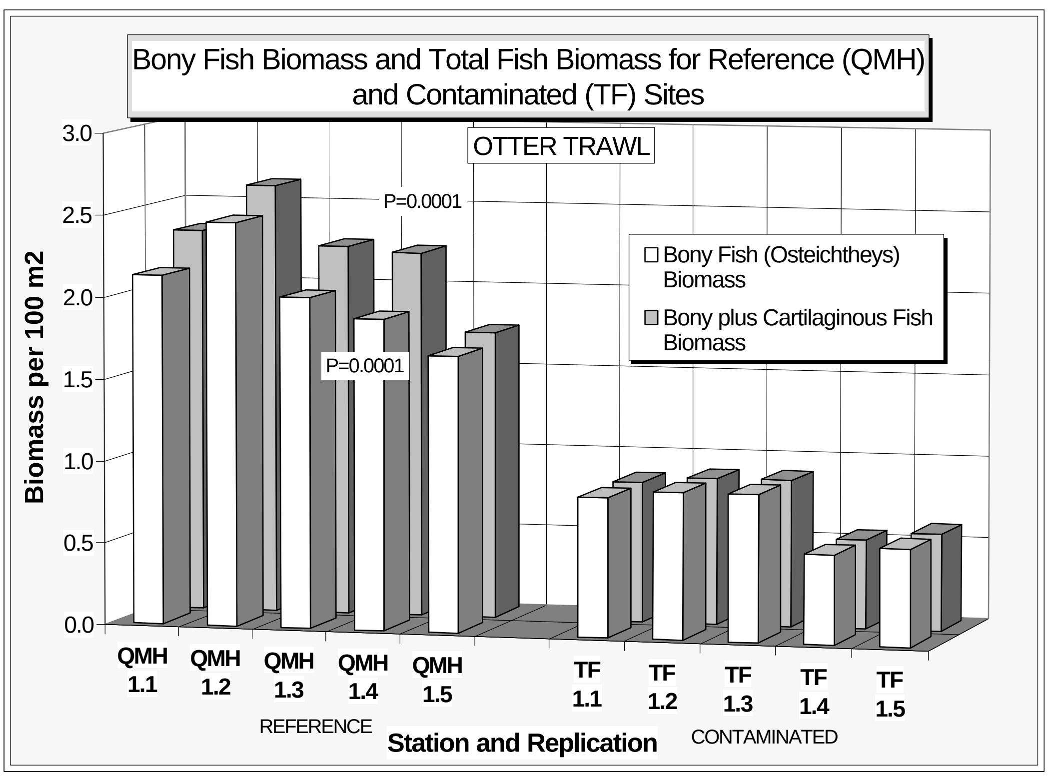


Figure 13-2b

Bony fish biomass and total fish biomass for reference and contaminated sites.



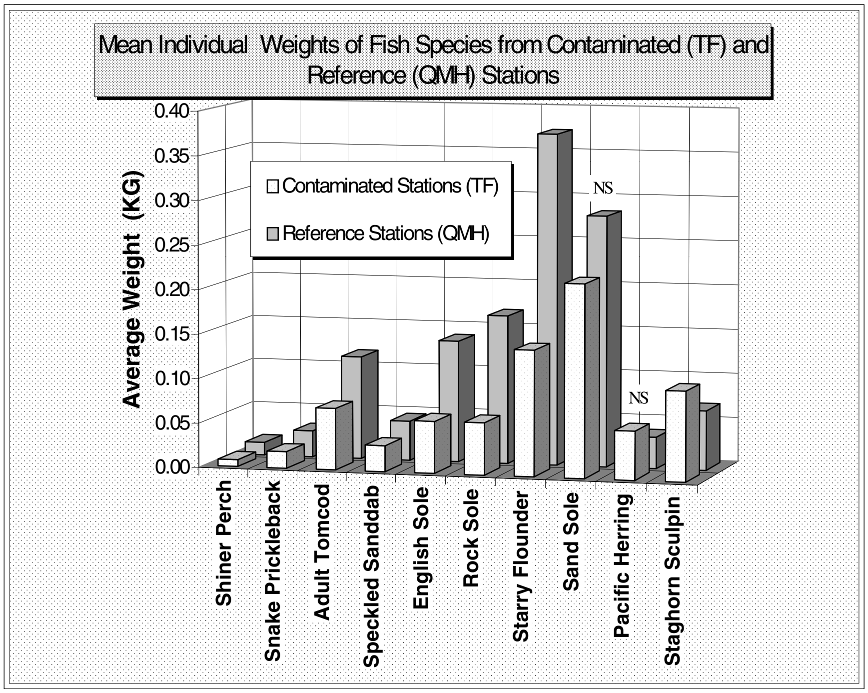


Figure 13-2c

Mean individual weights of fish species from contaminated and reference stations.

significantly greater from a reference area than from a comparable contaminated site.

The sensitive species index, derived from the proportion of sensitive species abundance or biomass to the total of sensitive plus tolerant species, was applied to the pilot study catch data. Index results showed significant differences for all comparisons (i.e., fish abundance and biomass, and fish plus invertebrate abundance and biomass between contaminated and reference sites). The results suggested that such an index, if tested independently for annual and seasonal variation, could be very useful in tracking recovery of an area after cleanup or remediation, or to help classify impacted sites relative to the benchmarks established through the biocriteria.

Pilot study results also indicated that fish species richness and fish species evenness were useful measurements in the site discrimination process.

Although no difference was found in species richness using the beam trawl sampling method, otter trawl catches indicated that fish species richness was notably greater at the reference site (16 species) than at the contaminated station (11 species). When statistically examined on a trawl-by-trawl basis (i.e., using the mean number of fish species per sample), fish species richness was significantly greater at the reference stations. Fish species evenness, as measured by the number of fish species ≥90% of total abundance, was also significantly higher at the reference stations, both when paired with the Thea Foss stations, and when compared as a whole. External abnormalities or anomalies, such as fin erosion or skin tumors, were extremely rare at all stations during both study years, thereby suggesting that it may not be a useful indicator of environmental stress.

The results of the first year of sampling indicated that raw or averaged abundance data were not useful in differentiating contaminated and reference sites. This discovery led to an increased effort in recording biomass data during the second study year, and to the inclusion of a more natural reference condition. Results of the second year of sampling emphasized the

Table 13-1. A preliminary list of tolerant and sensitive fish and invertebrate species from the Tacoma Waterways and Quartermaster Harbor.

FISH	
Tolerant Species	**Sensitive Species**
English sole Sand sole Flathead sole Pacific tomcod Shiner surfperch Snake prickleback Pacific staghorn sculpin	Spiny dogfish Spotted ratfish Longnose skate Rock sole Starry flounder Speckled sanddab Pile surfperch Striped surfperch Bay goby Blackbelly eelpout Bay pipefish Plainfin midshipman
INVERTEBRATE	
Pandalus danae: coonstripe shrimp *Crangon spp.*: sand shrimp	*Cucumaria miniata*: sea cucumber *Cucumaria piperata*: spotted sea cucumber
Cancer gracilis: purple cancer crab	*Pentamera populifera*: crescent sea cucumber
Cancer productus: red rock crab	*Parastichopus californica*: edible sea cucumber
Cancer magister: Dungeness crab *Lophopanopeus bellus*: crab	*Solaster stimpsoni*: sunstar *Pagurus spp.*: hermit crabs
Evasterias troschelli: mottled seastar *Metridium senile*: plume anemone	*Nassarius mendicus*: snail

ecologically important fact that the reference sites, despite fewer or equal numbers of fishes, supported more than twice the fish biomass than the contaminated site. Almost every fish species common to both areas was significantly larger, and fish species richness and evenness were significantly higher at the reference site.

The sensitive species index proved to be useful in differentiating sites. The identification of sensitive (intolerant) and tolerant demersal marine species is in its infancy, due in part to the paucity of data on demersal marine communities and the lack of quantitative sampling methods. With the development of these sampling techniques, the pilot study demonstrated that information on the demersal fauna should be included in any future ecologically-based indexes of pollution. Candidate attributes of demersal fauna which warrant further study are listed in Table 13-2.

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Table 13-2. Candidate attributes of demersal fauna showing significant differences in the present study.

Candidate Metrics	**Preliminary Expectation** from Present Study: **IMPAIRED SITE**	**Range of Values (and mean)** from Present Pilot Study: **IMPAIRED SITE:** Thea Foss Wty.	**Range of Values (and mean)** from Present Pilot Study: **REFERENCE SITE:** QM Hbr.
Total **Fish Abundance** per 100 m^2, 4-6 m. Depth. (10-15 m.—no difference).	Elevated or no difference	TF 1: 20.6 to 22.7 mean = 21.4	QMH 1: 8.3 to 14.2 mean = 11.9
Total **Fish Biomass** per 100 m^2	Reduced	0.54 to 0.97 kg (mean = 0.73)	0.81 to 4.82 kg (mean = 2.64)
Fish Species Richness (Number of fish species)	Reduced	per tow: 6-13 cumulative:10-14	per tow: 11-18 cumulative:15-18
Fish Species Evenness (Number of Fish Species ≥ 90% of Total Abundance)	Reduced	3-6 (mean = 3.7)	4-7 (mean = 5.2)
Mean Individual Weight and Size of all Species (except Pacific Herring and Staghorn Sculpin)	Reduced	e.g. English Sole 45 to 114 g (mean = 75 g.)	e.g. English Sole 125 to 484 g. (mean=204 g.)
Tolerant Species Abundance and Biomass (English Sole, Pacific Staghorn Sculpin, Pacific Tomcod, Shiner Surfperch, Snake Prickleback, Purple Crab, Mottled Seastar, Plum Anemone)	Elevated or (in some cases) no difference	e.g. English Sole 2.8-10.1 (5.3) per 100 m^2 e.g. juv. Tomcod 0.39 to 9.87 (7.3) e.g. Purple Crab 4.7 to 56.0 (22.8)	e.g. English Sole 0.2 to 6.1 (2.3) per 100 m^2 e.g. juv. Tomcod 0 to 0.69 (0.4) e.g. Purple Crab 0.0 to 6.3 (2.7)
Sensitive Species Abundance and Biomass (Bay Goby, Starry Flounder, Rock Sole, Cartilaginous Fish, Sea Cucumbers)	Reduced	e.g. Bay Goby 0.4 to 3.9 (1.7) per 100 m^2 e.g. *Cucumaria piperata* Zero	e.g. Bay Goby 28.6-41.9 (36.5) per 100 m^2 e.g. *Cucumaria piperata* 0.0 to 5.9 (2.5)
Sensitive Species Index (proportion of sensitive to sensitive + tolerant)	Reduced	0.016 to 0.098 mean = 0.049	0.075 to 0.787 mean = 0.357