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# Marine Sediment Monitoring Program

# II. Distribution and Structure of Benthic Communities in Puget Sound 1989-1993

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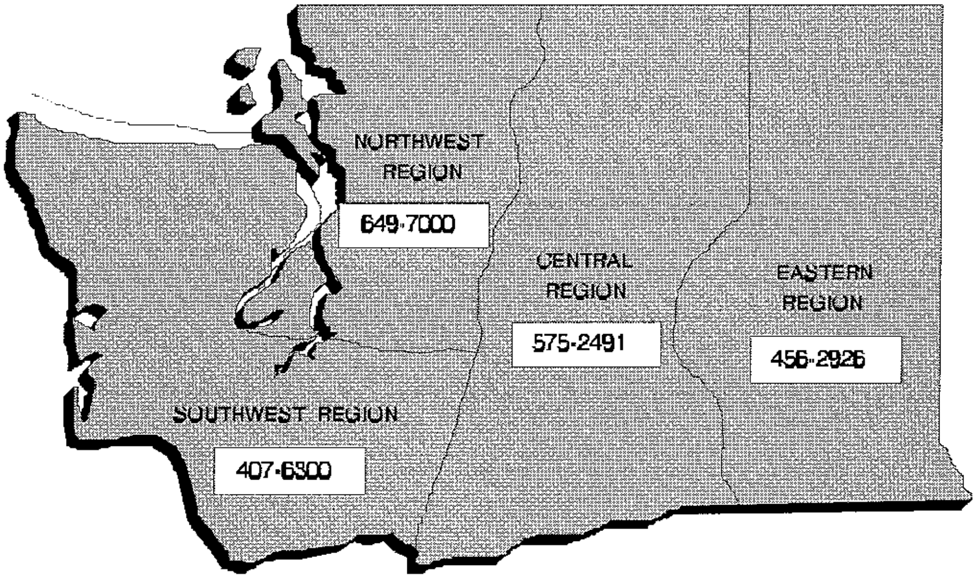


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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

# Marine Sediment Monitoring Program

# II. Distribution and Structure of Benthic Communities in Puget Sound 1989-1993

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# Abstract

The Marine Sediment Monitoring Program (MSMP) monitors sediment quality at sampling locations throughout Puget Sound. Objectives of the benthic component are to collect baseline data in contaminated and uncontaminated stations, as well as evaluate the condition of benthic macro-invertebrates in relation to concentrations of toxic chemicals in sediments. To address these objectives, this report documents spatial and temporal patterns of variation in species abundance and composition, and assesses effects from contamination at MSMP stations. In addition, the report identifies potential natural stresses that may structure benthic communities in Puget Sound and may constitute confounding factors in pollution monitoring studies.

Samples were collected March-April 1989-1993 from 76 monitoring stations located throughout Puget Sound, Hood Canal, and the Straits of Georgia and Juan de Fuca. Two types of stations were established: core stations, sampled once every year, and rotating stations, sampled once every three years in a rotating cycle alternating between the north, central, and south Puget Sound regions. Five van Veen grabs were collected at each station, and the organisms (1.0-mm sieve fraction) were identified to species. Sediment contaminants (not presented here), total organic carbon, total sulfide, and grain size were measured from the top 2 cm of paired samples.

Multivariate analysis techniques showed that infaunal assemblages in Puget Sound are primarily related to sediment composition and water depth, and secondarily to geographical location. Assemblages of numerically dominant species were characterized using rank analysis. The majority of the species in Puget Sound were not restricted to one substrate, but were broadly distributed in different types of substrates with peaks of abundance in sand, mixed sediment, or mud. Diversity measures identified some stations as consistently having low species richness. These stations were distinctly separated in cluster analysis, and consisted of upper reaches of inlets in south Puget Sound, semi-enclosed bays, and some depositional locations associated with river plumes. These locations have the potential for the development of low DO episodes in bottom waters and the accumulation of sulfide in sediments. Abundance also was low at many of these locations.

In general, spatial patterns in species abundance and composition appeared to be unrelated to contaminant concentrations at sampling locations. However, the polychaete *Aphelochaeta* sp. was distinctly associated with sediment contamination and/or organic enrichment. This species may be useful as an indicator of pollution. In addition, large fluctuations in abundance were associated with the numerical dominance of typically 20 species of benthic organisms plus the Phoronida. Temporal patterns in species abundance at some stations differing in sediment quality were homogeneous basin-wide and unrelated to contamination.

This study represents the first system-wide effort to characterize benthic assemblages in the Puget Sound region. The study evaluates the benthic component of the MSMP, suggests improvements to the design, and provides recommendations.

# Introduction

This report is the second part of a summary that presents the results of the Marine Sediment Monitoring Program (MSMP) from 1989 through 1995. Volume 1 presented the sediment chemistry and bioassay results (Llansó *et al.*, 1998). Volume 2 presents the biological findings for the period 1989-1993.

The background and objectives of the MSMP were stated in Volume 1. Two objectives focussing on the benthic component of the program were to:

(1) Collect baseline data and long-term data on Puget Sound sediments and macro-invertebrate communities in contaminated and uncontaminated areas.

(2) Evaluate the condition of Puget Sound benthic macro-invertebrate communities in relation to the concentration of toxic chemicals in sediments.

To address these two program level objectives, the present report describes spatial and temporal patterns of variation in species abundance and composition at MSMP stations, characterizes benthic assemblages in Puget Sound, and assesses potential effects from contamination. In addition, the report looks at natural stresses that may structure benthic communities and which may constitute confounding factors in pollution monitoring efforts. In its last section, the report evaluates the design of the benthic component of the MSMP, suggests next steps in the evaluation of benthic data, and provides recommendations.

# Methods

## Sampling Design

Benthic infauna were collected 1989-1995 at 86 stations established throughout Puget Sound, Hood Canal, the Strait of Georgia, and the Strait of Juan de Fuca (Figure 1). Data presented in this report are for the period 1989-1993 since at the time of report preparation the taxonomy for the 1994 and 1995 samples had not been completed.

Stations were selected based on criteria established by the Monitoring Management Committee (MMC, 1988). The stations were selected subjectively to ensure a variety of physical environments and wide geographical coverage. Station locations included centers of major basins, bays and inlets, nearshore areas, and historic sampling sites with data extending back to the 1960s. Station distribution, however, was biased toward nearshore areas of about 20 m or less in depth. It was thought that nearshore areas would be most important in terms of diversity of benthic organisms (MMC, 1988). Focussing more heavily in nearshore areas would also allow more stations to be assessed in regions where sediment quality problems may be emerging as a consequence of shoreline development.

In addition to identifying emerging problem areas, a main focus of the MSMP was to monitor ambient conditions in order to characterize background sediments. Therefore, stations were deliberately located away from the immediate vicinity of major known sources of sediment contamination.

Of the original 86 stations, 76 were kept in the program and 10 were dropped or moved because of difficulties in sampling (Table 1). Stations with very coarse sediments were eliminated because gravel and rocks prevented adequate sample collection. Data from these 10 stations were not examined. Stations were categorized as "core" or "rotating". Core stations (34) were sampled annually, and rotating stations (42) were sampled once every three years in sets of fourteen, alternating among northern, central, and southern areas in the Puget Sound region (Table 1; Figure 1). Rotating stations were developed in the second year (1990) of the program to provide more concentrated, though less frequent, coverage of all portions of Puget Sound. Therefore, 48 stations were sampled in any given year except for 1989, where a preliminary set of 50 stations was sampled. All sampling occurred during three weeks in late March or early April to allow for the measurement of the stable adult invertebrate population surviving over the winter (Tetra Tech, 1987).

## Sampling and Laboratory Procedures

Sampling was conducted according to the Puget Sound Estuary Program (PSEP) protocols (Tetra Tech, 1986; 1987) and procedures outlined in the MSMP Implementation Plan (Striplin, 1988). Five replicate sediment samples were collected at each station with a double 0.1 $m^2$ van Veen grab. The double van Veen consists of two separate compartments which allow simultaneous collection of chemistry and biological samples.

Sediment samples from one van Veen compartment were washed through a 1.0-mm mesh screen using running sea-water. Benthic organisms retained in the screen were transferred to 10% buffered formalin in sea-water, stained with Rose Bengal, and later sorted, enumerated, and identified to species level in the laboratory.

In the laboratory, samples were washed in fresh water and stored in 70% ethanol previous to sorting and identification. Organisms were sorted into five major taxonomic groups: Annelida, Arthropoda, Mollusca, Echinodermata, and miscellaneous phyla (combined). Quality Assurance and Control procedures (QA/QC) included the re-examination of 20% aliquots of every sample. Sorting QC required recovery of 95% of the total number of organisms in the sample by the initial sorter. Samples not meeting this removal criterion were completely resorted.

Faunal identifications were performed by taxonomists at the Department of Ecology, and by Marine Taxonomic Services (Corvallis, OR), EVS Environment Consultants (Seattle, WA), and MEC Analytical Systems (Carlsbad, CA). Identifications were conducted to the lowest taxonomic level possible, usually to species. For incomplete specimens, only the anterior or posterior ends were counted and identified, depending on the species. All identifications were made using binocular dissecting scopes at 40x magnification power, or using compound microscopes. If available, three representative organisms of each species or taxon were removed from the samples and placed in a voucher collection.

QA/QC procedures consisted of the re-identification of five percent of all samples by senior taxonomists qualified to identify organisms in each major taxonomic group. Senior taxonomists also reviewed and verified all the voucher specimens generated by the primary taxonomists. Reference lists of all the taxonomic literature used to identify the species, including publications describing recent changes in species nomenclature, were usually prepared and kept in laboratory files to aid in the identification of organisms in subsequent years.

Sediment characteristics that usually determine faunal composition were measured as described below. Further detail on laboratory procedures and sediment chemistry analyses can be found in Volume 1 of this report.

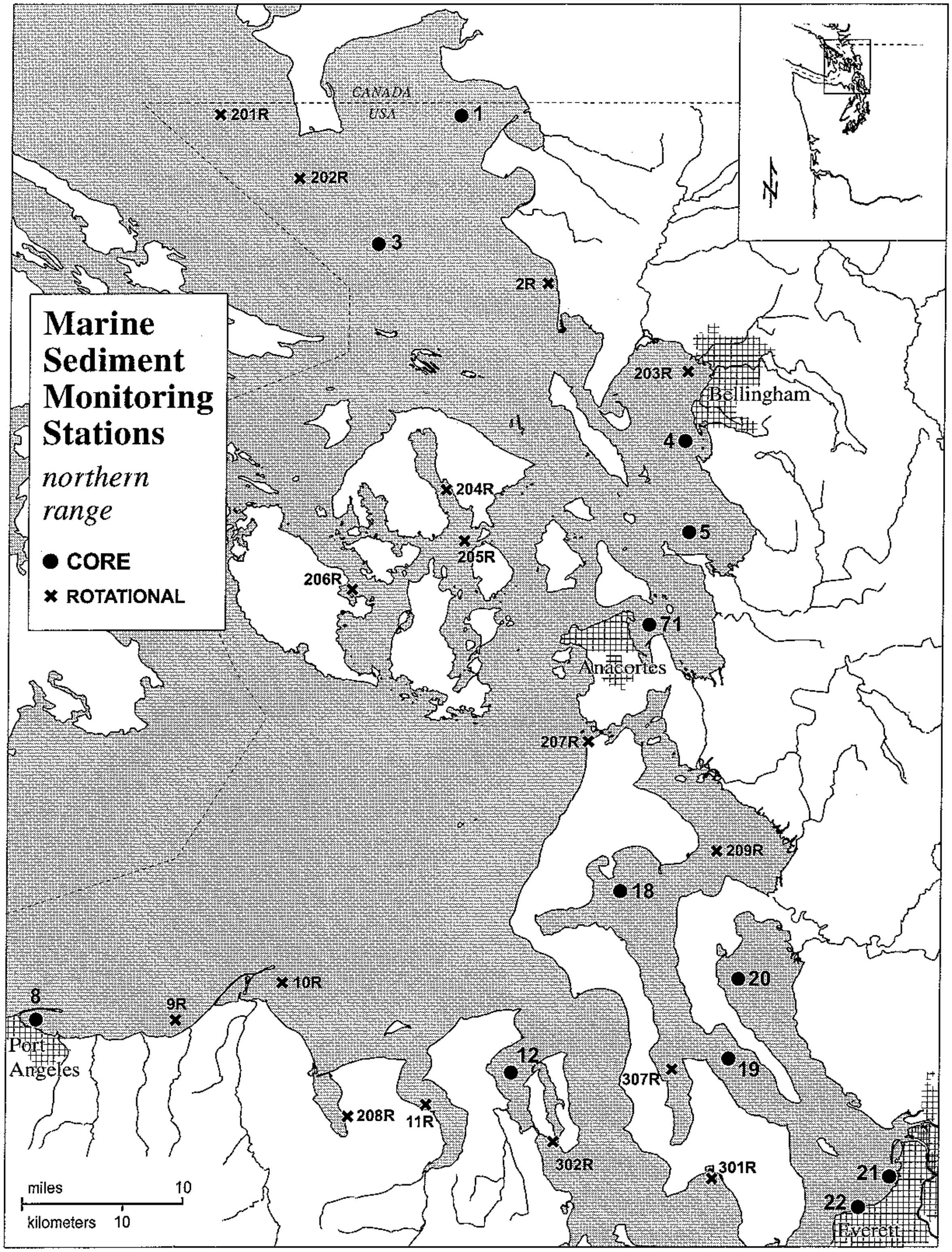



Figure 1A. Northern range of Puget Sound stations monitored by the MSMP.

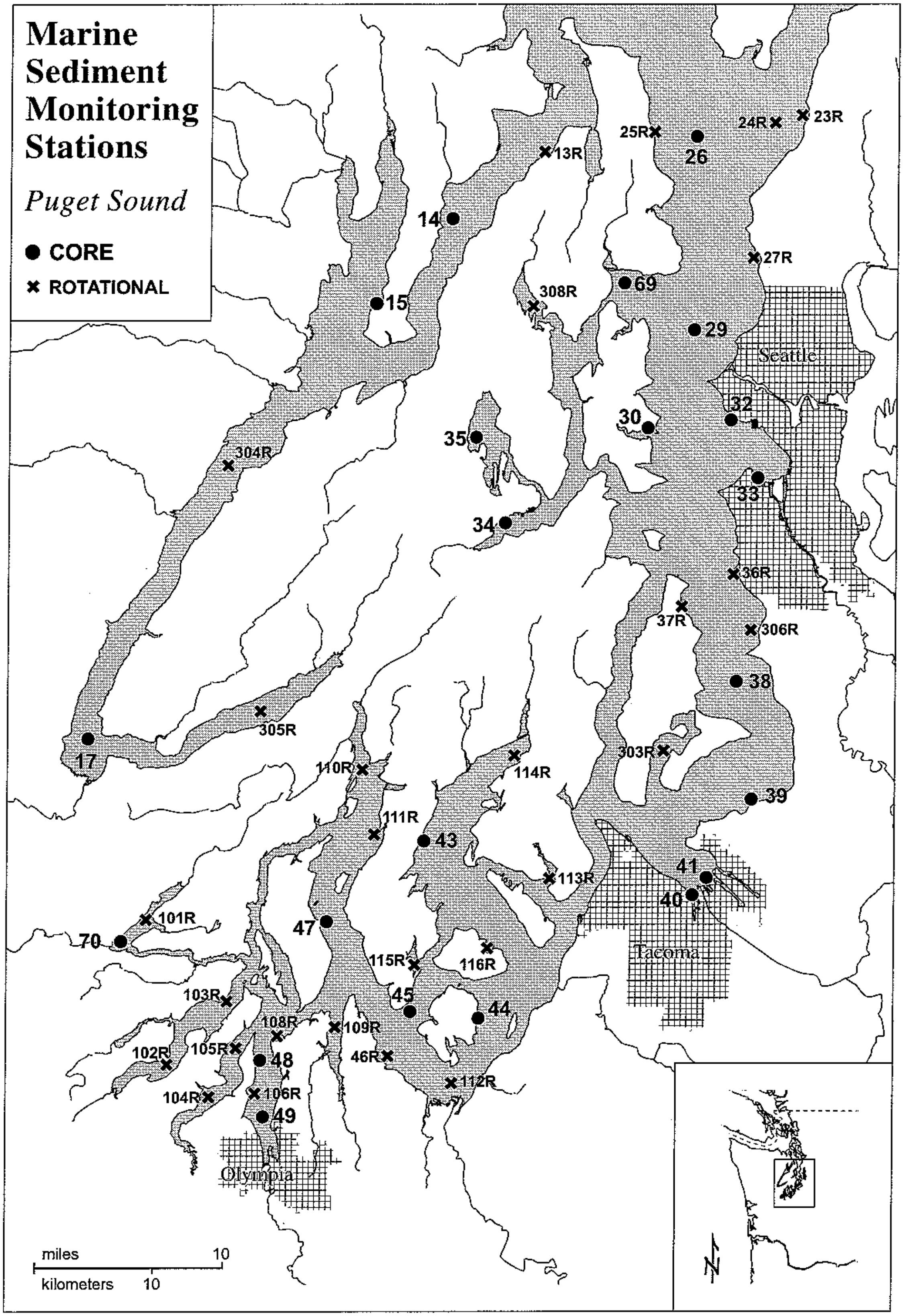



Figure 1B. Southern range of Puget Sound stations monitored by the MSMP.

Table 1. Designation, location and sampling schedule of marine sediment monitoring stations. An "X" denotes yearly data in the Marine Sediment Monitoring database. Core stations are sampled annually. Rotating stations are sampled in a 3 year rotation, and are designated with the letter "R".

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Semiahmoo Bay, Blaine | Core | 48 59.46 | 122 51.73 | 23 | X | X | X | X | X | X | X |
| 2R | Cherry Point | North | 48 50.04 | 122 44.11 | 20 | X | | X | | | X | |
| 3 | Strait of Georgia (North of Patos Is.) | Core | 48 52.22 | 122 58.71 | 223 | X | X | X | X | X | X | X |
| 4 | Bellingham Bay | Core | 48 41.04 | 122 32.29 | 24 | X | X | X | X | X | X | X |
| 5 | Samish Bay | Core | 48 35.85 | 122 32.00 | 21 | X | X | X | X | X | X | X |
| 6 | East of Anacortes | Core | 48 31.05 | 122 34.35 | 20 | X(1) | | | | | | |
| 7 | Strait of Juan de Fuca | Core | 48 12.10 | 123 14.34 | 133 | X(1) | | | | | | |
| 8 | Port Angeles | Core | 48 07.89 | 123 26.94 | 21 | X | X | X | X | X | X | X |
| 9 | Green Point | Core | 48 08.10 | 123 17.20 | 20 | X(2) | | | | | | |
| 9R | East of Green Point | North | 48 08.02 | 123 14.94 | 14 | | | X | | | X | |
| 10R | Dungeness Bay | North | 48 10.18 | 123 06.05 | 21 | X | | X | | | X | |
| 11R | Discovery Bay | North | 48 03.26 | 122 53.70 | 20 | X | | X | | | X | |
| 12 | Port Townsend Bay | Core | 48 05.05 | 122 46.59 | 21 | X | X | X | X | X | X | X |

Table 1. Continued.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13R | North Hood Canal (South of Bridge) | North | 47 50.26 | 122 37.74 | 20 | X | | X | | | X | |
| 16 | South Hood Canal | Core | 47 22.81 | 123 06.87 | 20 | X[(1)] | | | | | | |
| 17 | South Hood Canal, Great Bend | Core | 47 22.18 | 123 07.78 | 81 | X | X | X | X | X | X | X |
| 18 | Oak Harbor | Core | 48 15.37 | 122 37.49 | 19 | X | X | X | X | X | X | X |
| 19 | Saratoga Passage | Core | 48 05.86 | 122 28.29 | 123.5 | X | X | X | X | X | X | X |
| 20 | Port Susan | Core | 48 10.37 | 122 27.48 | 10.5 | X | X | X | X | X | X | X |
| 21 | Port Gardner (Everett) | Core | 47 59.13 | 122 14.57 | 20 | X | X | X | X | X | X | X |
| 22 | Mukilteo | Core | 47 57.33 | 122 17.18 | 20.5 | X | X | X | X | X | X | X |
| 23R | East Central Basin (South of Picnic Point) | Central | 47 52.24 | 122 20.07 | 20 | X | | | X | | | X |
| 24R | East Central Basin (West of Norma Beach) | Central | 47 51.86 | 122 21.93 | 182 | X | | | X | | | X |
| 25R | West Central Basin (Whidbey Basin) | Central | 47 51.31 | 122 30.21 | 20 | X | | | X | | | X |
| 26 | Central Basin | Core | 47 51.05 | 122 27.46 | 268 | X | X | X | X | X | X | X |
| 27R | Richmond Beach | Central | 47 45.57 | 122 23.18 | 21 | X | | | X | | | X |

Table 1. Continued.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | Jefferson Head | Core | 47 43.99 | 122 29.37 | 20 | X[(1)] | | | | | | |
| 29 | Shilshole | Core | 47 42.05 | 122 27.24 | 199 | X | X | X | X | X | X | X |
| 30 | Eagle Harbor | Core | 47 37.43 | 122 30.18 | 13.5 | X | X | X | X | X | X | X |
| 31 | West Point | Core | 47 39.28 | 122 26.12 | 22 | X[(1)] | | | | | | |
| 32 | Magnolia Bluff | Core | 47 37.91 | 122 24.52 | 21 | X | X | X | X | X | X | X |
| 33 | Elliott Bay (SE of Duwamish Head) | Core | 47 35.23 | 122 22.55 | 20 | X | X | X | X | X | X | X |
| 34 | Sinclair Inlet | Core | 47 32.83 | 122 39.73 | 9.5 | X | X | X | X | X | X | X |
| 35 | Dyes Inlet | Core | 47 36.81 | 122 41.92 | 12.5 | X | X | X | X | X | X | X |
| 36R | Brace Point | Central | 47 30.81 | 122 23.85 | 15 | X | | | X | | | X |
| 37R | North Vashon Island (South of Dolphin Point) | Central | 47 29.26 | 122 27.35 | 20.5 | X | | | X | | | X |
| 38 | Point Pully (3-Tree Point) | Core | 47 25.70 | 122 23.62 | 199 | X | X | X | X | X | X | X |
| 39 | Dash Point (East of Dumas Bay) | Core | 47 20.23 | 122 22.32 | 14.5 | X | X | X | X | X | X | X |
| 40 | City Waterway (Commencement Bay) | Core | 47 15.68 | 122 26.24 | 10 | X | X | X | X | X | X | X |

Table 1. Continued.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | Blair/Sitcum Waterways (Commencement Bay) | Core | 47 16.49 | 122 25.27 | 20.5 | X | X | X | X | X | X | X |
| 42 | Ruston (Commencement Bay) | Core | 47 18.24 | 122 29.95 | 39 | X(1) | | | | | | |
| 43 | Carr Inlet | Core | 47 17.87 | 122 44.55 | 19 | X | X | X | X | X | X | X |
| 44 | East Anderson Island | Core | 47 09.68 | 122 40.42 | 20 | X | X | X | X | X | X | X |
| 45 | Devil's Head | Core | 47 09.88 | 122 45.10 | 52 | X | X | X | X | X | X | X |
| 46R | West Nisqually (Johnson Point) | South | 47 07.91 | 122 46.97 | 22 | X | X | | | X | | |
| 47 | Case Inlet (Fudge Point) | Core | 47 13.98 | 122 50.98 | 20 | X | X | X | X | X | X | X |
| 48 | Outer Budd Inlet | Core | 47 07.44 | 122 55.16 | 21.5 | X | X | X | X | X | X | X |
| 49 | Inner Budd Inlet | Core | 47 04.79 | 122 54.81 | 5.25 | X | X | X | X | X | X | X |
| 50 | Oakland Bay, Shelton | Core | 47 12.61 | 123 04.55 | 7 | X(3) | | | | | | |
| 69 | Port Madison | Core | 47 44.15 | 122 32.11 | 33.5 | | X | X | X | X | X | X |
| 70 | Oakland Bay, Shelton | Core | 47 12.77 | 123 04.96 | 5.3 | | X | X | X | X | X | X |
| 71 | Fidalgo Bay, Cap Sante | Core | 48 30.55 | 122 35.23 | 6.5 | | X | X | X | X | X | X |
| 101R | North Oakland Bay | South | 47 13.92 | 123 03.17 | 5 | | X | | | X | | |

Table 1. Continued.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 102R | Inner Totten Inlet | South | 47 07.21 | 123 01.36 | 12 | | X | | | X | | |
| 103R | Mid Totten Inlet | South | 47 10.24 | 122 57.46 | 20 | | X | | | X | | |
| 104R | Inner Eld Inlet | South | 47 05.77 | 122 58.45 | 7 | | X | | | X | | |
| 105R | Outer Eld Inlet | South | 47 08.08 | 122 56.70 | 16 | | X | | | X | | |
| 106R | Mid Budd Inlet (East of Tykle Cove) | South | 47 05.99 | 122 55.32 | 12 | | X | | | X | | |
| 108R | Budd Inlet (West of Dover Point) | South | 47 08.70 | 122 53.93 | 20 | | X[(4)] | | | | | |
| 109R | Henderson Inlet | South | 47 09.19 | 122 50.02 | 20 | | X | | | X | | |
| 110R | Inner Case Inlet | South | 47 21.23 | 122 48.78 | 20 | | X | | | X | | |
| 111R | Mid Case Inlet | South | 47 18.22 | 122 47.80 | 21 | | X | | | X | | |
| 112R | Nisqually Delta | South | 47 06.74 | 122 41.94 | 20 | | X | | | X | | |
| 113R | Willochet Bay | South | 47 16.39 | 122 35.75 | 24 | | X | | | X | | |
| 114R | Henderson Bay | South | 47 22.08 | 122 38.85 | 18 | | X | | | X | | |
| 115R | Outer Filucy Bay | South | 47 12.19 | 122 44.75 | 18 | | X | | | X | | |
| 116R | Carr Inlet (North of McNeil Island) | South | 47 13.06 | 122 39.83 | 20 | | X[(4)] | | | | | |

Table 1. Continued.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 201R | Strait of Georgia, Roberts Bank | North | 48 59.47 | 123 12.41 | 121 | | | X | | | X | |
| 202R | Point Roberts | North | 48 55.91 | 123 05.59 | 117 | | | X | | | X | |
| 203R | Bellingham Bay | North | 48 45.00 | 122 32.00 | 12 | | | X | | | X | |
| 204R | East Sound | North | 48 38.31 | 122 52.57 | 31 | | | X | | | X | |
| 205R | NW Blakely Island (West of Obstruction Island) | North | 48 35.37 | 122 50.95 | 33 | | | X | | | X | |
| 206R | Friday Harbor | North | 48 32.58 | 123 00.78 | 18 | | | X | | | X | |
| 207R | West Beach, Whidbey Island | North | 48 23.96 | 122 40.26 | 28.5 | | | X | | | X | |
| 208R | Sequim Bay | North | 48 02.52 | 123 00.37 | 13.5 | | | X | | | X | |
| 209R | Skagit Bay | North | 48 17.72 | 122 29.31 | 21 | | | X | | | X | |
| 301R | Useless Bay | Central | 47 59.12 | 122 29.49 | 20 | | | | X | | | X |
| 302R | Oak Bay | Central | 48 01.16 | 122 42.87 | 19.5 | | | | X | | | X |
| 303R | Quartermaster Harbor | Central | 47 22.47 | 122 28.29 | 13.5 | | | | X | | | X |
| 304R | Hood Canal, Tekiu Point | Central | 47 35.26 | 122 58.74 | 175 | | | | X | | | X |

Table 1. Concluded.

| Station Number | Station Name | Rotation Schedule | Latitude (deg min N) | Longitude (deg min W) | Approx. Water Depth (Meters) | Year 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 305R | Hood Canal, Outer Lynch Cove | Central | 47 23.82 | 122 55.90 | 20 | | | | X | | | X |
| 306R | Seahurst, East Passage | Central | 47 28.23 | 122 22.56 | 75 | | | | X | | | X |
| 307R | Holmes Harbor, Whidbey Island | Central | 48 05.27 | 122 33.04 | 58 | | | | X | | | X |
| 308R | Liberty Bay, Poulsbo | Central | 47 43.06 | 122 38.21 | 16.5 | | | | X | | | X |

(1) Station discontinued after 1989. (2) Station relocated and renumbered as 9R. (3) Station relocated and renumbered as 70. (4) Station discontinued after 1990.

Total organic carbon (TOC) was measured by high temperature combustion from samples collected from the top 2 cm of sediments. Sediment particle size analysis followed procedures described in Folk (1980). Sand was separated from mud by wet sieving, and the mud fraction (particles $< 62.5\mu$) was analyzed for percent silt and clay by pipette. Sand fractions (percent very fine sand, fine sand, medium sand, coarse sand, and very coarse sand) were not categorized until 1994. Samples for total sulfide (TS) were preserved in a solution of zinc acetate, and the TS was determined by distillation of the acid-labile sulfide following spectrophotometric analysis (methylene blue method) or a titrimetric analysis (1990 samples). In addition, the general physical aspect of the sample, including the presence and type of debris in the sample and the color of the sediment surface, were recorded in the field. A Redox Potential Discontinuity (RPD) depth was measured visually for each sample in 1994 and 1995 (see Volume 1).

# Data Analysis

## Missing Data

Benthic data presented in this report are for the period 1989-1993. Stations with discontinued sampling (Table 1) were not included in the analyses. This leaves a total of 76 stations examined. In addition, Station 26 was not included in the analysis in 1989 because of missing arthropod data for replicates 2 and 4, and in 1990 and 1991 because sampling occurred off station location. All missing data were due to lost or damaged samples.

In addition to Station 26, data were missing from the following samples and years. In 1989, mollusc data were missing from Station 30 replicate 5 and Station 35 replicate 3. In 1990, arthropod data were missing from Station 8 replicate 4 and Station 29 replicate 4. In 1993, most organisms were missing from Station 20 replicate 5 and Station 29 replicate 1 because of sample preservation problems.

Missing data were treated as follows. For diversity indices, the average number of molluscs and arthropods in four replicates were used to estimate mollusc and arthropod missing data in the replicate from which they were missing. Missing data for Station 20 and Station 29 in 1993 were not estimated from averages of remaining replicates because the data missing were substantial and affected all groups of organisms. For these last stations, diversity computations were based on four replicates. Classification analyses also were based on four replicates in cases with missing data.

## Taxonomic Standardization and Elimination of Incidental Data

Data files were first standardized to ensure common species nomenclature. This was necessary because numerous taxonomists contributed to the database, many changes in nomenclature occurred since the inception of the program, and the taxonomy of many marine invertebrates in our region is poorly known. Uniform names and National Oceanographic Data Center (NODC) taxonomic codes were applied across data sets. Taxonomic differences were eliminated by cross-correlating species lists and by consulting with taxonomists to resolve discrepancies. Some of these discrepancies could only be resolved by re-examining archived specimens. Since time limitations prevented re-examination of specimens, those cases were treated by combining species at the genera or family levels. Also, some closely related species that are difficult to distinguish were combined in unresolved "species complexes".

For diversity and classification analyses, organisms that represent incidental catches or which may not be fully exposed to chemical contaminants in sediments, were eliminated from the data. These were (1) colonial organisms recorded with presence/absence data, (2) organisms associated with hard substrate, such as rock or shell, (3) organisms that have minimal contact with the sediment or are mostly pelagic, and (4) organisms that are mostly epibionts, *i.e.*, associated with sponges, hydroids, bryozoans, algae, or vascular plants. Following these criteria, a total of 167 taxa were removed from the data files, 86 of which were species-level identifications (Table 2). Organisms that are in full contact with the sediment such as burrowers, and those that plow through or inhabit the sediment surface, were kept in the analyses. Since they cannot be enumerated, colonial organisms were removed from all analyses. References used as guidance in the elimination of incidental data were Ricketts (1939), Bousfield (1973), Smith and Carlton (1975), Kozloff (1983; 1987), Behrens (1991), and Jensen (1995).

## Abundance

Mean faunal abundances were compared using one-factor analysis of variance (ANOVA) on transformed data if the assumptions of the test were met as indicated in Underwood (1981). The null hypothesis tested was that no difference existed in total species abundance between stations. When ANOVA assumptions were not met, distribution-free statistical procedures (Kruskal-Wallis test) were used. Transformation of counts to $\log_{10}(x)$ was necessary to remove heterogeneity of variances and normalize the data. Homogeneity of variances before and after transformation was tested using Bartlett's test (Zar, 1984). Statistical analyses were conducted in SYSTAT (SPSS Inc., Chicago, IL).

## Community Statistics

Community structure statistics were computed to discern patterns in species abundance and composition. Species Richness (*SR*) was computed using the formula given by Margalef (1958):

$$SR = \frac{(s-1)}{\ln N}$$

Table 2. Incidental taxa eliminated from data analysis and reasons for elimination. See text for further detail on criteria used to exclude these taxa.

| Taxa | Reason for Elimination |
|---|---|
| **Porifera** | |
| *Leucosolenia* sp. | hard substrate |
| | |
| **Hydrozoa** | presence/absence |
| | |
| **Anthozoa** | |
| *Diadumene* sp. | hard substrate |
| Limnactiniidae sp. A | hard substrate |
| *Metridium* sp. | hard substrate |
| *Metridium senile* | hard substrate |
| *Urticina coriacea* | hard substrate |
| | |
| **Polychaeta** | |
| *Circeis* sp. | hard substrate |
| *Circeis armoricana* | hard substrate |
| *Circeis spirillum* | hard substrate |
| *Hyalopomatus biformis* | hard substrate |
| *Neosabellaria cementarium* | hard substrate |
| *Polydora limicola* | hard substrate |
| *Pseudochitinopoma occidentalis* | hard substrate |
| *Serpula* sp. | hard substrate |
| *Serpula vermicularis* | hard substrate |
| Serpulidae | hard substrate |
| Spirorbidae | hard substrate |
| *Spirorbis* sp. | hard substrate |
| | |
| **Mollusca: Polyplacophora** | |
| *Lepidochitonia dentiens* | hard substrate |
| Polyplacophora | hard substrate |
| | |
| **Mollusca: Gastropoda** | |
| **Prosobranchia** | |
| *Cerithiopsis* sp. | epibiont |
| *Cerithiopsis signa* | epibiont |
| *Collisella* sp. | hard substrate |
| *Crepidula* sp. | hard substrate |
| *Crepidula* sp. A | hard substrate |
| *Crepipatella* sp. | hard substrate |
| *Crepipatella lingulata* | hard substrate |
| *Lacuna* sp. | epibiont, hard substrate |
| *Littorina* sp. | epibiont, hard substrate |
| *Margarites* sp. | epibiont, hard substrate |
| *Margarites pupillus* | epibiont, hard substrate |
| *Petaloconchus* sp. | hard substrate (vermetid) |

Table 2. Continued.

| Taxa | Reason for Elimination |
|---|---|
| *Petaloconchus compactus* | hard substrate (vermetid) |
| *Solariella* sp. | epibiont, hard substrate |
| | |
| **Mollusca: Gastropoda Opisthobranchia** | |
| Aeolidacea | epibiont |
| *Aeolidea* sp | epibiont |
| *Ancula* sp. | epibiont |
| *Armina californica* | epibiont, mostly on sea pens |
| *Corambe pacifica* | epibiont |
| *Corambe thompsoni* | epibiont |
| *Cuthona* sp. | epibiont |
| *Cuthona concinna* | epibiont |
| *Dendronotus* sp. | epibiont |
| *Diaphana* sp. | epibiont |
| *Diaphana californica* | epibiont |
| *Doto* sp. | epibiont |
| *Fiona pinnata* | epibiont |
| Flabellinidae | epibiont |
| Nudibranchia | epibiont |
| *Okenia* sp. | epibiont |
| *Onchidoris hystricina* | epibiont |
| *Polycera* sp | epibiont |
| | |
| **Mollusca: Bivalvia** | |
| *Bankia setacea* | borer in wood |
| *Hiatella* sp. | borer, hard substrate |
| *Hiatella arctica* | borer, hard substrate |
| *Mytilus* sp | hard substrate |
| *Mytilus edulis* | hard substrate |
| *Panomya* sp. | borer, hard substrate |
| *Panomya ampla* | borer, hard substrate |
| *Pododesmus cepio* | hard substrate |
| *Teredo* sp. | borer in wood |
| | |
| **Mollusca: Cephalopoda** | |
| *Rossia pacifica* | pelagic |
| | |
| **Arthropoda: Pycnogonida** | |
| *Achelia* sp. | epibiont |
| *Achelia chelata* | epibiont |
| *Achelia latifrons* | epibiont |
| *Anoplodactylus* sp. | epibiont |
| *Anoplodactylus erectus* | epibiont |
| *Nymphon pixellae* | epibiont |

Table 2. Continued.

| Taxa | Reason for Elimination |
|---|---|
| *Phoxichilidium femoratum* | epibiont |
| Pycnogonida | epibiont |
| *Pycnogonum* sp. | epibiont |
| **Arthropoda: Cirripedia** | |
| *Balanus* sp. | hard substrate |
| *Balanus crenatus* | hard substrate |
| *Balanus hesperius laevidomus* | hard substrate |
| Cirripedia | hard substrate |
| **Arthropoda: Mysidacea** | |
| *Acanthomysis* sp. | mostly pelagic |
| *Alienacanthomysis macropsis* | mostly pelagic |
| *Heteromysis odontops* | mostly pelagic |
| *Inusitatomysis insolita* | mostly pelagic |
| *Meterythrops robusta* | mostly pelagic |
| Mysidacea | mostly pelagic |
| *Mysidella americana* | mostly pelagic |
| *Neomysis* sp | mostly pelagic |
| *Neomysis kadiakensis* | mostly pelagic |
| *Neomysis mercedis* | mostly pelagic |
| *Pacifacanthomysis nephrophthalma* | mostly pelagic |
| *Pseudomma* sp. | mostly pelagic |
| *Pseudomma berkeleyi* | mostly pelagic |
| *Pseudomma truncatum* | mostly pelagic |
| *Xenacanthomysis* sp. | mostly pelagic |
| *Xenacanthomysis pseudomacropsis* | mostly pelagic |
| **Arthropoda: Isopoda** | |
| *Aega symmetrica* | parasitic in fish |
| *Argeia pugettensis* | parasitic in shrimp |
| *Idotea* sp. | epibiont |
| *Limnoria* sp. | borer in wood |
| *Limnoria lignorum* | borer in wood |
| *Rocinela* cf *americana* | parasitic in fish |
| *Rocinela belliceps* | parasitic in fish |
| *Synidotea* sp. | borer in wood |
| *Synidotea nebulosa* | borer in wood |
| *Synidotea nodulosa* | borer in wood |
| **Arthropoda: Amphipoda** | |
| **Gammaridea** | |
| Calliopiidae | pelagic |
| *Calliopius* sp. | pelagic |
| *Cyphocaris challengeri* | pelagic |

Table 2. Continued.

| Taxa | Reason for Elimination |
|---|---|
| *Dyopedos* sp. | epibiont |
| *Dyopedos articus* | epibiont |
| *Dyopedos bispinis* | epibiont |
| *Ericthonius* sp | epibiont |
| *Ericthonius brasiliensis* | epibiont |
| *Ericthonius hunteri* | epibiont |
| *Ericthonius rubricornis* | epibiont |
| Eusiridae | pelagic |
| *Eusirus* sp. | pelagic |
| *Eusirus cuspidatus* | pelagic |
| *Gammaropsis thompsoni* | epibiont |
| *Metopa* sp. | epibiont |
| *Matopa proboldes* | epibiont |
| *Metopella* sp | epibiont |
| *Parametopella* sp. | epibiont |
| *Peramphithoe* sp. | epibiont |
| *Probolisca* sp. | epibiont |
| *Proboloides* sp. | epibiont |
| *Rhachotropis* sp | pelagic |
| *Rhachotropis clemens* | pelagic |
| *Rhachotropis oculata* | pelagic |
| Stenothoidae | epibiont |
| *Stenothoe* sp. | epibiont |
| *Stenula* sp. | epibiont |
| **Arthropoda: Amphipoda Caprellidea** | |
| *Caprella* sp. | epibiont |
| *Caprella irregularis* | epibiont |
| *Caprella laeviuscula* | epibiont |
| *Caprella mendax* | epibiont |
| Caprellidea | epibiont |
| *Tritella pilimana* | epibiont |
| **Arthropoda: Amphipoda Hyperiidea** | |
| Hyperiidea | pelagic, epibiont |
| *Parathemisto pacifica* | pelagic, epibiont |
| **Arthropoda: Decapoda** | |
| *Fabia subquadrata* | commensal in mussels |
| Majidae | epibiont |
| *Oregonia* sp. | epibiont |
| *Oregonia gracilis* | epibiont |
| *Pugettia* sp. | epibiont |

Table 2. Concluded.

| Taxa | Reason for Elimination |
|---|---|
| *Pugettia producta* | epibiont |
| **Brachiopoda** | |
| *Terebratalia* sp. | mostly hard substrate |
| *Terebratalia transversa* | mostly hard substrate |
| *Terebratulina* sp. | mostly hard substrate |
| *Terebratulina unguicula* | mostly hard substrate |
| **Entoprocta** | presence/absence |
| **Ectoprocta** | presence/absence |
| **Ascidiacea** | |
| *Agnesia septemtrionalis* | hard substrate |
| *Ascidia* sp. | hard substrate |
| *Ascidia paratropa* | hard substrate |
| *Boltenia* sp. | hard substrate |
| *Boltenia villosa* | hard substrate |
| *Chelyosoma columbianum* | hard substrate |
| *Chelyosoma productum* | hard substrate |
| *Ciona intestinalis* | hard substrate |
| *Corella willmeriana* | hard substrate |
| Enterogona | hard substrate |
| *Eugyra arenosa* | hard substrate |
| Molgulidae | hard substrate |
| Phlebobranchia | hard substrate |
| *Pyura haustor* | hard substrate |
| *Pyura mirabilis* | hard substrate |
| Stolidobranchia | hard substrate |
| *Styela* sp. | hard substrate |
| *Styela gibbsii* | hard substrate |

where $s$ is the number of species per station and $N$ is the total number of individuals. Evenness ($J'$) was computed for each station using the formula provided by Pielou (1966):

$$J' = \frac{H'}{\ln s}$$

where $H'$ is the Shannon-Wiener index of diversity (Shannon, 1948) calculated as follows:

$$H' = \sum_{i=1}^{s} \left( \frac{n_i}{N} \right) \ln \left( \frac{n_i}{N} \right)$$

and $n_i$ is the number of individuals in the $i$ species.

SR varies from 0 for one species to large numbers for a high number of species. J', a measure of the distribution of individuals among the species, ranges from 0 for one species with many individuals and one or more species with one individual each, to 1 for equal numbers of individuals in each species. Species Richness and evenness were calculated on composite samples, *i.e.*, using the cumulative number of species in five replicates.

Diversity indices make assumptions about the relative abundance of species in natural communities, and they are dependent on sampling size (total area sampled). In addition, their values differ for communities at different stages in biotic succession, in different habitats or geographical areas, or at different times of the year. They also differ with different efforts in the level of taxonomic resolution. For all of the above reasons, comparisons of diversity values beyond the scope of this study should be avoided. In this report, SR is only used to examine the relative rank-order in species diversity of stations.

Total species numbers and diversity indices were calculated after standardization of data files and elimination of incidental organisms (see above). Then, for each taxon and *station*, records with more than one level of identification were removed from the data files, leaving records with the lowest level of identification. Platyhelminthes, nemerteans, and oligochaetes were combined at the phylum and class levels because they were seldom identified to species.

## Classification Analysis

Spatial trends in species distributions were analyzed using numerical classification (Boesch, 1977). Numerical classification (or cluster analysis) is a multivariate analysis technique that assigns species and samples to groups according to their similarity.

Results are graphically presented in the form of a dendogram where similar entities (species or samples) are grouped together. Forty-one to 48 stations were analyzed for each of five years (1989-1993) using the computer program COMPAH, updated and distributed by Eugene Gallagher (Environmental Science Program, University of Massachusetts, Boston, MA). Normal (by station) and inverse (by species) classifications were produced.

The Canberra metric coefficient (Lance and Williams, 1966) was used in its dissimilarity form:

$$D_{jk} = \frac{1}{s}\sum_{i=1}^{s}\frac{|x_{ij} - x_{ik}|}{(x_{ij} + x_{ik})}$$

where $D_{jk}$ is the degree of dissimilarity between samples $j$ and $k$, $s$ is the number of species, $x_{ij}$ is the mean abundance of species $i$ in sample $j$, and $x_{ik}$ is the mean abundance of species $i$ in sample $k$. This index compares the percent abundance of species present in two samples. It has been favored by some ecologists (*e.g.*, Boesch, 1973; Stephenson *et al.*, 1972) to overcome the disproportional large influence that species with high abundance have on the values of similarity measures. Because the Canberra metric coefficient is an average of a series of fractions, large abundance values contribute only to one of the fractions, and thus do not place a much heavier weight in the index than values of less abundant species. Group average (Sneath and Sokal, 1973), a combinatorial and hierarchical classificatory strategy, was used as a clustering method for its moderate amount of group chaining (see Boesch, 1977, for a detailed account on clustering methods). No attempt was made at identifying or reallocating misclassified entities.

Data for numerical classification of stations and species were reduced by (1) elimination of incidental organisms (see above), (2) elimination of taxa above the species level according to criteria described below, and (3) by elimination of species occurring in low frequencies. Data reduction is a common procedure in ecological surveys that generate large amounts of information. It is left to the criteria of the investigator to decide which species should be eliminated from the analysis, but generally, rare species occurring in less than some arbitrary frequency are eliminated. Provided they are not habitat restricted, the presence or absence of rare species in a sample usually offer no particular pattern, and often contribute to obscuring the distribution patterns of the more common species (Boesch, 1977).

For classification analysis, records with more than one level of identification for each taxon and *year* were treated according to a "40% rule" developed for this study. If the abundance at a higher level of identification (*e.g.*, genus) was less than 40% of the combined abundance of this and the next lower level (*e.g.* species), the lower level of identification was kept in the analysis and the higher level was removed from the analysis. Otherwise (the abundance at the higher level >40% of the combined abundance), the lower level of identification was merged to the higher level.

In addition, taxa occurring below one percent of the total station abundance at all stations in one year, were eliminated from the analysis. Using this procedure, 63.4 to 66.6 percent of the taxa, depending on the year, were eliminated from the analysis. These taxa, however, represented only 3.0 to 4.9 percent of the total abundance (Table 3), and many were sampled infrequently in Puget Sound.

Previous to the analysis, data were transformed to log (x+1) to lessen the sensitivity of the similarity measure to large abundances.

## Analysis of Station-by-Species Coincidence Tables

Nodal analysis (Williams and Lambert, 1961; Boesch, 1977) was used to relate the groups derived from normal and inverse classifications. Nodal analysis is graphically displayed in sample-by-species coincidence tables, where the density pattern of the cells of the table is expressed in terms of constancy and fidelity (see below).

A sample-by-species coincidence table is the original data matrix re-arranged such that the samples and species are grouped according to the results of the classification analysis. At the node or intersection of each sample and species group, results from two indices (constancy and fidelity) are displayed. These indices describe differences among sample groups based on the frequency of occurrence of species in the sample groups. Conversely, the distribution of species among the samples are examined by the frequency with which they occur in the sample groups. These two indices do not take into consideration differences in the abundance of species among the sample groups. For this, another index expresses the average abundance of species in a sample group in relation to the overall abundance across all sample groups. This index of relative abundance was not very useful when applied to the Puget Sound data set. This is because we wished to account for qualitative and quantitative differences in the classification analysis on a more or less equal basis. Therefore, patterns of species abundance were directly examined from inspection of the raw data in the sample-by-species coincidence tables.

Constancy (Stephenson *et al.*, 1972; Boesch, 1973) is the average presence of all species of a species group in a given sample group:

$$C_{ij} = \frac{a_{ij}}{(n_i n_j)}$$

where $a_{ij}$ is the number of occurrences of the species of species group $i$ in sample group $j$, and $n_i$ and $n_j$ are the number of species and samples in groups $i$ and $j$, respectively.

Table 3. Total number of taxa and total mean abundance (n=5 replicates) of organisms available for classification analysis (records with more than one level of identification removed, see methods) before and after reduction of taxa occurring below one percent of the total abundance per station for all stations.

| | Year | | | | |
|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | 1992 | 1993 |
| **Number of Taxa** | | | | | |
| Before 1% cut | 410 | 382 | 444 | 476 | 392 |
| After 1% cut | 146 | 140 | 156 | 159 | 134 |
| Percent eliminated | 64.4 | 63.3 | 64.9 | 66.6 | 65.8 |
| Percent remaining | 35.6 | 36.7 | 35.1 | 33.4 | 34.2 |
| **Mean Abundance** | | | | | |
| Before 1% cut | 18908.8 | 17906.8 | 20421.2 | 20429.8 | 17156.3 |
| After 1% cut | 18246.0 | 17367.8 | 19689.8 | 19435.2 | 16571.1 |
| Percent eliminated | 3.5 | 3.0 | 3.6 | 4.9 | 3.4 |
| Percent remaining | 96.5 | 97.0 | 96.4 | 95.1 | 96.6 |

The index is 1 when all species occur in all samples of a group, and 0 when none of the species occur in a sample group.

Fidelity (Boesch 1973; 1977) is the degree to which species are restricted to particular sample groups. It expresses the frequency of occurrence of all species of a species group in a given sample group compared to their overall frequency of occurrence in all sample groups:

$$F_{ij} = \frac{a_{ij}\sum_j n_j}{n_j \sum_j a_{ij}}$$

where the terms of the equation are as in the constancy index. An index $< 1$ indicates that the frequency of occurrence of the species of a species group in a sample group is less than their overall frequency, and an index $> 1$ indicates that the frequency of occurrence of the species of a species group in a sample group is greater than their overall frequency.

## Dominance

Dominance was examined by grouping stations according to their similarity in the classification analysis, and hence, to shared physical and biological characteristics. For each station and year, species were arranged in order of descending average density. Rank scores were assigned to the ten top species, and the scores were summed over all years. The scores were then averaged by the number of years for which the station was sampled, and the averages summed across groups of stations to obtain a rank value. Species having the highest ranking values were listed. Averaging was conducted to standardize scores and account for unequal sampling effort of stations.

## Temporal Trends in Abundance

Temporal trends in abundance were analyzed for significance using nonparametric procedures. The Mann-Kendal test was used to test the null hypothesis of no trend in total mean abundance per station against the alternative hypothesis of either an upward or downward trend (Gilbert, 1987). The Mann-Kendal test is a "sign" test. All possible differences in data values are computed, and the sign of the difference is used to compute a statistic that is compared to a tabled probability. To test for homogeneity of direction of species in stations sharing a common basin, the Mann-Kendal statistic was computed and used to obtain a homogeneity chi-square statistic that was compared to tabled probabilities (Gilbert, 1987).

## Computer Programs Used in Data Analysis

Standardization of benthic data files and elimination of incidental data were carried out in Microsoft Excel. Community structure statistics were calculated using programs written in SYSTAT (SPSS Inc., Chicago, IL). Removal of records with more than one level of identification by station (in diversity indices) or year ("40% rule" in classification analyses) was conducted in Microsoft Access. Elimination of rare species (one percent species abundance cut in classification analyses) was conducted using the program REDUCE in PRIMER version 3.1b (Plymouth Routines in Multivariate Ecological Research, Plymouth Marine Laboratory, Prospect Place, Plymouth, UK). PRIMER was also used to produce initial station classifications (not presented here) using the Bray-Curtis similarity measure. Wherever formatting and concatenation of data matrices were necessary, the program COMPOSE (Cornell University, Ithaca, NY) was used. Constancy and fidelity were calculated in Access, and results were displayed using macros written in Excel. Temporal trends in abundance were examined using Excel.

# Results

## Sediment Characteristics

### Composition

Soft bottom substrates are generally classified according to sediment grain size and to shell and organic matter content. Several types of substrates have been recognized, such as gravel, shell/sand, sand, mud, and organic (Kendall, 1983). Gross habitat types, for example, can be subjectively defined according to pre-determined percentages of sand and mud. We have done this in Volume 1 of this report. However, these categories are not entirely distinct entities; each type may include varying mixtures of sand, silt, clay, shell, and organic material. Infaunal organisms respond differently to these compositional mixtures as well as to many other physical and chemical factors within the sediment. Accordingly, here we have looked at the relationship between grain size and species composition. The ranges used to categorize the sediments were based on the grouping of stations in cluster analysis (see below), and thus on the observed species distributional patterns.

Four classes of sediments were distinct in the analysis: sands, silty-sands, mixed, and clays. Sediments classified as sand consisted of ≥80% sand. Sediments classified as silty-sand had sand in the range of 62%-80% and low amounts of clay (<13%). Sediments classified as mixed had sand in the range of 20%-68% and generally a larger proportion of clay up to 23%. Sediments classified as clay had higher amounts of clay (20%-55%) and typically a low amount of sand (≤20%).

These four classes of sediments did not have sharp boundaries, but overlapped at both ends of their ranges. For example, some stations with a proportion of clay in the range 20%-23% could be classified either as mixed or as clay. These stations, however, were primarily associated with either clay or mixed-type stations in the dendogram depending on their relative proportions of silt and sand. Stations with clay in the range 20%-23%, large amounts of silt, and low amounts of sand below 16%, were associated with clay-type stations. Stations with clay in the range 20%-23%, but with larger amounts of sand up to 58%, were associated with mixed-type stations. Similarly, some stations with a proportion of sand in the range 62%-68% could be classified either as silty-sand or as mixed, depending on the amount of clay. These stations were classified on the basis of both their relative proportions of sand, silt and clay, and their association with other stations in the dendogram.

Based on the above classification, sediments from 19 stations were sands, 5 were silty-sands, 12 were mixed, and 27 were clays. Thirteen additional stations consisted of sediments of more than one type in different years. Of these 13 stations, 3 more often had sands, 2 silty-sands, 3 mixed, and 3 more often had clays. Two stations had mixed sediments in one year, and either clay or silty-sand in the second year. Sediment class for each station is given in Appendix A.

## Organic Carbon

Total organic carbon (TOC) ranged from 0.06% to 4.0%. In an attempt to relate TOC to groups of stations in the classification analysis, the sediments were classified according to their TOC content as having low (≤ 1.5%), moderate (1.6%-2.5%), or high (>2.5%) TOC concentrations. Most sand and silty-sand sediments (97.6% of the stations in all five years) had low TOC concentrations. Mixed sediments (81.8%) generally had low TOC concentrations but some (10.9%) had moderate concentrations and a few (7.3%) had high concentrations. Clay sediments (61.5%) generally had moderate TOC concentrations, with about equal proportions of these sediments (17.6% and 20.9%, respectively) having low or high TOC concentrations.

Concentrations >2.5% TOC were measured in sediments of Port Angeles (Station 8), Sequim Bay (Station 208R), Dyes Inlet (Station 35), Sinclair Inlet (Stations 34), Shelton (Station 70), and inlet ends in South Puget Sound (Stations 49, 101R, 102R, 104R, 106R, and 110R), with the exception of Carr Inlet.

## Sulfides

Total sulfide (TS) concentration in sediments was classified as low or undetected (≤50 mg/kg dry weight), moderate (50-100 mg/kg), high (100-500 mg/kg) and very high (>500 mg/kg). The threshold separating low from moderate TS concentrations was chosen to approximate an existing preliminary Apparent Effect Threshold (AET) of 45 mg/kg (PTI, 1989). The other ranges are arbitrary, and should be revised after additional information is examined in relation to correlative effects of TS on community structure. This is because TS includes metal sulfides. Benthic organisms, however, respond to hydrogen sulfide, which is only a portion of the TS in sediments.

There was no clear relationship between TS and station group separation in the classification analysis. However, TS concentrations >100 mg/kg were measured in some terminal inlets and semi-enclosed bays, or in areas associated with fresh water plumes, where density stratification is likely to restrict mixing of the water column, and hence, replenishment of dissolved oxygen to bottom waters. Stations with TS >100 mg/kg were listed in Volume 1 of this report, but the list is repeated here so it can be readily compared to results from the analysis of benthic data.

Stations in terminal inlets or semi-enclosed bays with high TS were Sequim Bay (Station 208R), Lynch Cove (Station 305R), Dyes Inlet (Station 35), Sinclair Inlet (Station 34), Eagle Harbor (Station 30), Budd Inlet (Stations 48 and 49), and Inner Totten Inlet (Station 102R). Stations with high TS where water column density stratification and low DO are likely to occur seasonally were Saratoga Passage

(Station 19), Holmes Harbor (Station 307R), and the Strait of Georgia (Station 3). Bellingham Bay (Station 4) might be included in this last group. High TS at these stations was not recorded in all years.

# Community Structure

## Abundance

The total mean abundance of macrofauna by station and year is shown in Table 4. Mean abundance (all organisms included) ranged from 42 individuals per 0.1 $m^2$ at Saratoga Passage (Station 19) to 2,158 individuals per 0.1 $m^2$ at Commencement Bay (Station 41) in 1989. On average, these two stations respectively exhibited the lowest and the highest abundance for the period 1989-1993. As it would be expected given the large and heterogeneous geographical area covered by the MSMP, there were significant differences in total mean abundance among stations for each year (Kruskal-Wallis, $p<0.001$).

Mean abundance was relatively high at stations in urban areas where the highest concentrations of contaminants were measured. For example, Port Angeles (Station 8), Eagle Harbor (Station 30), Elliott Bay (Station 33), Dyes Inlet (Station 35), and City Waterway in Commencement Bay (Station 40, also known as Thea Foss Waterway), exhibited macrofaunal densities ranging from 269 to 755 individuals per 0.1 $m^2$ (mean = 515.7; median = 562.8) (Table 4). Relative to all other stations, these stations did not exhibit either depressed or enhanced abundance. The highest densities of organisms (>1,000 individuals per 0.1 $m^2$) were found in Discovery Bay (Station 11R), North Hood Canal (Station 13R), Sinclair Inlet (Station 34), and Commencement Bay (Station 41). The sediments in Discovery Bay and North Hood Canal were sands and contamination was undetected. The sediments in Sinclair Inlet and Commencement Bay (Station 41) consisted of mud and were primarily contaminated with trace metals and organic compounds (resin acids and sterols), respectively.

Core stations with consistent (between year) lowest mean abundance were Saratoga Passage (Station 19), Point Pully (Station 38), Inner Budd Inlet (Station 49), and Oakland Bay at Shelton (Station 70) (Table 4). The Strait of Georgia (Station 3) exhibited low mean abundance in 1990 and 1994 (1994 abundance not shown in this report). Rotating stations with lowest mean abundance were North Oakland Bay (Station 101R), Inner Totten Inlet (Station 102R), Inner Eld Inlet (Station 104R), Mid Case Inlet (Station 111R), Henderson Bay (Station 114R), Sequim Bay (Station 208R), South Hood Canal (Stations 304R and 305R), and Holmes Harbor (Station 307R). Except for Inner Budd Inlet and Shelton, all the preceding stations are located in rural areas of Puget Sound, and all are away from major industrial centers. With the exception of Saratoga Passage, Strait of Georgia, and Point Pully, these stations also are associated with terminal inlets or semi-enclosed bays. Saratoga Passage and the Strait of Georgia are influenced by the discharge plumes of two major freshwater inputs to the region, respectively the Skagit and the Fraser rivers. Point Pully is a deep station in the main basin of Puget Sound.

In stations arranged by abundance (Figures 2-4), Saratoga Passage (Station 19) exhibited significantly lower mean abundance than all other stations in 1989 (ANOVA followed by partial *a posteriori* Tukey Multiple Comparison, $p<0.001$). In 1990, Saratoga Passage (Station 19), Henderson Bay (Station 114R) and Point Pully (Station 38) had significantly lower mean abundance than stations up the rank ($p<0.01$) (Station 3 excluded from the analysis because of the large variance), except for Shelton (Station 70) and Inner Budd Inlet (Station 49), which did not differ from this group of three stations ($p>0.05$).

In 1991, Saratoga Passage (Station 19) had significantly lower mean abundance than stations up the rank ($p<0.01$). Next, Shelton (Station 70) did not differ from Point Pully (Station 38), Sequim Bay (Station 208R) or Inner Budd Inlet (Station 49) ($p>0.05$), but exhibited significantly lower mean abundance than stations ranking above this group ($p<0.01$).

In 1992, mean abundance was not significantly different ($p>0.05$) among stations in South Hood Canal (Stations 304R and 305R), Shelton (Station 70), Saratoga Passage (Station 19), Holmes Harbor (Station 307R), and Inner Budd Inlet (Station 49), but were (except for Inner Budd Inlet) significantly lower ($p<0.05$) than stations up the rank. In 1993 mean abundance was not significantly different ($p>0.05$) among Saratoga Passage (Station 19), Henderson Bay (Station 114R), Mid Case Inlet (Station 111R), and Shelton (Station 70), but was significantly lower in this group than stations up the rank ($p<0.05$), except for North Oakland Bay (Station 101R).

The relationships between abundance and sediment parameters (percent silt-clay, total organic carbon, and total sulfide) were examined for all years combined. Abundance variables examined were station total mean abundance (all organisms included), and the abundance and percent abundance contributions per station of the following six major taxonomic groups: annelids, bivalves, gastropods, crustaceans, echinoderms, and other phyla (combined).

In general, abundance was not strongly related to any sediment parameter. There were only weak correlations ($r = 0.21$-$0.36$) between the following variables. Percent silt-clay was inversely correlated with total mean abundance ($r = -0.24$) and the abundance of annelids (-0.23), gastropods (-0.36), crustaceans (-0.23), and other phyla (-0.23). Percent total organic carbon was inversely correlated with total mean abundance ($r = -0.26$) and the abundance of gastropods (-0.27). Total sulfide (detected values) was inversely correlated with total mean abundance ($r = -0.28$) and the abundance of crustaceans (-0.24) and other phyla (-0.24), and positively correlated with percent

Table 4. Total abundance (mean number of individuals per 0 1 $m^2$ and SD in parenthesis) of benthic macrofauna at stations in Puget Sound, 1989-1993. n = 5, except for Stations 20 and 29 in 1993 where n = 4 (A) All organisms (with the exception of presence/absence taxa) included (B) Incidental organisms (see Table 2) excluded. Blanks denote stations not sampled in a given year.

| Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| **A. All organisms included** | | | | | |
| 1 Semiahmoo Bay, Blaine | 403 2 (122 2) | 599.0 (243 6) | 395 6 (113 3) | 804 2 (135 4) | 523 4 (92 8) |
| 2R Cherry Point | 359.0 (105 6) | | 256 0 (54.4) | | |
| 3 Strait of Georgia | 338.6 (236.1) | 57 0 (37 0) | 173 0 (117 6) | 250.4 (79 4) | 182.0 (76.7) |
| 4 Bellingham Bay | 297.4 (28.5) | 472.0 (143 1) | 231 2 (18 6) | 201 4 (16.3) | 215.6 (43 4) |
| 5 Samish Bay | 255 8 (44 3) | 504.4 (29 3) | 281 8 (45.5) | 247 6 (44 8) | 269 4 (52 3) |
| 8 Port Angeles | 388 6 (22 2) | 592 0 (569 6) | 269 4 (59 5) | 356 2 (93 6) | 354 0 (114.6) |
| 9R East of Green Point | 554.0 (161 2) | | 660.0 (133 7) | | |
| 10R Dungeness Bay | 649 0 (85 2) | | 549 8 (204 5) | | |
| 11R Discovery Bay | 992 0 (121 0) | | 1489 8 (329 6) | | |
| 12 Port Townsend Bay | 360 8 (30 2) | 493.4 (56.9) | 378 6 (41 2) | 347 4 (32 3) | 392 4 (44.6) |
| 13R North Hood Canal | 1387 4 (229 1) | | 1110 2 (409.6) | | |
| 14 Hood Canal, Bangor | 283.6 (49.9) | 238 6 (117.5) | 203 6 (49 6) | 327.0 (67 5) | 354.6 (76 1) |
| 15 Dabob Bay | 350.0 (141.9) | 282.6 (50.0) | 649.0 (33 9) | 365 0 (83.6) | 330 2 (51 8) |
| 17 S Hood Canal, Great Bend | 117 6 (25 7) | 194.6 (73 3) | 384.0 (29 2) | 236 2 (35 8) | 228 4 (20 0) |
| 18 Oak Harbor | 283 2 (170 4) | 266.4 (41 6) | 562 2 (187.5) | 566 2 (104 5) | 837 0 (107 5) |
| 19 Saratoga Passage | 42.0 (5.7) | 67 8 (12 1) | 49 8 (12.0) | 85 6 (14 8) | 64 6 (15 1) |
| 20 Port Susan | 424.4 (56.3) | 378 8 (31 9) | 187.8 (34 1) | 485 2 (67 3) | 284.8 (34 2) |
| 21 Port Gardner | 924.4 (118 5) | 761 8 (170 3) | 573.4 (79 1) | 1203 8 (108 3) | 659.6 (164.9) |
| 22 Mukilteo | 327 8 (69 7) | 386.4 (35.8) | 393 2 (101 3) | 744 6 (241 3) | 392 0 (71.1) |
| 23R East Central Basin | 438 8 (68.0) | | | 843 0 (104 8) | |
| 24R East Central Basin | 98.8 (18.5) | | | 267.4 (62 1) | |
| 25R West Central Basin | 368.8 (89.7) | | | 882.8 (168 5) | |
| 26 Central Basin | (a) | (b) | (b) | 492 2 (93.4) | 241 0 (38 6) |
| 27R Richmond Beach | 616 8 (62 0) | | | 641 6 (104 4) | |
| 29 Shilshole | 165 0 (51.7) | 260 6 (48 4) | 304.2 (39.2) | 469.2 (53 2) | 441.5 (45.7) |
| 30 Eagle Harbor | 668.6 (244 4) | 420.2 (85.3) | 335.0 (75 0) | 337.2 (22.1) | 360.6 (105.5) |
| 32 Magnolia Bluff | 647 0 (121.4) | 616.6 (192.6) | 529 8 (115 7) | 402 4 (13.8) | 362 4 (76 0) |
| 33 Elliott Bay | 617 0 (44 6) | 461 8 (71.8) | 609 2 (117 6) | 562 8 (136 8) | 594 6 (28.5) |
| 34 Sinclair Inlet | 580 8 (194 2) | 456 8 (120 7) | 1017 8 (453 6) | 1025.6 (480.2) | 731 6 (130 9) |
| 35 Dyes Inlet | 661 2 (358.1) | 754 6 (206.6) | 526.4 (152 5) | 721.0 (371.8) | 384.6 (50 1) |
| 36R Brace Point | 416.2 (65.4) | | | 255 0 (91.4) | |
| 37R North Vashon Island | 569.0 (170 8) | | | 749 8 (219 0) | |
| 38 Point Pully | 117 4 (28 2) | 77.8 (11.3) | 126 8 (26.8) | 169 0 (43.4) | 196 0 (37.6) |
| 39 Dash Point | 240 4 (62 5) | 200 0 (63 5) | 172.8 (44 4) | 164.0 (19 6) | 182.8 (29.9) |
| 40 Commencement Bay | 668.6 (50.7) | 370.8 (75.7) | 605.6 (117 3) | 654.0 (85 6) | 617.2 (70 1) |
| 41 Commencement Bay | 2158 2 (825 5) | 2076.2 (164.9) | 1692 0 (235 5) | 918 0 (161 5) | 808 0 (142.5) |
| 43 Carr Inlet | 569 0 (79 9) | 649.8 (58.5) | 668 8 (74.2) | 858 8 (73 7) | 686 4 (95.2) |
| 44 East Anderson Island | 473 2 (134 7) | 696 2 (230 8) | 456.2 (145 3) | 571.2 (74 2) | 661.6 (74 0) |
| 45 Devil's Head | 249.8 (71.8) | 267 4 (33.7) | 191 4 (59 3) | 236.0 (29 2) | 284.0 (53 1) |

Table 4. Continued.

| Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| 46R West Nisqually | 395.6 (78.2) | 448.0 (106.5) | | | 675.6 (108.9) |
| 47 Case Inlet | 407.0 (135.0) | 547.0 (56.4) | 590.8 (74.3) | 797.8 (231.4) | 722.4 (121.9) |
| 48 Outer Budd Inlet | 313.6 (84.9) | 294.2 (60.8) | 163.4 (29.8) | 297.2 (45.2) | 250.0 (67.9) |
| 49 Inner Budd Inlet | 140.0 (10.0) | 124.0 (47.5) | 140.4 (26.1) | 112.2 (26.0) | 203.0 (32.5) |
| 69 Port Madison | | 333.0 (68.9) | 514.2 (87.6) | 528.6 (89.3) | 632.4 (110.2) |
| 70 Oakland Bay, Shelton | | 111.4 (26.4) | 93.2 (11.9) | 84.4 (35.9) | 104.8 (39.7) |
| 71 Fidalgo Bay | | 511.2 (74.8) | 239.8 (37.0) | 431.0 (72.5) | 327.6 (33.2) |
| 101R North Oakland Bay | | 187.8 (45.0) | | | 127.6 (16.0) |
| 102R Inner Totten Inlet | | 158.6 (82.0) | | | 82.2 (48.2) |
| 103R Mid Totten Inlet | | 196.2 (30.9) | | | 542.2 (189.5) |
| 104R Inner Eld Inlet | | 182.6 (46.1) | | | 247.6 (17.8) |
| 105R Outer Eld Inlet | | 448.4 (114.1) | | | 346.2 (49.6) |
| 106R Mid Budd Inlet | | 374.4 (47.5) | | | 358.0 (72.5) |
| 109R Henderson Inlet | | 582.0 (107.0) | | | 661.8 (174.5) |
| 110R Inner Case Inlet | | 271.2 (118) | | | 335.6 (46.5) |
| 111R Mid Case Inlet | | 211.2 (83.3) | | | 99.4 (47.5) |
| 112R Nisqually Delta | | 169.8 (55.9) | | | 285.0 (58.5) |
| 113R Willochet Bay | | 395.8 (82.9) | | | 548.4 (77.9) |
| 114R Henderson Bay | | 81.0 (29.1) | | | 82.6 (11.4) |
| 115R Outer Filucy Bay | | 451.6 (132.7) | | | 438.4 (99.7) |
| 201R Roberts Bank | | | 892.0 (182.7) | | |
| 202R Point Roberts | | | 196.0 (32.6) | | |
| 203R Bellingham Bay | | | 260.0 (48.6) | | |
| 204R East Sound | | | 225.0 (64.3) | | |
| 205R NW Blakely Island | | | 396.0 (23.6) | | |
| 206R Friday Harbor | | | 525.0 (161.9) | | |
| 207R West Beach | | | 459.0 (68.0) | | |
| 208R Sequim Bay | | | 128.0 (18.2) | | |
| 209R Skagit Bay | | | 401.2 (33.9) | | |
| 301R Useless Bay | | | | 297.8 (162.6) | |
| 302R Oak Bay | | | | 222.6 (67.0) | |
| 303R Quartermaster Harbor | | | | 274.2 (43.7) | |
| 304R Hood Canal, Tekiu Point | | | | 62.6 (19.1) | |
| 305R Hood Canal, Lynch Cove | | | | 100.6 (34.8) | |
| 306R Seahurst | | | | 266.2 (113.8) | |
| 307R Holmes Harbor | | | | 95.6 (27.4) | |
| 308R Liberty Bay | | | | 559.0 (155.9) | |
| **B. Incidental organisms excluded** | | | | | |
| 1 Semiahmoo Bay, Blaine | 403.2 (122.2) | 595.8 (248.6) | 395.6 (113.3) | 804.2 (135.4) | 522.4 (92.1) |
| 2R Cherry Point | 358.6 (105.4) | | 255.8 (54.1) | | |
| 3 Strait of Georgia | 336.8 (237.1) | 56.4 (36.5) | 170.6 (118.5) | 248.8 (78.6) | 181.6 (76.3) |
| 4 Bellingham Bay | 297.4 (28.5) | 472.0 (143.1) | 231.0 (18.3) | 201.2 (16.5) | 215.6 (43.4) |
| 5 Samish Bay | 255.2 (44.6) | 503.6 (29.4) | 281.6 (45.1) | 247.6 (44.8) | 269.0 (52.2) |

Table 4. Continued

| Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| 8 Port Angeles | 388.2 (22.5) | 592.0 (569.6) | 266.4 (60.2) | 353.6 (93.7) | 353.0 (115.2) |
| 9R East of Green Point | 538.8 (155.0) | | 552.0 (114.3) | | |
| 10R Dungeness Bay | 645.2 (83.3) | | 545.6 (205.3) | | |
| 11R Discovery Bay | 958.6 (109.1) | | 1450.0 (329.3) | | |
| 12 Port Townsend Bay | 360.6 (30.4) | 493.0 (56.7) | 378.4 (41.4) | 345.2 (33.8) | 389.4 (45.6) |
| 13R North Hood Canal | 1376.4 (226.9) | | 1082.2 (417.4) | | |
| 14 Hood Canal, Bangor | 281.8 (50.8) | 230.8 (118.2) | 190.8 (40.0) | 318.0 (58.7) | 338.8 (69.3) |
| 15 Dabob Bay | 346.0 (138.1) | 281.2 (49.6) | 647.6 (34.1) | 362.6 (82.8) | 328.8 (50.4) |
| 17 S Hood Canal, Great Bend | 117.2 (25.3) | 192.4 (73.7) | 384.0 (29.2) | 236.2 (35.8) | 226.6 (20.3) |
| 18 Oak Harbor | 283.2 (170.4) | 265.2 (41.9) | 561.0 (189.2) | 565.4 (103.9) | 833.6 (106.6) |
| 19 Saratoga Passage | 40.0 (7.1) | 66.0 (12.4) | 49.2 (12.3) | 83.8 (14.5) | 62.6 (14.0) |
| 20 Port Susan | 424.4 (56.3) | 378.6 (31.8) | 187.8 (34.1) | 483.8 (66.8) | 282.0 (32.9) |
| 21 Port Gardner | 924.2 (118.6) | 761.8 (170.3) | 573.4 (79.1) | 1202.8 (108.7) | 659.4 (165.1) |
| 22 Mukilteo | 327.8 (69.7) | 385.8 (36.1) | 393.0 (101.5) | 742.6 (242.1) | 391.6 (71.3) |
| 23R East Central Basin | 433.6 (68.8) | | | 767.0 (197.7) | |
| 24R East Central Basin | 97.8 (18.1) | | | 261.8 (63.9) | |
| 25R West Central Basin | 363.2 (89.8) | | | 867.0 (171.3) | |
| 26 Central Basin | (a) | (b) | (b) | 484.2 (94.5) | 223.2 (27.5) |
| 27R Richmond Beach | 608.0 (58.5) | | | 626.8 (96.4) | |
| 29 Shilshole | 164.0 (51.8) | 258.6 (46.5) | 302.4 (39.4) | 468.0 (53.5) | 438.8 (45.9) |
| 30 Eagle Harbor | 666.8 (244.4) | 419.8 (85.1) | 334.0 (75.5) | 335.2 (22.3) | 359.6 (105.5) |
| 32 Magnolia Bluff | 638.8 (117.9) | 598.6 (189.8) | 523.2 (115.1) | 395.0 (13.6) | 349.8 (69.5) |
| 33 Elliott Bay | 617.0 (44.6) | 461.0 (71.2) | 603.6 (113.9) | 557.2 (134.3) | 591.2 (29.1) |
| 34 Sinclair Inlet | 570.6 (190.8) | 449.0 (116.3) | 984.8 (439.5) | 960.8 (429.3) | 708.8 (126.3) |
| 35 Dyes Inlet | 642.8 (333.4) | 740.8 (197.3) | 505.6 (132.4) | 708.8 (365.9) | 377.6 (43.3) |
| 36R Brace Point | 412.4 (68.3) | | | 250.0 (88.9) | |
| 37R North Vashon Island | 552.2 (168.2) | | | 729.2 (212.2) | |
| 38 Point Pully | 116.2 (27.8) | 76.8 (11.8) | 125.6 (26.5) | 167.6 (43.1) | 193.8 (37.4) |
| 39 Dash Point | 239.0 (61.1) | 199.0 (62.6) | 171.8 (44.2) | 162.6 (18.6) | 181.4 (29.6) |
| 40 Commencement Bay | 668.2 (50.9) | 369.0 (75.1) | 605.4 (117.3) | 653.4 (85.7) | 616.8 (69.7) |
| 41 Commencement Bay | 2158.2 (825.5) | 2076.0 (164.7) | 1692.0 (235.5) | 915.4 (162.7) | 802.2 (136.8) |
| 43 Carr Inlet | 569.0 (79.9) | 649.2 (57.7) | 668.8 (74.2) | 858.4 (74.0) | 685.8 (95.9) |
| 44 East Anderson Island | 467.0 (134.1) | 666.4 (226.6) | 446.0 (142.6) | 560.2 (72.0) | 653.2 (71.7) |
| 45 Devil's Head | 249.2 (71.4) | 267.2 (33.6) | 190.6 (59.1) | 236.0 (29.2) | 283.6 (53.2) |
| 46R West Nisqually | 390.4 (78.3) | 443.2 (106.9) | | | 673.4 (109.3) |
| 47 Case Inlet | 398.8 (132.0) | 521.4 (57.2) | 564.2 (61.2) | 764.4 (216.1) | 666.8 (92.7) |
| 48 Outer Budd Inlet | 312.8 (84.9) | 294.2 (60.8) | 160.2 (29.0) | 293.6 (42.8) | 247.2 (68.7) |
| 49 Inner Budd Inlet | 137.8 (10.4) | 123.4 (47.9) | 140.4 (26.1) | 112.2 (26.0) | 202.8 (32.8) |
| 69 Port Madison | | 332.2 (67.7) | 512.8 (86.6) | 524.6 (87.1) | 626.6 (111.8) |
| 70 Oakland Bay, Shelton | | 111.2 (26.1) | 86.0 (7.7) | 70.4 (18.2) | 96.4 (29.5) |
| 71 Fidalgo Bay | | 506.6 (73.8) | 239.8 (37.0) | 427.8 (74.5) | 327.4 (32.8) |
| 101R North Oakland Bay | | 187.4 (45.0) | | | 127.2 (15.7) |
| 102R Inner Totten Inlet | | 150.2 (72.7) | | | 81.0 (48.4) |
| 103R Mid Totten Inlet | | 191.8 (29.8) | | | 535.6 (182.5) |
| 104R Inner Eld Inlet | | 181.8 (46.0) | | | 246.2 (17.8) |

Table 4. Concluded.

| Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|
| 105R Outer Eld Inlet | | 447.8 (114.9) | | | 345.2 (49.1) |
| 106R Mid Budd Inlet | | 374.2 (47.8) | | | 357.0 (72.1) |
| 109R Henderson Inlet | | 577.4 (101.3) | | | 659.2 (173.5) |
| 110R Inner Case Inlet | | 271.2 (118.0) | | | 334.4 (44.4) |
| 111R Mid Case Inlet | | 210.0 (81.7) | | | 93.2 (43.6) |
| 112R Nisqually Delta | | 167.2 (56.1) | | | 272.4 (54.0) |
| 113R Willochet Bay | | 392.0 (79.1) | | | 548.4 (77.9) |
| 114R Henderson Bay | | 80.4 (29.9) | | | 82.6 (11.4) |
| 115R Outer Filucy Bay | | 449.6 (132.6) | | | 436.2 (98.6) |
| 201R Roberts Bank | | | 879.4 (176.8) | | |
| 202R Point Roberts | | | 195.6 (32.2) | | |
| 203R Bellingham Bay | | | 259.6 (47.8) | | |
| 204R East Sound | | | 225.0 (64.3) | | |
| 205R NW Blakely Island | | | 393.4 (24.8) | | |
| 206R Friday Harbor | | | 524.6 (162.1) | | |
| 207R West Beach | | | 457.4 (66.0) | | |
| 208R Sequim Bay | | | 127.8 (18.5) | | |
| 209R Skagit Bay | | | 398.4 (36.3) | | |
| 301R Useless Bay | | | | 250.8 (84.5) | |
| 302R Oak Bay | | | | 221.4 (68.1) | |
| 303R Quartermaster Harbor | | | | 273.6 (44.2) | |
| 304R Hood Canal, Tekiu Point | | | | 61.2 (18.0) | |
| 305R Hood Canal, Lynch Cove | | | | 100.4 (34.6) | |
| 306R Seahurst | | | | 262.0 (109.4) | |
| 307R Holmes Harbor | | | | 95.4 (27.8) | |
| 308R Liberty Bay | | | | 535.8 (118.2) | |

[a] Abundance not reported because data from two replicates were missing. [b] Abundance not reported because station was sampled off location

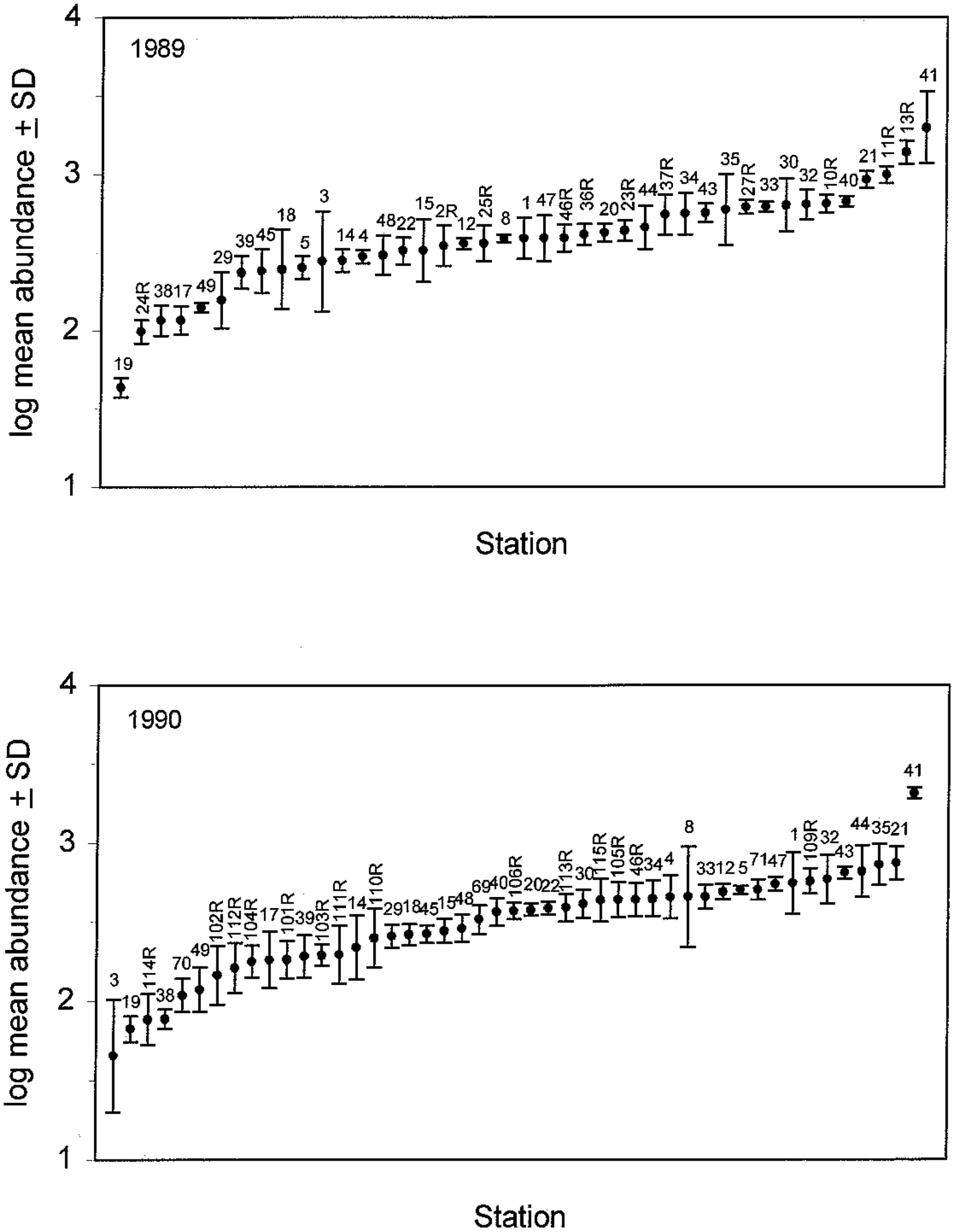



Figure 2. Total mean abundance (log ± SD) of benthic macrofauna in stations arranged from low to high abundance. Upper graph, 1989; lower graph, 1990.

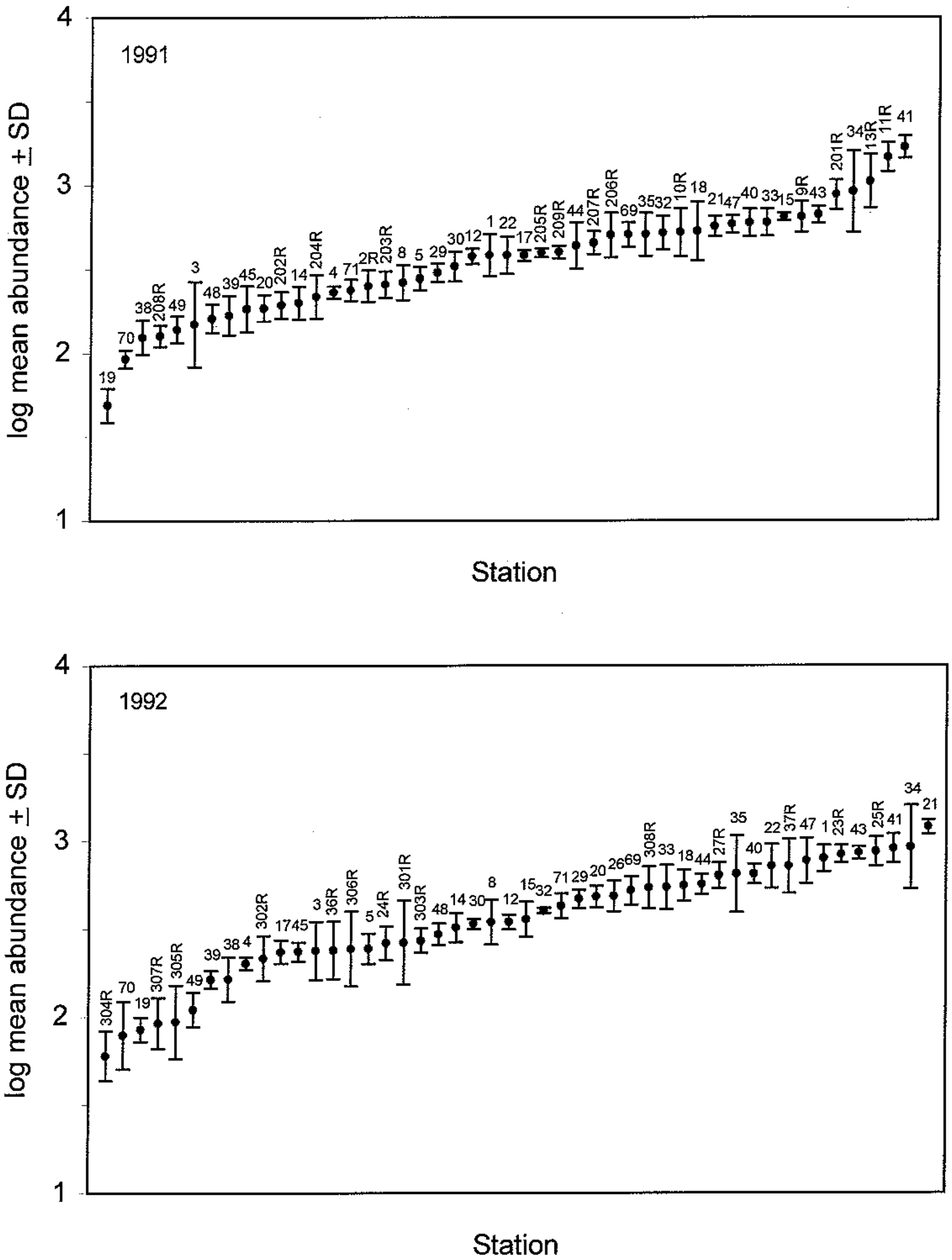



Figure 3. Total mean abundance (log ± SD) of benthic macrofauna in stations arranged from low to high abundance. Upper graph, 1991; lower graph, 1992.

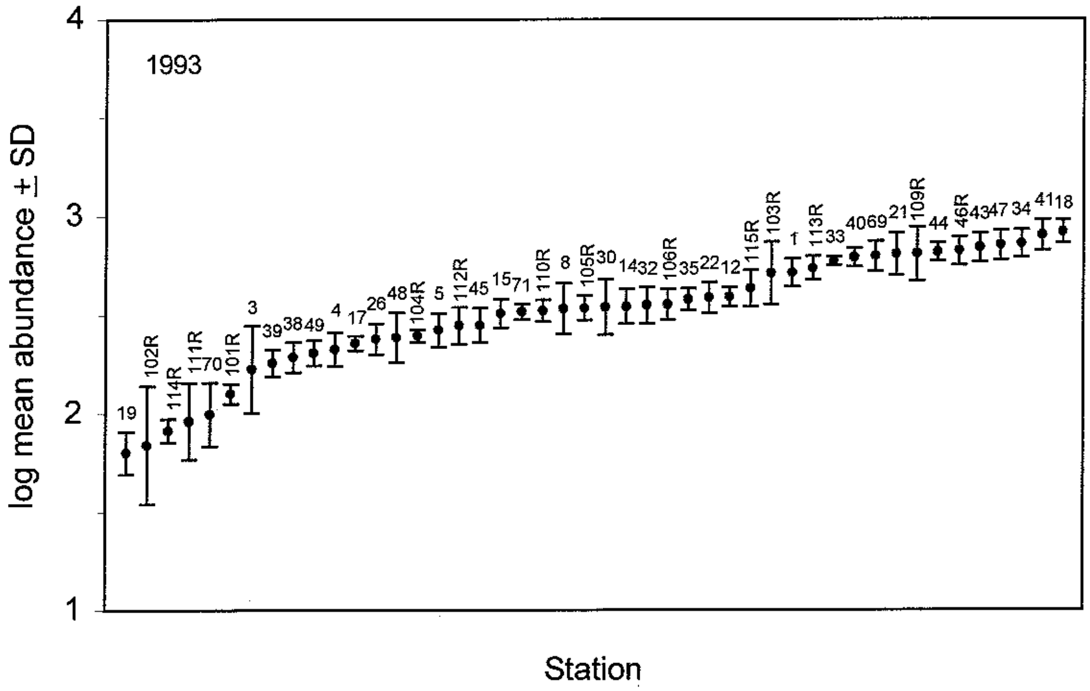



Figure 4. Total mean abundance (log ± SD) of benthic macrofauna in stations arranged from low to high abundance, 1993.

annelids (0.22). With the exception of this last relationship, there was no correlation (r < 0.21) between the percent abundance contribution of taxonomic groups and sediment parameters. Station total mean abundance patterns were also examined in relation to metal and total PAH concentrations in sediments. No associations between these variables were found.

## Species Composition

Excluding hydrozoans, ectoprocts, and entoprocts (presence/absence data), a total of 846 taxa were identified to the species or subspecies level from 1989 to 1993. In addition, 77 taxa were identified exclusively to the genus level. We have included in this total some distinct species that were recorded in the MSMP but were combined into complexes during the standardization process. Oligochaetes were not identified to species except in 1993, and are therefore not included in the total. A complete taxonomic list of macro-invertebrates found in the MSMP is provided in Appendix B.

Polychaetes accounted for 46% (389) of the species and were the dominant component of macrobenthos in Puget Sound. Arthropods accounted for 27% (233) of the species, molluscs for 17% (143), and the remaining taxa accounted for 10% (81) of the species. Scrutiny of the data by station and species revealed consistent species composition patterns across years; however, there was high spatial and temporal variability in the numerical contribution of these species to the total abundance per station. Overall, as dominance shifted between taxa, the relative proportion of organisms grouped in six major taxonomic groups varied (Appendix C, see below). However, for all years, polychaetes were numerically dominant in most stations, and accounted for more than 75% of the total number of organisms at 13 stations.

The percent contribution of annelids, bivalves, gastropods, crustaceans, echinoderms, and other phyla to the total abundance per station is shown in Appendix C. Several groups of stations could be distinguished according to the relative abundance of four of these taxonomic groups (Table 5).

Two stations were numerically dominated (>97%) by annelids: Sequim Bay (Station 208R) and South Hood Canal at Lynch Cove (Station 305R). These two stations are located in rural areas and both are affected by periodic hypoxia (see Discussion). Two groups of stations consisted predominantly of annelids with bivalves and crustaceans in variable but significant densities. The sediments at these stations were mostly mixed or sands, but some such as Henderson Bay (Station 114R) and East Sound (Station 204R) were clays. The percentage of crustaceans at these stations decreased with increasing clay content, but this relationship was not strong.

A third group of stations consisted largely of annelids and crustaceans, and the sediments were sand, mixed, or mud. Other groups of stations had various combinations of taxa (Table 5). For example, a fourth group consisted of

Table 5. Stations (selection) arranged by percent abundance of four major taxonomic groups. Shown is the range (rounded) and mean percent of five years (1989-1993). See Table 1 for station location.

| | | Percent Abundance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Annelida | | Bivalvia | | Crustacea | | Echinodermata | |
| Predominant Taxa | Station | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Annelids | 208R | 99 | -- | 0 | -- | 1 | -- | 0 | -- |
| | 305R | 98 | -- | 0 | -- | 0 | -- | 0 | -- |
| Annelids and bivalves | 2R | 58-69 | 63.7 | 13-20 | 16.6 | 5-7 | 6.2 | 1-2 | 1.4 |
| | 3 | 20-77 | 57.3 | 12-65 | 26.9 | 9-16 | 11.9 | 0-1 | 0.3 |
| | 114R | 69-71 | 70.0 | 5-16 | 10.7 | 1-2 | 1.5 | 3-9 | 5.8 |
| Annelids, bivalves, and crustaceans | 8 | 58-82 | 70.7 | 8-18 | 13.0 | 8-19 | 12.5 | 0-1 | 0.6 |
| | 10R | 76-77 | 76.7 | 9-11 | 10.3 | 10-13 | 11.6 | 0-0 | 0.1 |
| | 14 | 30-54 | 44.8 | 21-53 | 30.8 | 11-23 | 17.5 | 0-2 | 1.4 |
| | 20 | 56-76 | 67.8 | 15-20 | 16.7 | 1-23 | 11.7 | 0-0 | 0.0 |
| | 26 | 35-55 | 44.8 | 10-23 | 16.5 | 28-31 | 29.3 | 0-1 | 0.4 |
| | 33 | 39-57 | 49.3 | 14-31 | 20.8 | 17-29 | 25.2 | 1-7 | 2.2 |
| | 39 | 32-54 | 38.0 | 14-28 | 19.8 | 25-44 | 36.3 | 0-1 | 0.2 |
| | 40 | 40-59 | 48.8 | 16-32 | 24.5 | 9-29 | 22.0 | 0-7 | 2.0 |
| | 71 | 51-63 | 55.3 | 15-23 | 17.3 | 14-23 | 18.0 | 4-6 | 5.3 |
| | 202R | 78 | -- | 8 | -- | 9 | -- | 2 | -- |
| | 204R | 43 | -- | 22 | -- | 24 | -- | 6 | -- |
| | 301R | 48 | -- | 21 | -- | 23 | -- | 1 | -- |
| | 302R | 30 | -- | 26 | -- | 30 | -- | 5 | -- |
| | 306R | 55 | -- | 22 | -- | 20 | -- | 0 | -- |
| Annelids and crustaceans | 11R | 48-60 | 53.9 | 3-6 | 4.6 | 27-42 | 34.4 | 0-0 | 0.1 |
| | 27R | 38-49 | 43.3 | 8-11 | 9.5 | 36-46 | 40.0 | 1-1 | 1.1 |
| | 30 | 46-70 | 58.9 | 8-19 | 11.3 | 15-38 | 25.0 | 0-3 | 1.1 |
| | 32 | 56-70 | 61.8 | 5-11 | 8.1 | 17-28 | 21.9 | 1-4 | 2.9 |
| | 34 | 65-85 | 76.8 | 2-4 | 2.8 | 10-26 | 16.7 | 1-1 | 0.7 |
| | 36R | 37-42 | 39.6 | 10-16 | 12.9 | 41-44 | 42.4 | 1-1 | 0.6 |
| | 37R | 66-67 | 66.7 | 5-8 | 6.3 | 14-17 | 15.6 | 2-4 | 2.6 |
| | 44 | 54-71 | 64.4 | 4-11 | 7.1 | 12-27 | 17.1 | 2-8 | 3.4 |
| | 45 | 64-74 | 71.4 | 3-8 | 5.4 | 9-18 | 14.0 | 3-7 | 4.0 |
| | 49 | 39-86 | 55.8 | 2-16 | 7.4 | 5-36 | 20.3 | 0-4 | 2.3 |
| | 104R | 57-83 | 70.0 | 1-3 | 2.2 | 4-30 | 17.0 | 0-2 | 0.9 |
| | 111R | 57-68 | 62.4 | 7-9 | 8.5 | 7-24 | 15.4 | 0-4 | 1.9 |
| | 112R | 61-62 | 61.6 | 6-10 | 8.2 | 14-22 | 18.2 | 0-0 | 0.0 |
| | 203R | 65 | -- | 5 | -- | 21 | -- | 6 | -- |
| | 209R | 37 | -- | 15 | -- | 42 | -- | 1 | -- |
| | 303R | 37 | -- | 1 | -- | 54 | -- | 3 | -- |
| | 307R | 81 | -- | 3 | -- | 11 | -- | 0 | -- |
| Annelids, crustaceans, and echinoderms | 35 | 21-53 | 44.3 | 1-1 | 1.0 | 34-53 | 41.1 | 5-21 | 9.9 |
| | 43 | 25-34 | 30.3 | 4-7 | 5.5 | 28-40 | 32.8 | 24-33 | 28.1 |
| | 46R | 32-56 | 43.9 | 2-7 | 4.3 | 26-43 | 34.3 | 6-17 | 10.1 |
| | 69 | 34-55 | 40.8 | 3-22 | 12.3 | 26-39 | 30.5 | 1-30 | 13.0 |

Table 5. Concluded.

| Predominant Taxa | Station | Annelida Range | Annelida Mean | Bivalvia Range | Bivalvia Mean | Crustacea Range | Crustacea Mean | Echinodermata Range | Echinodermata Mean |
|---|---|---|---|---|---|---|---|---|---|
| | | **Percent Abundance** | | | | | | | |
| | 105R | 35-42 | 38.4 | 2-3 | 2.3 | 23-26 | 24.5 | 26-31 | 28.7 |
| | 106R | 32-41 | 36.3 | 2-2 | 2.0 | 34-45 | 39.7 | 17-20 | 18.5 |
| | 109R | 28-35 | 31.6 | 1-1 | 1.0 | 36-38 | 36.8 | 27-30 | 28.5 |
| | 110R | 27-35 | 31.2 | 1-5 | 2.7 | 13-20 | 16.6 | 34-53 | 43.5 |
| | 113R | 31-35 | 33.0 | 5-16 | 10.7 | 22-29 | 25.6 | 18-36 | 26.9 |
| | 115R | 37-43 | 40.2 | 1-7 | 4.1 | 13-16 | 14.6 | 30-46 | 37.9 |
| Annelids, bivalves, crustaceans and echinoderms | 4 | 15-57 | 36.3 | 14-33 | 24.5 | 7-27 | 16.6 | 3-33 | 18.4 |
| | 5 | 19-36 | 26.2 | 20-41 | 31.0 | 9-30 | 18.9 | 10-30 | 18.2 |
| | 9R | 73 | -- | 7 | -- | 2 | -- | 16 | -- |
| | 12 | 22-32 | 24.8 | 6-27 | 17.2 | 8-15 | 12.8 | 35-46 | 41.8 |
| Bivalves | 13R | 8-14 | 11.1 | 71-72 | 71.6 | 10-12 | 11.4 | 0-0 | 0.1 |
| | 17 | 14-54 | 33.7 | 35-83 | 57.4 | 0-10 | 6.2 | 0-0 | 0.0 |
| | 18 | 23-55 | 37.2 | 32-66 | 52.5 | 1-6 | 2.8 | 0-0 | 0.0 |
| | 24R | 18-41 | 29.8 | 16-63 | 39.5 | 12-29 | 20.5 | 1-3 | 2.2 |
| | 29 | 9-32 | 17.1 | 31-76 | 59.2 | 10-31 | 18.6 | 0-1 | 1.1 |
| | 41 | 19-52 | 32.2 | 43-70 | 56.5 | 4-10 | 5.5 | 0-8 | 2.2 |
| | 101R | 14-22 | 18.3 | 59-71 | 64.8 | 7-11 | 8.9 | 3-4 | 3.7 |
| | 205R | 25 | -- | 54 | -- | 5 | -- | 8 | -- |
| | 206R | 38 | -- | 45 | -- | 5 | -- | 2 | -- |
| | 207R | 36 | -- | 55 | -- | 4 | -- | 0 | -- |
| | 304R | 18 | -- | 59 | -- | 8 | -- | 3 | -- |
| Bivalves, crustaceans, and annelids | 21 | 16-27 | 21.5 | 39-54 | 48.8 | 18-35 | 28.3 | 0-0 | 0.0 |
| | 22 | 12-22 | 16.3 | 32-42 | 36.0 | 30-44 | 35.3 | 0-0 | 0.1 |
| | 23R | 16-16 | 16.1 | 26-44 | 35.0 | 22-38 | 29.9 | 0-0 | 0.2 |
| | 25R | 14-37 | 25.1 | 18-52 | 35.4 | 27-40 | 33.8 | 1-1 | 0.8 |
| | 38 | 13-24 | 18.8 | 7-51 | 30.1 | 32-61 | 45.4 | 2-4 | 2.4 |
| Crustaceans | 48 | 8-25 | 16.7 | 8-23 | 13.0 | 53-81 | 64.4 | 0-5 | 1.1 |
| Crustaceans and echinoderms | 1 | 9-25 | 16.1 | 4-9 | 6.2 | 26-55 | 36.7 | 29-54 | 40.2 |

approximately equal proportions of annelids, crustaceans, and echinoderms with few bivalves. A fifth group consisted of annelids, crustaceans, and echinoderms and a higher proportion of bivalves. A sixth group was numerically dominated by bivalves. The remaining of the stations were characterized by molluscs, crustaceans, and other phyla in various percentages.

The grouping of stations according to the percent abundance of taxonomic groups did not reveal any clear pattern in relation to contaminant concentrations in sediments. And, although in general a relationship between grain size and percent abundance could be identified, there was not a strong relationship. Some stations with either sand or mud were numerically dominated by the same taxonomic group. This is expected, as broad taxonomic groups represent a mixture of organisms with different life styles and feeding behaviors. Also, grain size is only one structuring factor. Other physical or biological factors that were not measured (*e.g.*, additional sediment properties such as porosity or shear strength, the hydrodynamic regime of the boundary layer, or the type and density of epibenthic predators) are likely to influence community structure in Puget Sound.

One last observation that can be extracted from the examination of Appendix C is the large inter-annual variability in the relative abundance of taxonomic groups at many of the stations in Puget Sound. In the following section we look at diversity and examine the relative contribution to this variability of shifts in species dominance.

## Diversity

Diversity was examined by looking separately at its two components, species richness (as measured by Margalef's SR) and the distribution of individuals among the species (evenness, as measured by Pielou's J'). Species richness remained relatively constant across years for most stations (Table 6). Rankings of SR values across years were highly concordant for stations common to all years (Kendall coefficient of concordance W =0.91; Friedman test statistic $\chi^2$ =131.87, $p<0.001$) and for rotating stations in 1990 and 1993 (Kendall coefficient of rank correlation $\tau$ =0.76; $t_s$ =7.52, $p<0.001$). Stations with variation greater than 15% around the mean SR value are indicated in Table 6. Only twelve stations showed this level of inter-annual variability.

Species richness (SR <7.0) was consistently low at some stations (Table 6). The number of species occurring at these stations was generally below 50, which represents 29% to 33% of the highest number of species recorded in the MSMP. Species richness was low in many of the stations that exhibited low abundance. For example, the Strait of Georgia (Station 3), Inner Budd Inlet (Station 49), Shelton (Station 70), Sequim Bay (Station 208), South Hood Canal (Stations 304R and 305R), and Holmes Harbor (Station 307R), generally had SR values below 7.0 (Table 7). Other stations with low species richness included Semiahmoo Bay in Blaine (Station 1), Hood Canal at Great Bend (Station 17), Outer Budd Inlet (Station 48), and East Sound in the San Juan Islands (Station 204R) (Table 7). In addition, most rotating stations located in the upper or middle reaches of inlets in South Puget Sound (*e.g.*, Carr Inlet, Case Inlet, Totten Inlet, Eld Inlet, and Oakland Bay) exhibited low species richness.

Evenness (Table 8) varied with fluctuations in the abundance of a few common species. Concordance of rankings among J' values across years was lower than concordance among SR values, but agreement among ranks was significant for both, core stations (Kendall coefficient of concordance W =0.67; Friedman test statistic $\chi^2$ =96.98, $p<0.001$) and rotating stations in 1990 and 1993 (Kendall coefficient of rank correlation $\tau$ =0.41; $t_s$ =4.06, $p<0.001$).

The lowest evenness values (J' <0.35) were recorded at Sequim Bay (Station 208R), North Hood Canal (Station 13R), Hood Canal at Great Bend (Station 17), Hood Canal at Lynch Cove (Station 305R), Commencement Bay at the Blair-Sitcum waterways (Station 41), Inner Budd Inlet (Station 49) and Outer Budd Inlet (Station 48) (Table 8). Stations with low evenness (J' <0.50) or showing variability in J' values greater than 0.15 units, reflected the numerical dominance of typically 20 species of benthic organisms plus the Phoronida (Table 9). Some of these species (*e.g.*, *Amphiodia urtica/periercta*, *Macoma carlottensis*, *M. nasuta*, *Aphelochaeta* sp., *Axinopsida serricata*, *Paraprionospio pinnata*) respond to organic enrichment, and because of their opportunistic life history strategies, may show large increases or decreases in abundance. The numerical dominance of these species at some locations may provide information about natural or human-related organic inputs to Puget Sound.

In order to couple the measures of species richness and dominance provided above, the Shannon index of diversity was calculated for each station and year, and is shown in Figure 5 as the average of five years. Inspection of Figure 5 shows immediately that Sequim Bay (Station 208R) and South Hood Canal at Lynch Cove (Station 305R) had the lowest diversity. At these two stations richness was low (the number of species was 4 and 23, respectively), and due to the abundance of *Nephtys cornuta* and *Paraprionospio pinnata* (see Table 9), evenness was also low. The very low diversity at these stations is indicative of communities under stress. South Hood Canal at Great Bend (Station 17) also had low species richness and, particularly in 1991, low evenness due to the numerical dominance of *Axinopsida serricata*. All three locations are affected by hypoxia (see Discussion).

Other stations with relatively few species included Inner (Station 49) and Outer (Station 48) Budd Inlet. These two stations also exhibited low evenness in 1993. However, the lack of a consistent pattern of low evenness in all years is reflected in the higher diversity averages, particularly at Station 49 (Figure 5).

Additionally, the Shannon index shows that North Hood Canal (Station 13R) and Commencement Bay at Blair-Sitcum waterways (Station 41) were clearly less diverse than most other stations (Figure 5). Surprisingly, however, the number of species at

Table 6. Species richness as computed by Margalef's SR. Stations with values for which the coefficient of variation >15% are indicated by asterisks. Blanks denote stations not sampled in a given year. SR ranges from 0 (one species) to high numbers (high species richness).

| Station | | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|
| 1 | Semiahmoo Bay, Blaine | 6.14 | 5.63 | 5.53 | 6.51 | 4.68 |
| 2R | Cherry Pt | 12.63 | -- | 13.78 | -- | -- |
| 3* | Strait of Georgia | 10.74 | 4.63 | 5.93 | 7.04 | 6.31 |
| 4 | Bellingham Bay | 9.75 | 9.67 | 7.24 | 10.18 | 9.04 |
| 5 | Samish Bay | 8.71 | 9.07 | 8.15 | 8.85 | 8.74 |
| 8 | Port Angeles | 13.95 | 11.95 | 12.87 | 14.65 | 13.62 |
| 9R | Green Pt | -- | -- | 5.81 | -- | -- |
| 10R | Dungeness Bay | 15.62 | -- | 15.99 | -- | -- |
| 11R* | Discovery Bay | 18.67 | -- | 14.87 | -- | -- |
| 12 | Port Townsend Bay | 10.90 | 9.48 | 9.69 | 8.60 | 9.91 |
| 13R | North Hood Canal | 14.04 | -- | 11.64 | -- | -- |
| 14 | Hood Canal Bangor | 15.31 | 17.47 | 16.79 | 16.84 | 18.77 |
| 15 | Dabob Bay | 18.28 | 15.09 | 13.62 | 14.06 | 16.03 |
| 17 | S Hood Canal, Great Bend | 5.97 | 5.10 | 5.03 | 4.82 | 4.98 |
| 18* | Oak Harbor | 7.19 | 7.38 | 7.94 | 11.09 | 11.76 |
| 19 | Saratoga Passage | 7.62 | 8.29 | 10.38 | 9.48 | 9.98 |
| 20* | Port Susan | 9.68 | 8.09 | 8.77 | 11.86 | 8.93 |
| 21 | Port Gardner (Everett) | 9.61 | 8.14 | 8.42 | 9.42 | 8.79 |
| 22 | Mukilteo | 10.83 | 12.05 | 11.76 | 14.16 | 13.48 |
| 23R* | East Central Basin Picnic Pt | 13.32 | -- | -- | 17.38 | -- |
| 24R | East Central Basin Norman Beach | 11.22 | -- | -- | 10.57 | -- |
| 25R* | West Central Basin | 10.96 | -- | -- | 14.35 | -- |
| 26 | Central Basin | (a) | (b) | (b) | 16.47 | 16.58 |
| 27R | Richmond Beach | 17.55 | -- | -- | 20.31 | -- |
| 29 | Shilshole | 10.00 | 9.00 | 7.79 | 7.50 | 7.48 |
| 30 | Eagle Harbor | 10.52 | 10.87 | 13.93 | 12.01 | 11.75 |
| 32 | Magnolia Bluff | 20.92 | 18.31 | 19.78 | 20.02 | 19.32 |
| 33 | Elliott Bay Duwamish Head | 14.85 | 15.04 | 16.53 | 17.12 | 17.25 |
| 34 | Sinclair Inlet | 10.49 | 8.71 | 8.84 | 10.15 | 8.95 |
| 35 | Dyes Inlet | 8.55 | 8.17 | 8.55 | 9.06 | 7.47 |
| 36R | Brace Point | 14.48 | -- | -- | 16.21 | -- |
| 37R | North Vashon Island | 21.44 | -- | -- | 22.80 | -- |
| 38* | Pt Pully | 9.53 | 7.06 | 8.38 | 6.58 | 6.71 |
| 39 | Dash Point | 10.78 | 11.77 | 11.90 | 12.44 | 11.07 |
| 40 | Commencement Bay City Waterwa | 11.40 | 12.52 | 13.08 | 13.61 | 15.20 |
| 41* | Commencement Bay Blair/Sitcum | 7.33 | 8.11 | 7.86 | 9.90 | 11.13 |
| 43 | Carr Inlet | 12.38 | 12.03 | 14.18 | 13.07 | 11.96 |
| 44 | East Anderson Island | 19.12 | 18.64 | 20.29 | 21.25 | 18.97 |
| 45 | Devil's Head | 10.29 | 10.02 | 10.25 | 10.48 | 11.67 |
| 46R | West Nisqually Johnson Pt | 12.85 | 13.78 | -- | -- | 13.69 |
| 47* | Case Inlet Fudge Pt | 13.83 | 17.50 | 17.53 | 22.45 | 17.03 |
| 48 | Outer Budd Inlet | 7.22 | 6.73 | 6.58 | 6.59 | 5.91 |
| 49 | Inner Budd Inlet | 4.74 | 4.83 | 5.19 | 6.17 | 5.06 |
| 69 | Port Madison | -- | 15.17 | 16.48 | 18.68 | 18.03 |

Table 6. Concluded.

| | Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|
| 70 | Oakland Bay, Shelton | -- | 6.66 | 5.13 | 6.15 | 6.72 |
| 71 | Fidalgo Bay Cap Sante | -- | 12.16 | 10.21 | 13.35 | 11.71 |
| 101R | North Oakland Bay | -- | 6.15 | -- | -- | 6.69 |
| 102R | Inner Totten Inlet | -- | 4.68 | -- | -- | 5.19 |
| 103R | Mid Totten Inlet | -- | 10.63 | -- | -- | 12.49 |
| 104R | Inner Eld Inlet | -- | 5.43 | -- | -- | 4.78 |
| 105R | Outer Eld Inlet | -- | 8.30 | -- | -- | 9.17 |
| 106R | Mid Budd Inlet | -- | 5.18 | -- | -- | 6.08 |
| 109R | Henderson Inlet | -- | 6.02 | -- | -- | 6.14 |
| 110R* | Inner Case Inlet | -- | 5.83 | -- | -- | 4.41 |
| 111R* | Mid Case Inlet | -- | 11.83 | -- | -- | 7.71 |
| 112R* | Nisqually Delta | -- | 8.93 | -- | -- | 13.04 |
| 113R | Willochet Bay | -- | 13.93 | -- | -- | 15.43 |
| 114R | Henderson Bay | -- | 6.03 | -- | -- | 5.00 |
| 115R | Outer Filucy Bay | -- | 10.54 | -- | -- | 10.08 |
| 201R | Strait of Georgia, Roberts Bank | -- | -- | 14.48 | -- | -- |
| 202R | Strait of Georgia, Pt Roberts | -- | -- | 12.27 | -- | -- |
| 203R | Bellingham Bay | -- | -- | 10.83 | -- | -- |
| 204R | East Sound | -- | -- | 5.14 | -- | -- |
| 205R | NW Blakely Island | -- | -- | 11.51 | -- | -- |
| 206R | Friday Harbor | -- | -- | 16.27 | -- | -- |
| 207R | Whidbey Island West Beach | -- | -- | 13.20 | -- | -- |
| 208R | Sequim Bay | -- | -- | 0.46 | -- | -- |
| 209R | Skagit Bay | -- | -- | 11.34 | -- | -- |
| 301R | Useless Bay | -- | -- | -- | 13.26 | -- |
| 302R | Oak Bay | -- | -- | -- | 13.75 | -- |
| 303R | Quartermaster Harbor | -- | -- | -- | 9.57 | -- |
| 304R | Hood Canal, Tekiu Point | -- | -- | -- | 6.22 | -- |
| 305R | Hood Canal Lynch Cove | -- | -- | -- | 3.54 | -- |
| 306R | Seahurst East Passage | -- | -- | -- | 17.28 | -- |
| 307R | Holmes Harbor | -- | -- | -- | 5.68 | -- |
| 308R | Liberty Bay | -- | -- | -- | 12.32 | -- |

(a) Index not reported because data from two replicates were missing. (b) Index not calculated because samples were taken off station location.

Table 7. Stations with Margalef's Species Richness below 7.0 by year, in rank order from low to high. The number of species at these stations was generally below 50, which represents 29-33% of the species recorded at the station with the highest species richness in Puget Sound. Note that the same core stations (sampled annually and designated with a number <100) appear in the list for most years. Also, the same rotating stations (sampled on a three year rotation and designated with a number >100 and the letter "R") in south Puget Sound (100R-series) appear in the list in 1990 and 1993.

| 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|
| 49 Inner Budd Inlet | 3 Strait of Georgia | 208R Sequim Bay | 305R Lynch Cove | 110R Inner Case Inlet |
| 17 S. Hood Canal | 102R Inner Totten Inlet | 17 S. Hood Canal | 17 S. Hood Canal | 1 Semiahmoo Bay |
| 1 Semiahmoo Bay | 49 Inner Budd Inlet | 70 Oakland Bay | 307R Holmes Harbor | 104R Inner Eld Inlet |
| | 17 S. Hood Canal | 204R East Sound | 70 Oakland Bay | 17 S. Hood Canal |
| | 106R Mid Budd Inlet | 49 Inner Budd Inlet | 49 Inner Budd Inlet | 114R Henderson Bay |
| | 104R Inner Eld Inlet | 1 Semiahmoo Bay | 304R Tekiu Point | 49 Inner Budd Inlet |
| | 1 Semiahmoo Bay | 9R Green Point | 1 Semiahmoo Bay | 102R Inner Totten Inlet |
| | 110R Inner Case Inlet | 3 Strait of Georgia | 38 Point Pully | 48 Outer Budd Inlet |
| | 109R Henderson Inlet | 48 Outer Budd Inlet | 48 Outer Budd Inlet | 106R Mid Budd Inlet |
| | 114R Henderson Bay | | 3 Strait of Georgia | 109R Henderson Inlet |
| | 101R N. Oakland Bay | | | 3 Strait of Georgia |
| | 70 Oakland Bay | | | 101R N. Oakland Bay |
| | 48 Outer Budd Inlet | | | 38 Point Pully |
| | | | | 70 Oakland Bay |

Table 8. Evenness as computed by Pielou's J'. Blanks denote stations not sampled in a given year. J' ranges from 0 (low evenness) to 1 (high evenness).

| | Station | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|
| 1 | Semiahmoo Bay, Blaine | 0.62 | 0.53 | 0.51 | 0.46 | 0.52 |
| 2R | Cherry Pt. | 0.69 | -- | 0.75 | -- | -- |
| 3 | Strait of Georgia | 0.66 | 0.76 | 0.70 | 0.54 | 0.62 |
| 4 | Bellingham Bay | 0.74 | 0.66 | 0.64 | 0.69 | 0.74 |
| 5 | Samish Bay | 0.71 | 0.70 | 0.74 | 0.72 | 0.70 |
| 8 | Port Angeles | 0.75 | 0.50 | 0.76 | 0.75 | 0.65 |
| 9R | Green Pt. | -- | -- | 0.46 | -- | -- |
| 10R | Dungeness Bay | 0.59 | -- | 0.64 | -- | -- |
| 11R | Discovery Bay | 0.67 | -- | 0.58 | -- | -- |
| 12 | Port Townsend Bay | 0.60 | 0.59 | 0.54 | 0.58 | 0.52 |
| 13R | North Hood Canal | 0.37 | -- | 0.33 | -- | -- |
| 14 | Hood Canal, Bangor | 0.67 | 0.80 | 0.84 | 0.72 | 0.77 |
| 15 | Dabob Bay | 0.82 | 0.81 | 0.46 | 0.72 | 0.76 |
| 17 | S Hood Canal Great Bend | 0.58 | 0.63 | 0.27 | 0.42 | 0.55 |
| 18 | Oak Harbor | 0.59 | 0.52 | 0.46 | 0.53 | 0.44 |
| 19 | Saratoga Passage | 0.85 | 0.59 | 0.85 | 0.80 | 0.82 |
| 20 | Port Susan | 0.65 | 0.70 | 0.72 | 0.66 | 0.72 |
| 21 | Port Gardner (Everett) | 0.52 | 0.59 | 0.61 | 0.55 | 0.55 |
| 22 | Mukilteo | 0.58 | 0.58 | 0.58 | 0.59 | 0.62 |
| 23R | East Central Basin Picnic Pt. | 0.60 | -- | -- | 0.57 | -- |
| 24R | East Central Basin Norman Beach | 0.86 | -- | -- | 0.56 | -- |
| 25R | West Central Basin | 0.55 | -- | -- | 0.43 | -- |
| 26 | Central Basin | (a) | (b) | (b) | 0.73 | 0.82 |
| 27R | Richmond Beach | 0.61 | -- | -- | 0.69 | -- |
| 29 | Shilshole | 0.66 | 0.48 | 0.44 | 0.36 | 0.40 |
| 30 | Eagle Harbor | 0.49 | 0.61 | 0.70 | 0.69 | 0.69 |
| 32 | Magnolia Bluff | 0.63 | 0.65 | 0.73 | 0.73 | 0.74 |
| 33 | Elliott Bay Duwamish Head | 0.65 | 0.66 | 0.70 | 0.71 | 0.70 |
| 34 | Sinclair Inlet | 0.62 | 0.65 | 0.39 | 0.44 | 0.58 |
| 35 | Dyes Inlet | 0.53 | 0.54 | 0.64 | 0.48 | 0.54 |
| 36R | Brace Point | 0.64 | -- | -- | 0.76 | -- |
| 37R | North Vashon Island | 0.65 | -- | -- | 0.76 | -- |
| 38 | Pt. Pully | 0.70 | 0.80 | 0.64 | 0.61 | 0.65 |
| 39 | Dash Point | 0.62 | 0.66 | 0.74 | 0.72 | 0.75 |
| 40 | Commencement Bay City Waterwa | 0.59 | 0.67 | 0.68 | 0.68 | 0.71 |
| 41 | Commencement Bay Blair/Sitcum | 0.32 | 0.34 | 0.37 | 0.52 | 0.49 |
| 43 | Carr Inlet | 0.57 | 0.57 | 0.58 | 0.60 | 0.66 |
| 44 | East Anderson Island | 0.73 | 0.69 | 0.82 | 0.77 | 0.76 |
| 45 | Devil's Head | 0.61 | 0.62 | 0.71 | 0.69 | 0.67 |
| 46R | West Nisqually Johnson Pt. | 0.74 | 0.71 | -- | -- | 0.67 |
| 47 | Case Inlet Fudge Pt. | 0.67 | 0.73 | 0.71 | 0.75 | 0.76 |
| 48 | Outer Budd Inlet | 0.48 | 0.56 | 0.61 | 0.43 | 0.31 |
| 49 | Inner Budd Inlet | 0.73 | 0.69 | 0.73 | 0.76 | 0.34 |
| 69 | Port Madison | -- | 0.75 | 0.72 | 0.72 | 0.72 |
| 70 | Oakland Bay Shelton | -- | 0.67 | 0.72 | 0.81 | 0.75 |

Table 8. Concluded.

| Station | | 1989 | 1990 | 1991 | 1992 | 1993 |
|---|---|---|---|---|---|---|
| 71 | Fidalgo Bay Cap Sante | -- | 0 78 | 0.80 | 0.77 | 0.75 |
| 101R | North Oakland Bay | -- | 0.49 | -- | -- | 0.58 |
| 102R | Inner Totten Inlet | -- | 0.73 | -- | -- | 0 53 |
| 103R | Mid Totten Inlet | -- | 0 78 | -- | -- | 0 70 |
| 104R | Inner Eld Inlet | -- | 0.68 | -- | -- | 0.42 |
| 105R | Outer Eld Inlet | -- | 0.58 | -- | -- | 0.59 |
| 106R | Mid Budd Inlet | -- | 0 64 | -- | -- | 0 60 |
| 109R | Henderson Inlet | -- | 0.52 | -- | -- | 0 51 |
| 110R | Inner Case Inlet | -- | 0.58 | -- | -- | 0.58 |
| 111R | Mid Case Inlet | -- | 0.77 | -- | -- | 0.69 |
| 112R | Nisqually Delta | -- | 0 67 | -- | -- | 0 72 |
| 113R | Willochet Bay | -- | 0.66 | -- | -- | 0.69 |
| 114R | Henderson Bay | -- | 0.71 | -- | -- | 0.66 |
| 115R | Outer Filucy Bay | -- | 0 64 | -- | -- | 0 62 |
| 201R | Strait of Georgia Roberts Bank | -- | -- | 0.46 | -- | -- |
| 202R | Strait of Georgia Pt Roberts | -- | -- | 0 75 | -- | -- |
| 203R | Bellingham Bay | -- | -- | 0.76 | -- | -- |
| 204R | East Sound | -- | -- | 0.75 | -- | -- |
| 205R | NW Blakely Island | -- | -- | 0.55 | -- | -- |
| 206R | Friday Harbor | -- | -- | 0 74 | -- | -- |
| 207R | Whidbey Island West Beach | -- | -- | 0.56 | -- | -- |
| 208R | Sequim Bay | -- | -- | 0.10 | -- | -- |
| 209R | Skagit Bay | -- | -- | 0 59 | -- | -- |
| 301R | Useless Bay | -- | -- | -- | 0.71 | -- |
| 302R | Oak Bay | -- | -- | -- | 0.78 | -- |
| 303R | Quartermaster Harbor | -- | -- | -- | 0 71 | -- |
| 304R | Hood Canal, Tekiu Point | -- | -- | -- | 0.69 | -- |
| 305R | Hood Canal, Lynch Cove | -- | -- | -- | 0 34 | -- |
| 306R | Seahurst East Passage | -- | -- | -- | 0 78 | -- |
| 307R | Holmes Harbor | -- | -- | -- | 0 55 | -- |
| 308R | Liberty Bay | -- | -- | -- | 0.63 | -- |

[a] Index not reported because data from two replicates were missing. [b] Index not calculated because samples were taken off station location.

Table 9. Numerically dominant species in Puget Sound responsible for low evenness (J'<0.50) or fluctuations in evenness at listed stations. A= Amphipoda, B= Bivalvia, C= Cumacea, D= Decapoda, E= Echinodermata, O= Ostracoda, P= Polychaeta, S= Sipuncula. This table was constructed by inspecting data files and selecting the species with the largest discrepancies in abundance (averaged over 5 replicates) across years (stations sampled more than once) or within a year (stations sampled once). The abundance of these species was artificially lowered to eliminate the discrepancy and the index re-calculated to examine the influence of these species on fluctuations in J'.

| Species | Station |
|---|---|
| *Amphiodia urtica-periercta* (E) | 1 Semiahmoo Bay, 35 Dyes Inlet |
| *Aphelochaeta* sp. (P) | 8 Port Angeles, 30 Eagle Harbor, 35 Dyes Inlet, 41 Commencement Bay |
| *Axinopsida serricata* (B) | 17 S. Hood Canal, 18 Oak Harbor, 41 Commencement Bay |
| *Eudorella pacifica* (C) | 35 Dyes Inlet, 48 Outer Budd Inlet |
| *Euphilomedes carcharodonta* (O) | 13R N. Hood Canal, 25R W. Central Basin |
| *Macoma calcarea* (B) | 3 Strait of Georgia |
| *Macoma carlottensis* (B) | 24R E. Central Basin, 29 Shilshole, 38 Point Pully |
| *Macoma nasuta* (B) | 101R N. Oakland Bay |
| *Nephtys cornuta* (P) | 102R Inner Totten Inlet, 208R Sequim Bay |
| *Paraprionospio pinnata* (P) | 49 Inner Budd Inlet, 104R Inner Eld Inlet, 305R Lynch Cove |
| *Pectinaria californiensis* (P) | 19 Saratoga Passage |
| Phoronida | 15 Dabob Bay, 18 Oak Harbor |
| *Phyllochaetopterus prolifica* (P) | 34 Sinclair Inlet, 35 Dyes Inlet |
| *Pinnixa schmitti* (D) | 30 Eagle Harbor, 35 Dyes Inlet |
| *Protomedeia grandimana* (A) | 1 Semiahmoo Bay |
| *Psephidia lordi* (B) | 13R N. Hood Canal, 25R W. Central Basin, 101R N. Oakland Bay |
| *Spiochaetopterus costarum* (P) | 18 Oak Harbor |
| *Spiophanes berkeleyorum* (P) | 18 Oak Harbor |
| *Spiophanes bombyx* (P) | 9R Green Point, 25R W. Central Basin |
| *Thysanocardia nigra* (S) | 201R Roberts Bank |
| *Yoldia* sp. (B) | 3 Strait of Georgia |

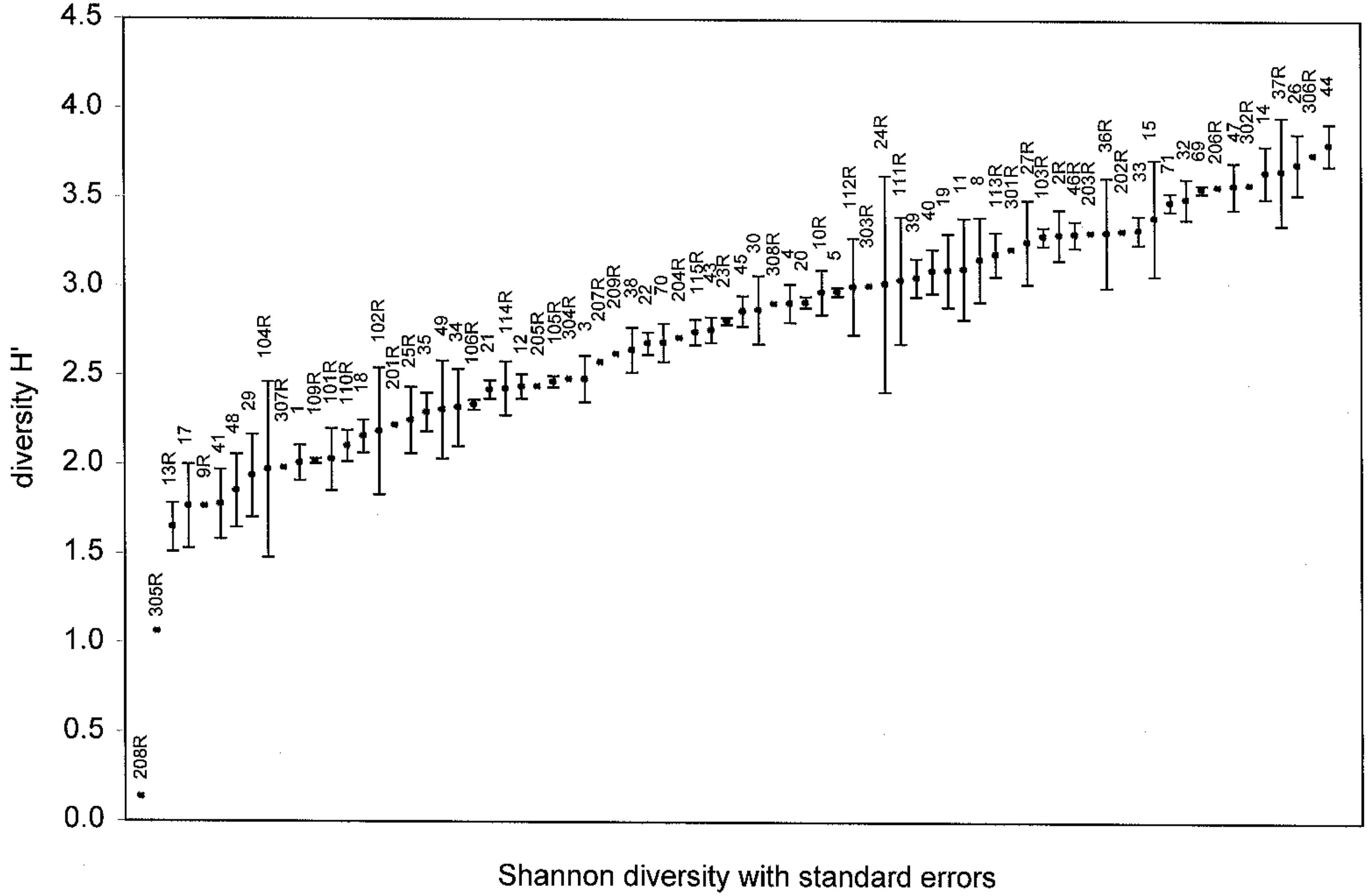



Figure 5. Shannon diversity H' of stations arranged from low to high diversity. All years included.

these stations were among the highest in Puget Sound. Particularly, North Hood Canal had a rich assemblage of up to 125 species. Diversity was low because of the high numerical dominance of a few species. Thus, the separate estimates of species richness and evenness provided valuable insight into the diversity at these locations. This insight would have been lost had Shannon diversity been used as the sole criterion to rank stations in the MSMP.

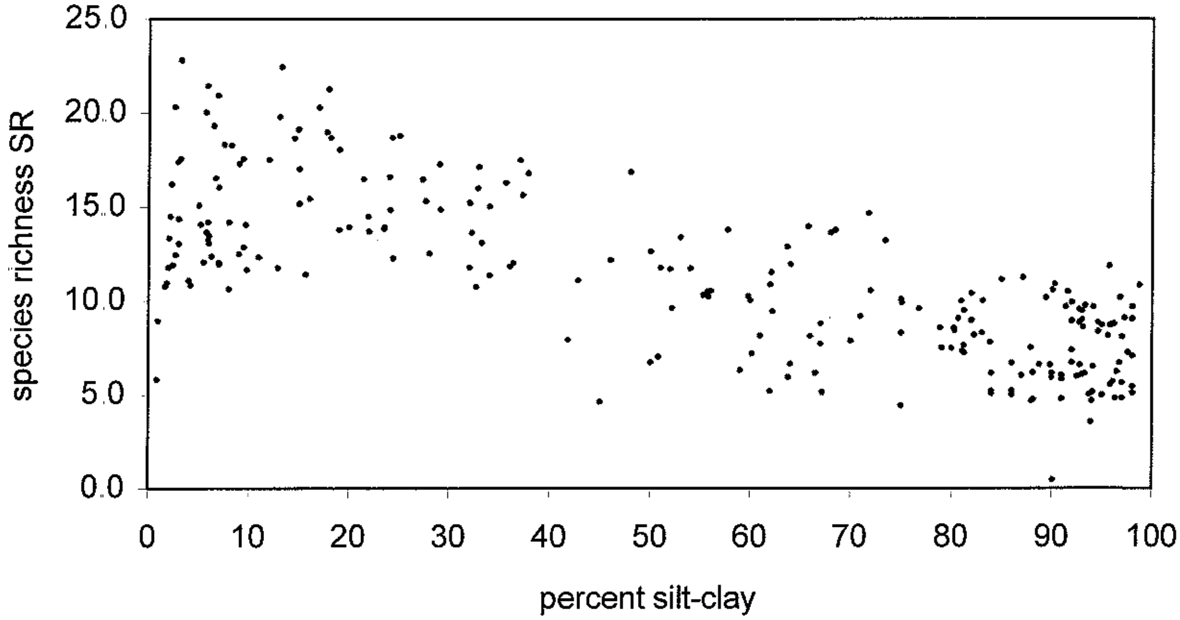
Dominance in North Hood Canal and Commencement Bay (Station 41) was due to different species. North Hood Canal was dominated by *Psephidia lordi* and *Euphilomedes carcharodonta*, which were ubiquitous primarily in sand or mixed substrates in Puget Sound. Commencement Bay was dominated by *Aphelochaeta* sp. and *Axinopsida serricata*, which were found to be associated with organic enrichment and pollution in other studies (see Discussion). While North Hood Canal consisted of clean sands, a variety of contaminants were detected in the sediments of Station 41, most notably resin acids and high concentrations of sterols.

Species richness was inversely correlated with percent silt-clay ($r = -0.75$) and total organic carbon ($r = -0.64$) (Figure 6). In stations grouped by sediment type, mud substrates generally supported fewer species than mixed substrates, with sands supporting the highest number of species (Figure 7). Species richness was inversely correlated with the concentration of total sulfide in sediments ($r = -0.39$), but the relationship was weak. In stations grouped by sulfide concentration, however, a decrease in species richness with sulfide became clear (Figure 7). Evenness was not correlated with grain size or organic carbon, although it was weakly and inversely correlated with sulfide ($r = -0.32$).

## Similarities among Stations

Classification analyses of stations for 1989-1993 are shown in Figures 8 through 12. These analyses are based on mean species abundance. The 1989 data also were analyzed for each individual replicate, and the replicates were found to cluster by station. Only two of the 243 replicate samples included in the analysis were classified in different station groups. Although the analysis of separate replicates was not conducted for all years due to computational difficulties, the 1989 results suggest that the averaging of replicates to examine species distributional patterns is probably adequate.

Results from the classification analyses showed consistent patterns of spatial variation. These patterns could be explained primarily on the basis of differences in substrate and water depth, and secondarily on the basis of differences in species composition and abundance between north and south Puget Sound. There was no clear separation of stations in relation to low or moderate (see Volume 1) contaminant concentrations in sediments.



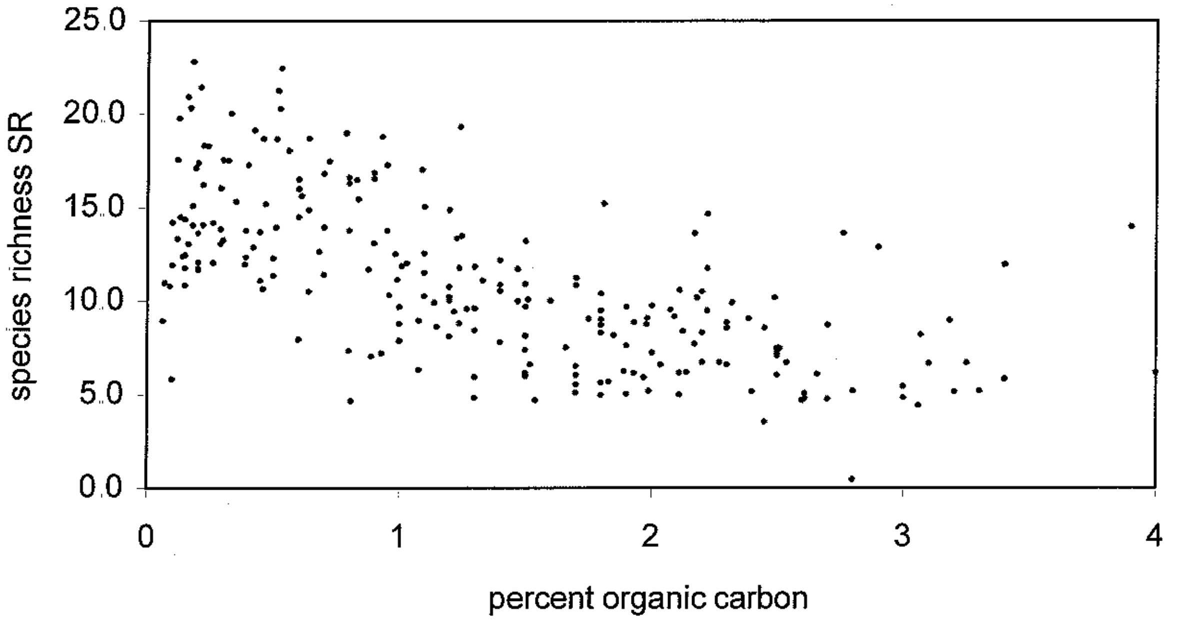




Figure 6. Species richness as a function of percent silt and clay (upper graph) and percent total organic carbon (lower graph) in sediments.

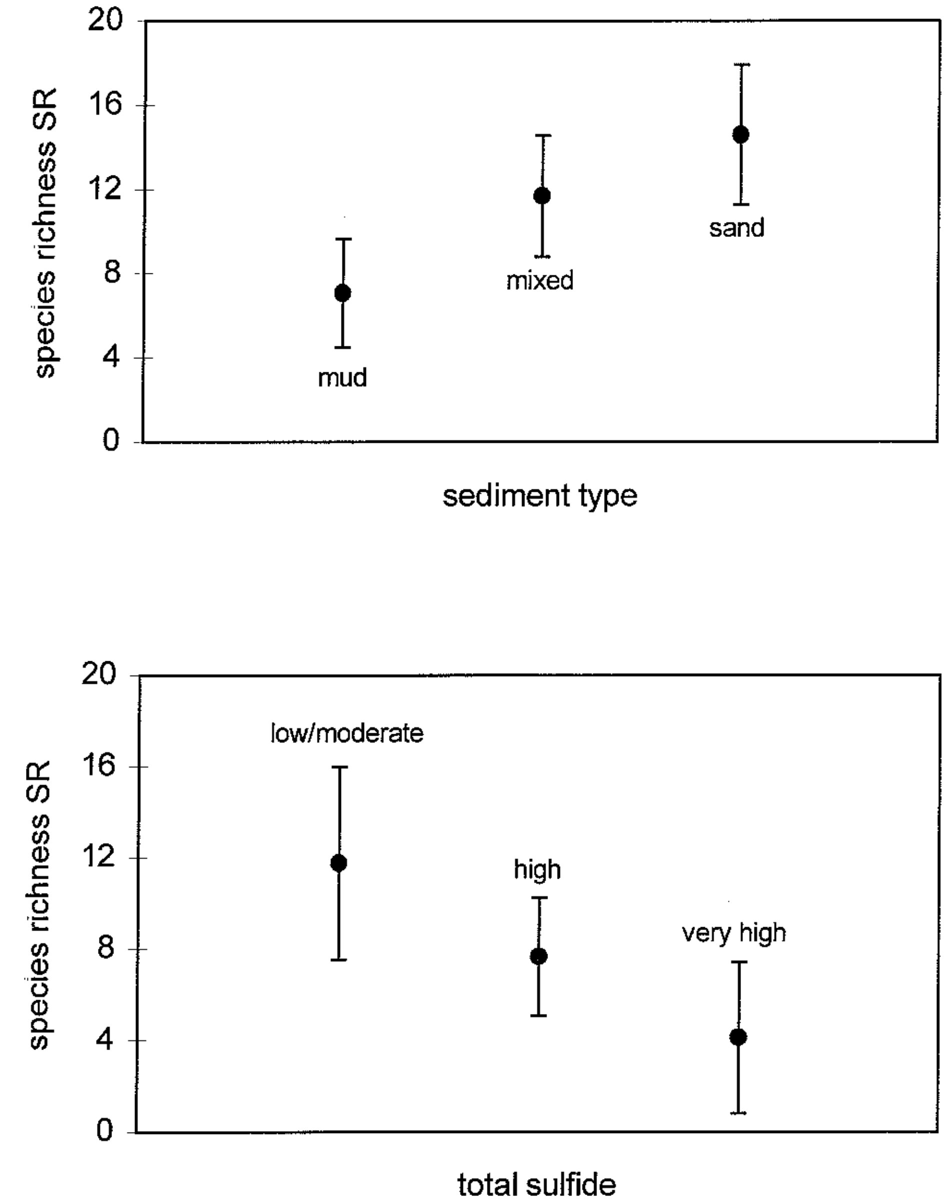



Figure 7. Species richness SR (mean ± SD) of stations categorized by sediment type (upper graph) and total sulfide (lower graph). Low/moderate, <100 mg/kg S; high, 100-500 mg/kg S; very high, >500 mg/kg S.

Sand and silty-sand stations were separated from clay stations, and generally from mixed stations. Also, clay and mixed stations were often separated into distinct groups at higher similarity levels. Deep (80-200) clay stations formed a distinct group, regardless of location in the Puget Sound region. Shallow (≤ 20 m) clay stations were separated into north and south Puget Sound groups. A group of inlet end stations in south Puget Sound was distinct, especially for the two years (1990 and 1993) for which rotating stations were sampled in south Puget Sound. These clusters are identified in bold in Figures 8-12. In 1989, the deep clay station group included Devil's Head (Station 45), which is a moderately deep (52 m) station (Figure 8).

A few stations had low affinity with other stations. Among these, Station 3 in the Strait of Georgia was consistently separated from all others. Also, rotating stations in south Hood Canal (Station 305R), Holmes Harbor (Station 307R), and Sequim Bay (Station 208R) had low affinity with other stations. These rotating stations showed reduced faunal abundance and low species richness. In addition, Green Point (Station 9R) was distinctly separated in cluster analysis (Figure 10). Green Point had 40% coarse sands and exhibited a distinct fauna unlike any other station in the MSMP.

In general, there was a relationship between total organic carbon (TOC) and sediment type, and hence, between TOC and station group separation. For example, most station groups with sand or mixed sediments had low TOC concentrations (<1.5%), and inlet ends in south Puget Sound generally exhibited high TOC values (>2.5%). No relationship between total sulfide and station group separation was found.

## Inverse Classification and Station-by-Species Coincidence Tables

Twenty (1989) to 37 (1992) groups of species were distinguished in inverse classification analyses. This distinction was based on the separation of species groups from other groups in the analysis, rather than on a predetermined level of similarity. Most group separations were clear in the dendograms, but in some cases subjective judgment was necessary in the identification of species groups. Because of their large size, the dendograms are not shown here. Instead, the species group separation was examined in station-by-species coincidence tables in terms of constancy and fidelity (nodal analysis). Constancy diagrams for 1989-1993 are shown in Figures 13 through 17 and fidelity diagrams are shown in Figures 18 through 22.

Some species showed clear affinities with some of the station groups. This is indicated by the high density pattern of some of the cells in the lower part of the constancy and fidelity diagrams. Other species had no particular affinity with any one station group but presented high constancy and low fidelity across most station groups. This is indicated by a band of high density pattern in the upper part of the constancy diagrams.

Species groups displaying an overall high constancy (≥ 0.5) in the upper part of the constancy diagrams (Figures 13-17), consisted of eurytopic species of broad distribution in all sediment types. These species were categorized as occurring in "all substrates" in Table 10. They were abundant in both sand and mud. Most other species were present in a variety of sediments, but predominated numerically in specific substrate types. These species are indicated with "all" in parenthesis in Table 10 and were categorized as occurring in one of several substrates ("sand and silt", "sand to mixed", silt and clay", "mixed to clay", and "clay"). Thus, the distribution of most species in Puget Sound did not exhibit sharp boundaries, but were broad and overlapping, with peaks of abundance along the grain size gradient.

Species groups displaying high fidelity (Figures 18-22) provided partial explanation for the separation of clusters in the classification analysis. In particular, species groups displaying high fidelity and high constancy indicate species that occur in many or all the stations of a station group, but seldom occur elsewhere. Some of these species were restricted to specific habitat types such as "shallow sand" or "deep clay'' (Table 10), or to specific locations within Puget Sound (*e.g.*, south Puget Sound). The identification of these species through nodal analysis significantly contributed to the characterization of particular assemblages in Puget Sound. Because constancy and fidelity are based exclusively on presence/absence data, assemblages were also characterized by numerically dominant species. The results from this characterization are presented in the next section.

# Dominant and Characteristic Species

The top numerically dominant species by sediment type and water depth are shown in Table 11. Sediment type and water depth were chosen as criteria to group stations because they were consistently identified as major factors associated with the separation of stations in the classification analysis. The stations were arranged in four major habitat classes: sand, mixed, clay, and deep clay. Silty-sand stations were combined with sand stations, as they formed the least distinct group in the classification analysis.

Overall, sand stations were dominated by the ostracod *Euphilomedes carcharodonta* and the polychaete *Prionospio jubata* (Table 11). The bivalve *Axinopsida serricata* and the amphipod *Rhepoxynius abronius/variatus* were next in rank. Mixed stations were dominated by *A. serricata*, followed by the polychaete *Aphelochaeta* sp. and the cumacean *Eudorella pacifica*. Dominant species of clay stations were the ophiuroid *Amphiodia urtica/periercta*, the cumacean *E. pacifica*, the polychaete *Sigambra tentaculata*, and the decapod *Pinnixa occidentalis/schmitti*. Deep clay stations were dominated by the bivalves *Macoma carlottensis* and *A. serricata*, and by the polychaete *Pectinaria californiensis*.

For comparative purposes, the range and average in density and number of species of these four habitat classes are given in Table 12. As previously noted, sand substrates supported higher number of species and abundance than clay substrates, with deep clay stations having the lowest abundance. Commencement Bay (Station 41) and Sequim Bay (Station 208R) were considered outliers and excluded from these averages as indicated in Table 12 and explained below.

Commencement Bay (Station 41) was considered an outlier because of the extremely high abundance of two species, the cirratulid polychaete *Aphelochaeta* sp. (mostly *Aphelochaeta* sp. C) and the thyasirid bivalve *Axinopsida serricata*. *Aphelochaeta* sp. was present at many stations in Puget Sound. However, elevated densities of this species were found only at urban stations where organic enrichment or moderate contamination were identified (see Volume 1 of this report). *Aphelochaeta* was numerically dominant in Port Angeles (Station 8), Eagle Harbor (Station 30), Sinclair Inlet (Station 34), Dyes Inlet (Station 35), and Commencement Bay (Stations 40 and 41). Interestingly, *Aphelochaeta* did not make up a significant percentage of the fauna in Elliott Bay (Station 33), notwithstanding the extensive contamination detected at this station. The species, however, dominates areas in Elliott Bay near "hot spots" of chemical contamination (see Discussion). *Aphelochaeta* accounted for 50.9% of the fauna in Eagle Harbor in 1989, 53.3% of the fauna in Port Angeles in 1990, and 46.3% of the fauna in Commencement Bay (Station 41) in 1989 and 45.5% in 1990. At the other urban stations, *Aphelochaeta* accounted for less than 35%, although it ranked within the top five species in 23 out of 30 sampling cruises. One characteristic of this species was its large variability among replicates and across years.

*Axinopsida serricata* accounted for 40.5%-62% of the fauna in Commencement Bay (Station 41), 1989-1993. The density of *Axinopsida* at this station was the highest of any species recorded in Puget Sound. In addition, *Axinopsida* was dominant in South Hood Canal Great Bend (Station 17), Oak Harbor (Station 18), Port Gardner (Station 21), Mukilteo (Station 22), and Station 40 in Commencement Bay. *Axinopsida* accounted for 33.7%-62.9% of the fauna at Great Bend, with a record high of 80.9% in 1991. It accounted for 31%-55.6% in Oak Harbor, 17.2%-29.9% in Port Gardner, 16.6%-25% in Mukilteo, and 7.7%-21.3% in Station 40. *Axinopsida* was typical of organic enrichment in other studies and may be particularly tolerant of reducing sediment conditions.

Station 208R was considered an outlier because of the extremely low diversity and abundance of infaunal organisms. The only species exhibiting any significant abundance at this station was the polychaete *Nephtys cornuta*.

Characteristic species (*i.e.*, those species that were mostly station group-specific but were not among the top-ranked dominants) were identified from the nodal diagrams. North Puget Sound clay stations were characterized by the polychaetes *Cossura* sp. and *Levinsenia gracilis*. South Puget Sound clay stations were characterized by the polychaete *Sigambra tentaculata* and the bivalves *Macoma nasuta* and *Macoma yoldiformis*. Echinoderms such as the holothurian *Molpadia intermedia* and the echinoid *Brisaster latifrons* characterized deep water stations.

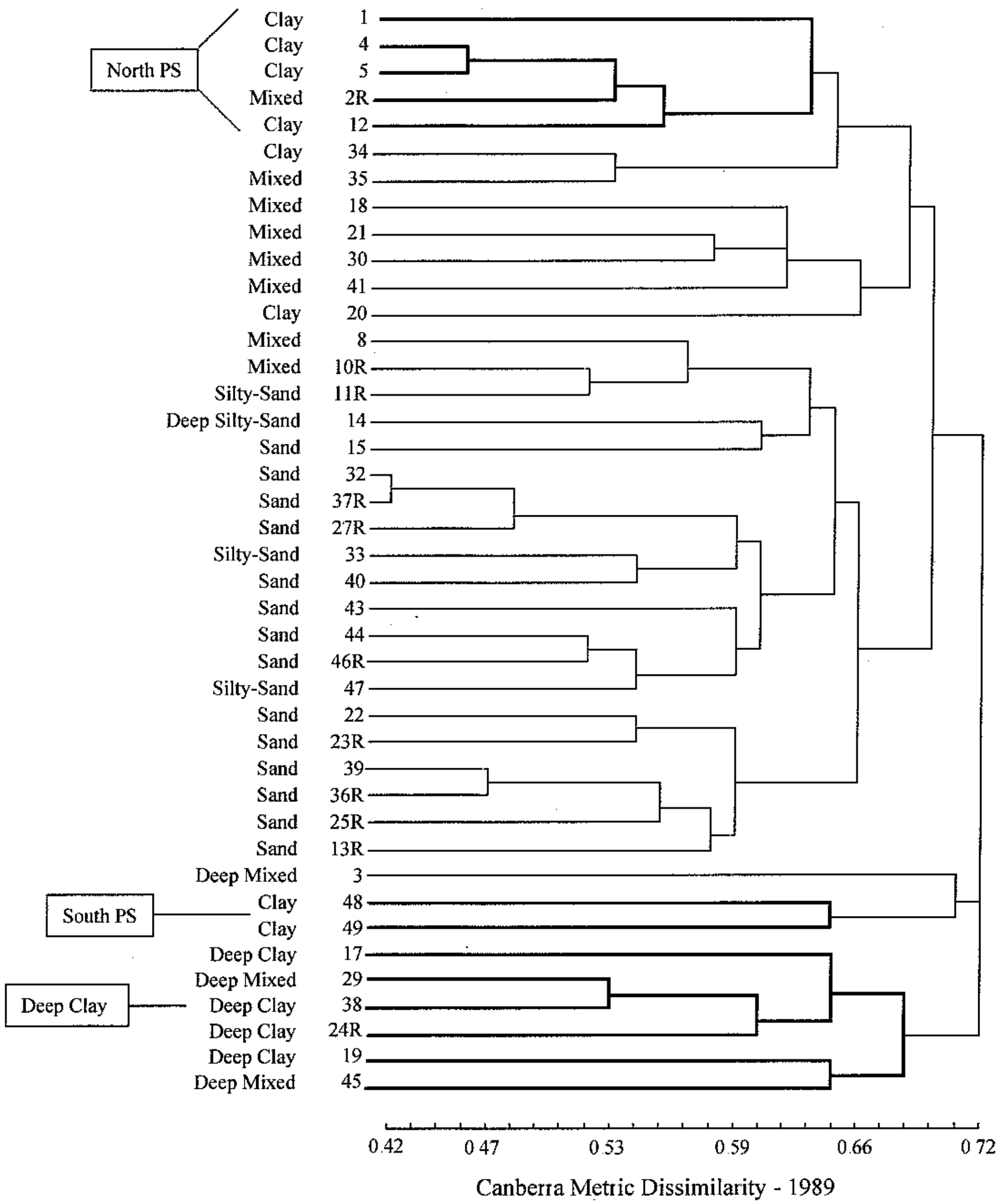



Figure 8. Classification analysis of stations for 1989. Indicated in the dendogram is the station number and the sediment type at each station. The resemblance scale is in terms of dissimilarity; short connections in the dendogram indicate a higher similarity than longer connections.

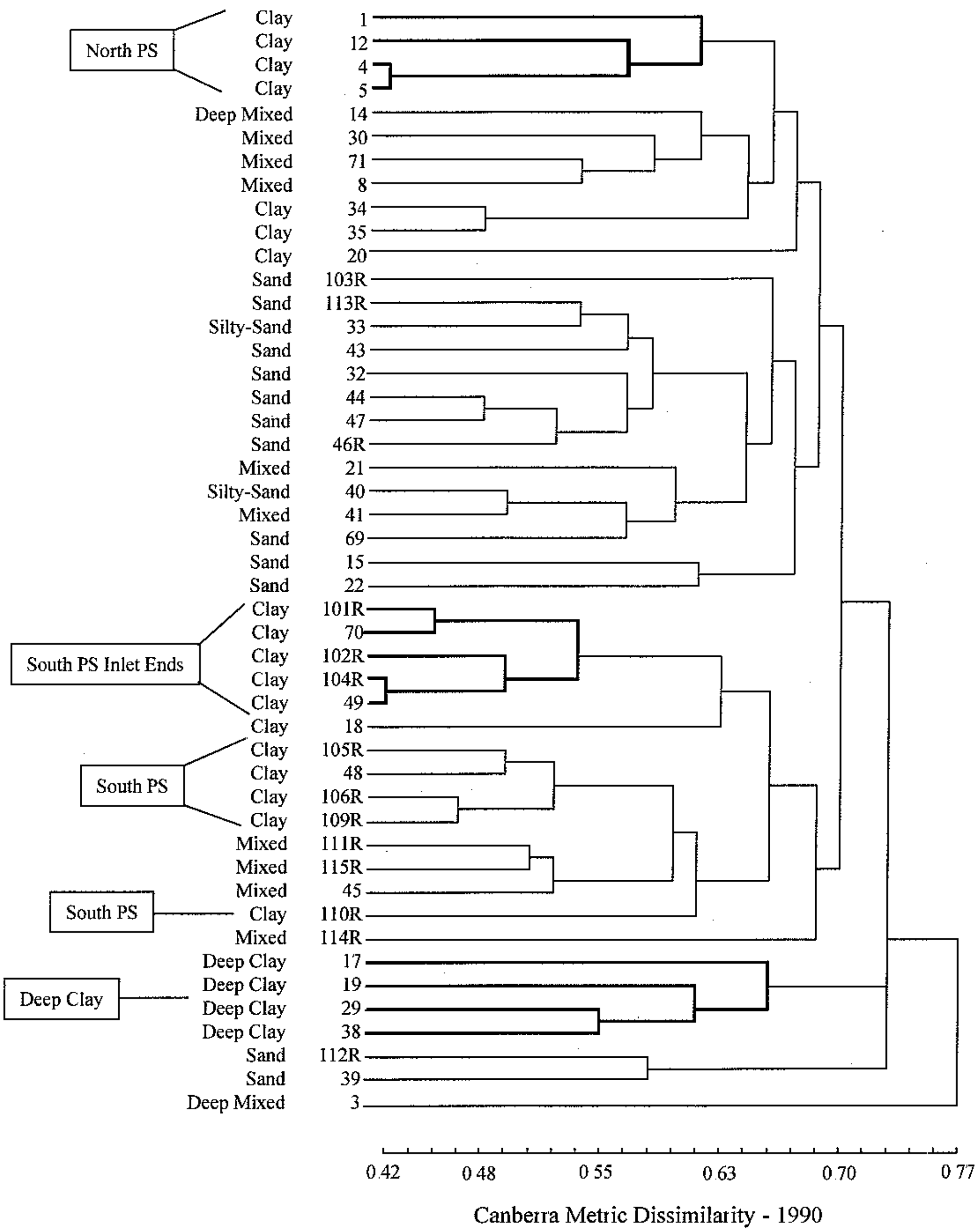



Figure 9. Classification analysis of stations for 1990. Indicated in the dendogram is the station number and the sediment type at each station. The resemblance scale is in terms of dissimilarity; short connections in the dendogram indicate a higher similarity than longer connections.

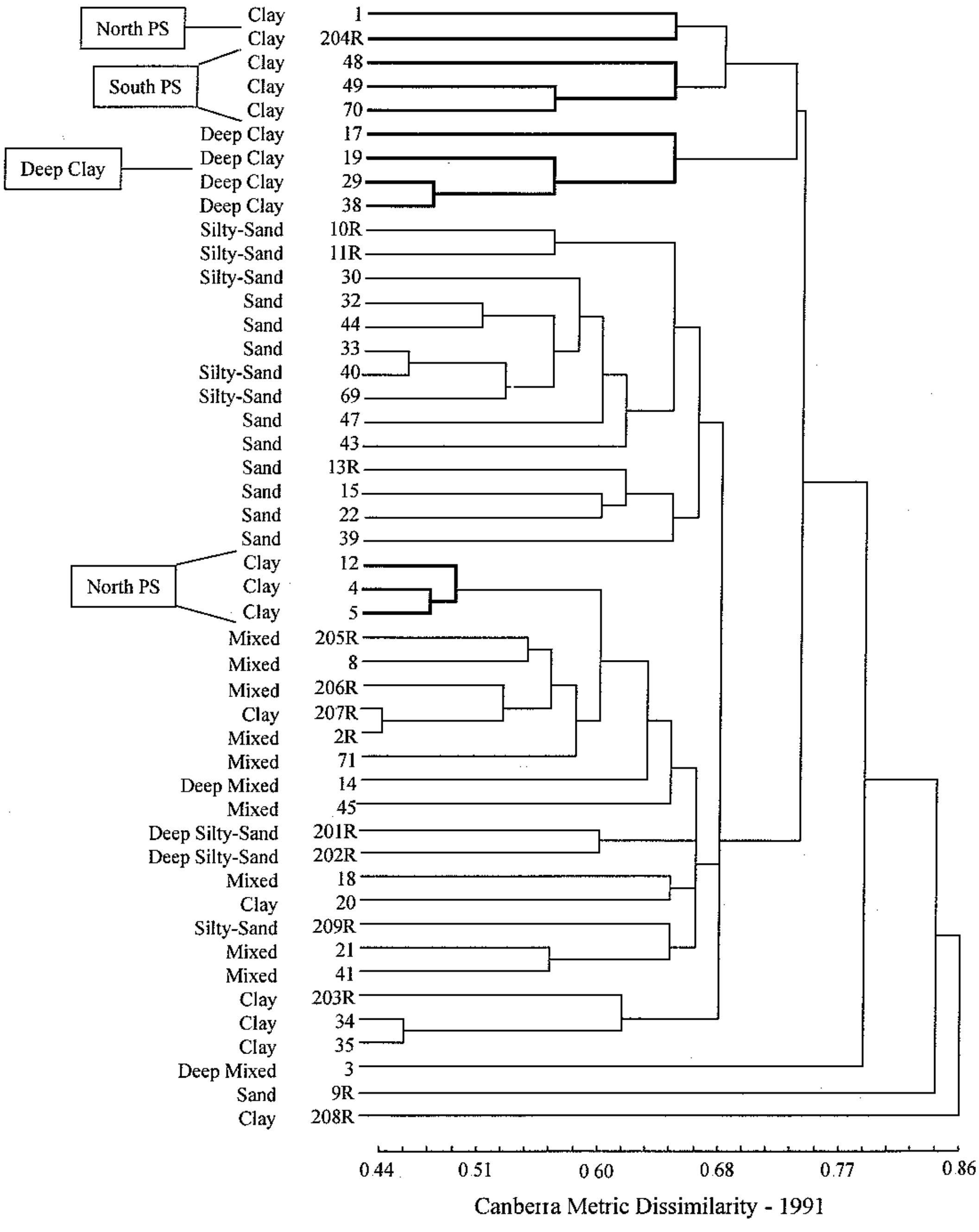



Figure 10. Classification analysis of stations for 1991. Indicated in the dendogram is the station number and the sediment type at each station. The resemblance scale is in terms of dissimilarity; short connections in the dendogram indicate a higher similarity than longer connections.

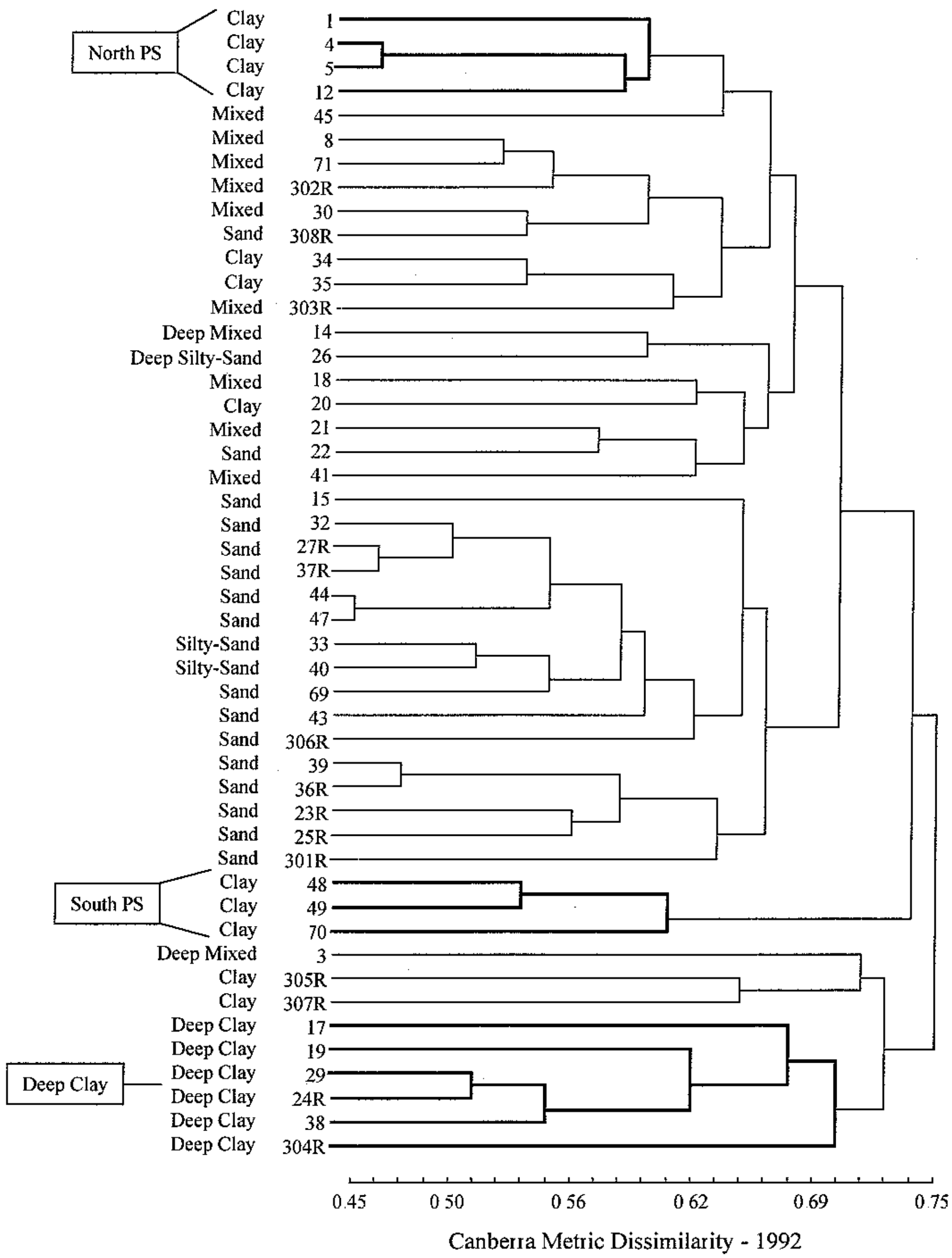



Figure 11. Classification analysis of stations for 1992. Indicated in the dendogram is the station number and the sediment type at each station. The resemblance scale is in terms of dissimilarity; short connections in the dendogram indicate a higher similarity than longer connections.

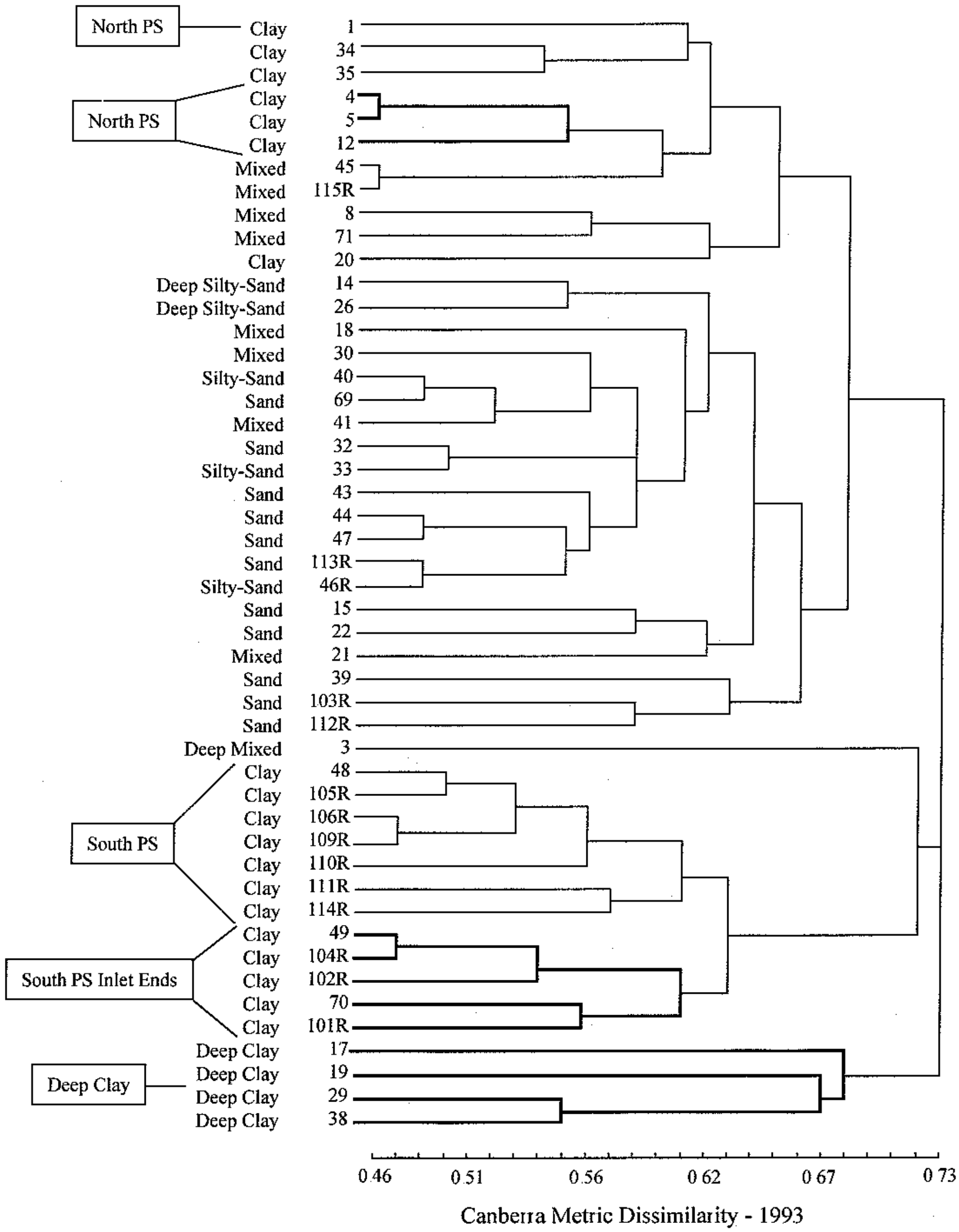



Figure 12. Classification analysis of stations for 1993. Indicated in the dendogram is the station number and the sediment type at each station. The resemblance scale is in terms of dissimilarity; short connections in the dendogram indicate a higher similarity than longer connections.

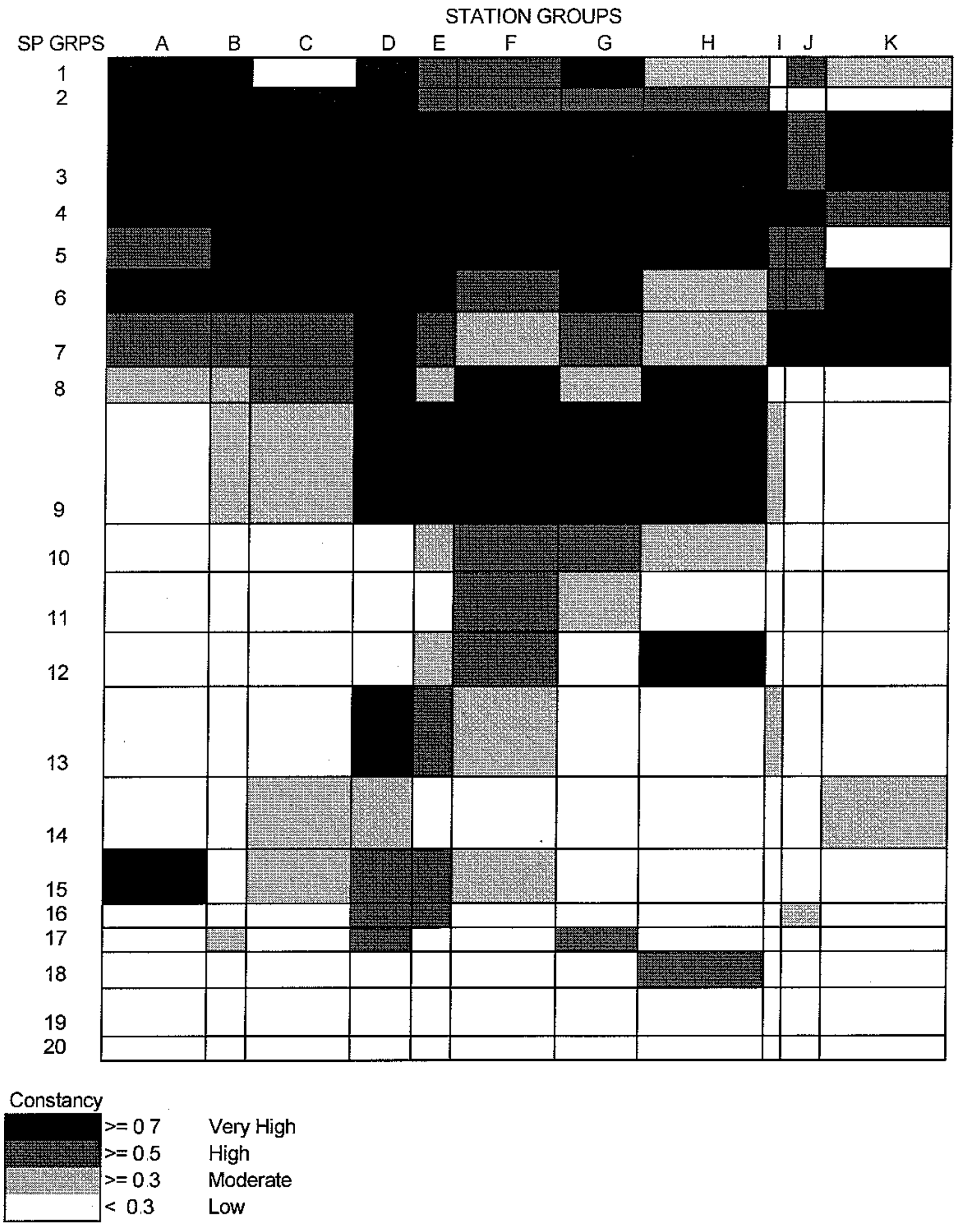



Figure 13. Nodal analysis of constancy for 1989. The width of the rows and columns in the diagram is proportional to the number of stations and species in each group. The species and station groups identified by classification analysis of MSMP stations are listed in Appendix D.

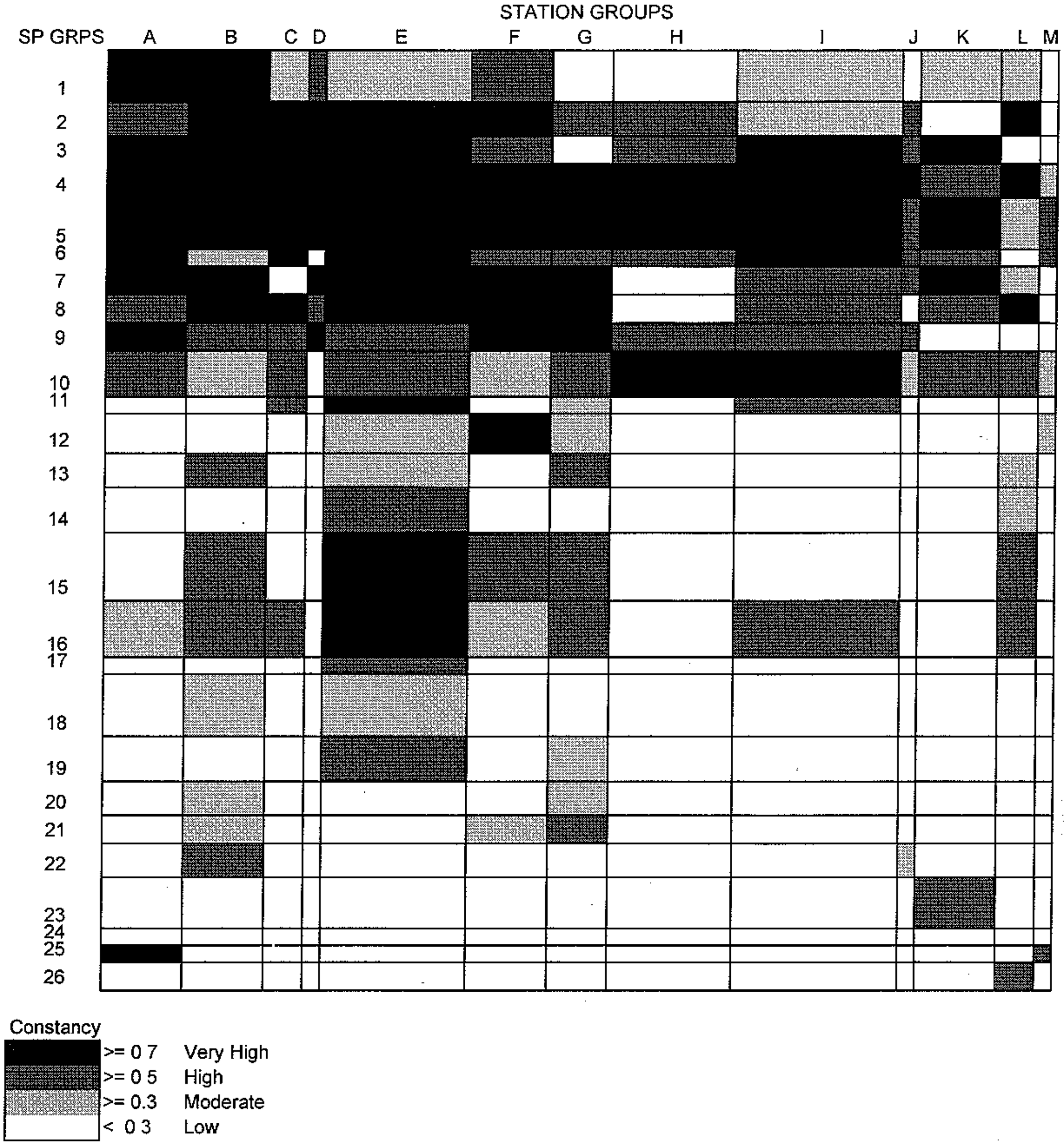



Figure 14. Nodal analysis of constancy for 1990. The width of the rows and columns in the diagram is proportional to the number of stations and species in each group. The species and station groups identified by classification analysis of MSMP stations are listed in Appendix D.

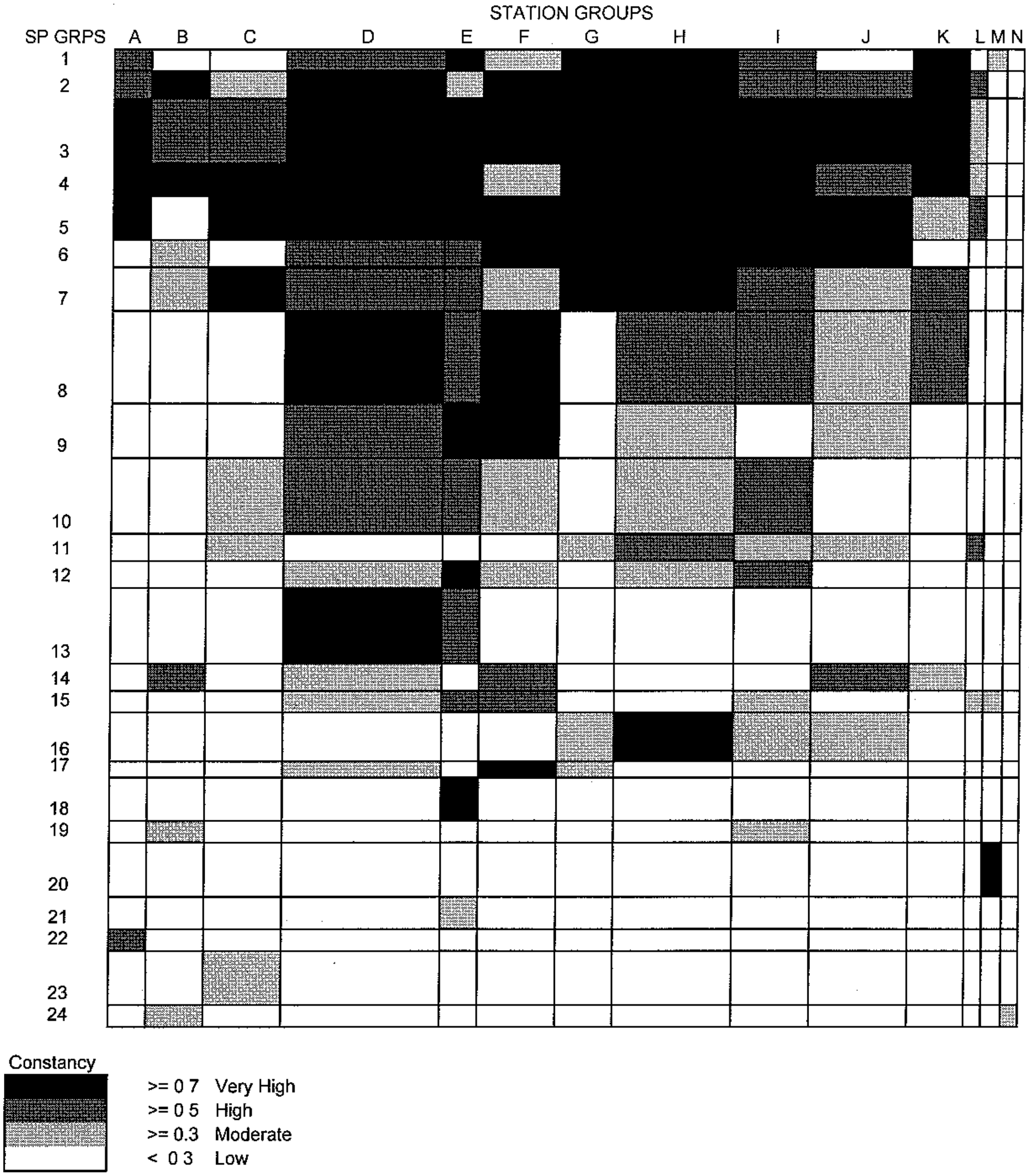



Figure 15. Nodal analysis of constancy for 1991. The width of the rows and columns in the diagram is proportional to the number of stations and species in each group. The species and station groups identified by classification analysis of MSMP stations are listed in Appendix D.

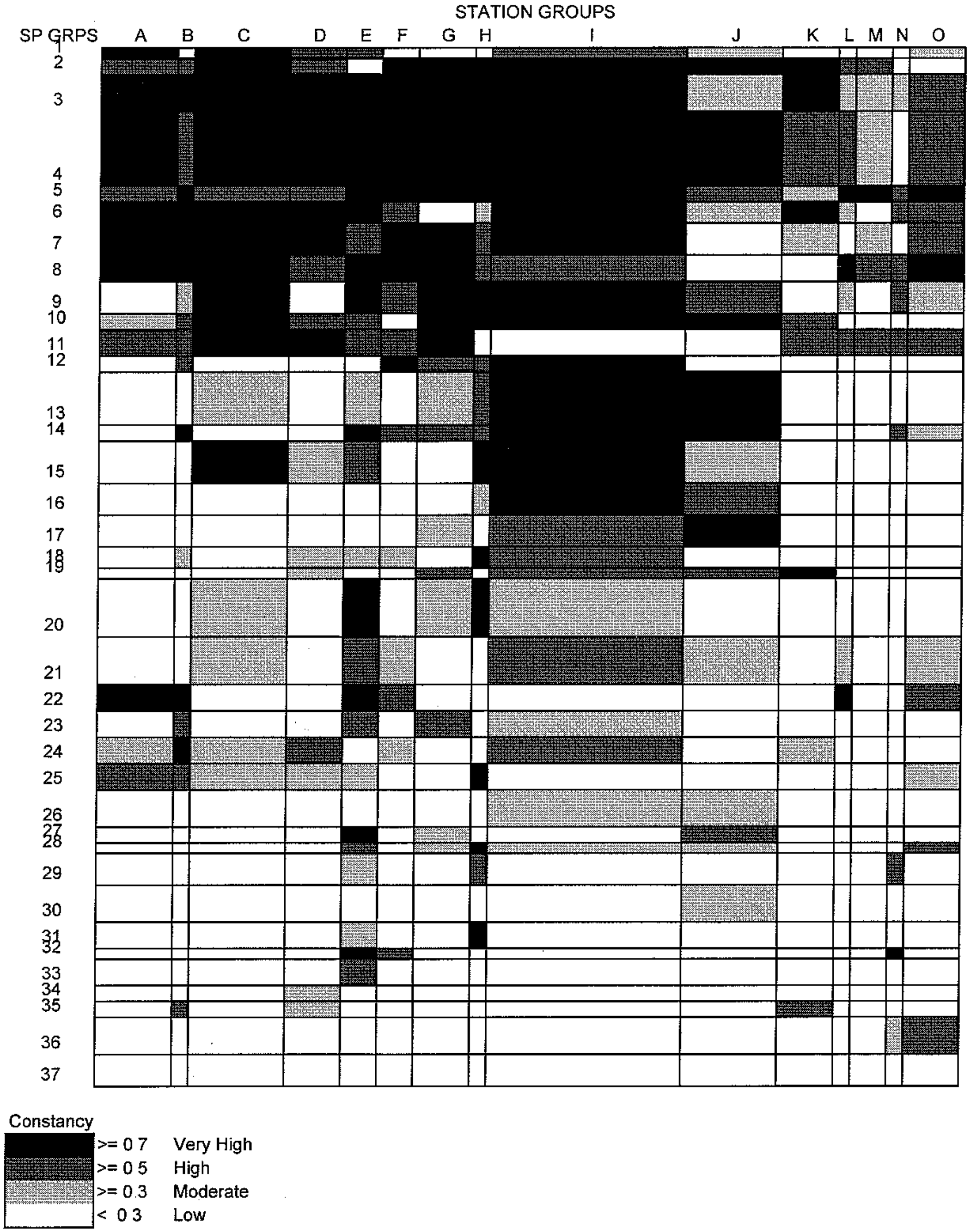



Figure 16. Nodal analysis of constancy for 1992. The width of the rows and columns in the diagram is proportional to the number of stations and species in each group. The species and station groups identified by classification analysis of MSMP stations are listed in Appendix D.

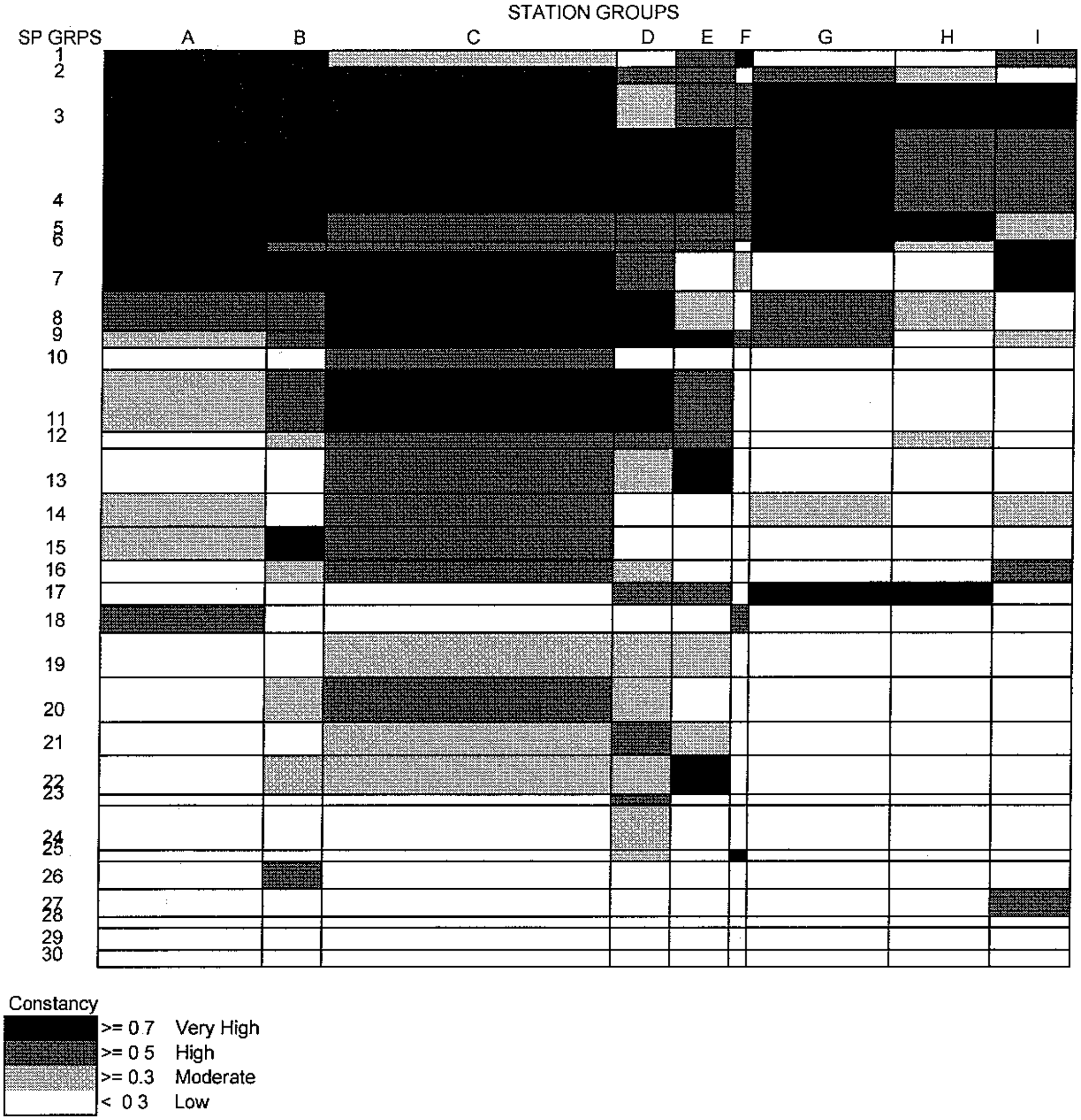



Figure 17. Nodal analysis of constancy for 1993. The width of the rows and columns in the diagram is proportional to the number of stations and species in each group. The species and station groups identified by classification analysis of MSMP stations are listed in Appendix D.

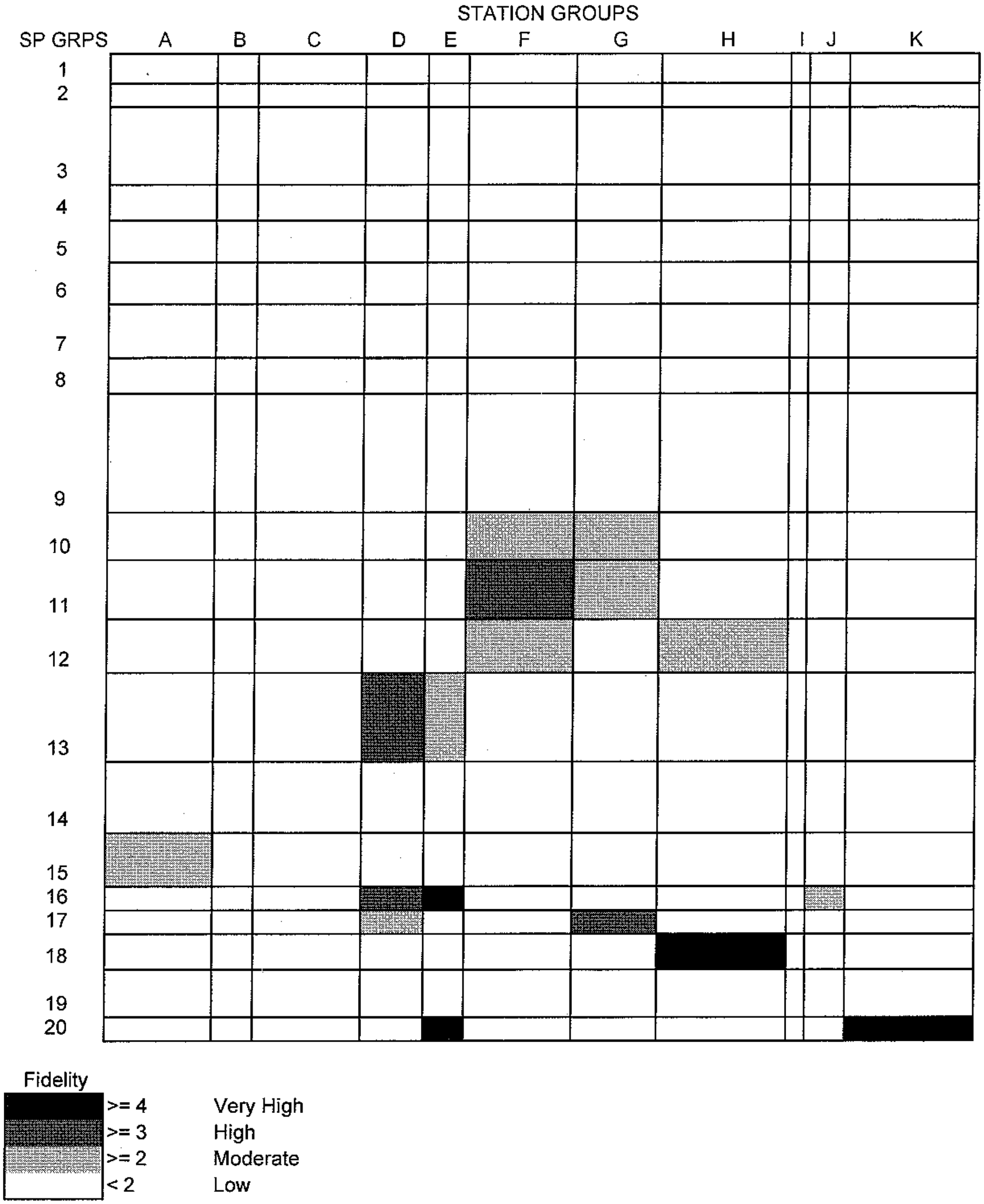



Figure 18. Nodal analysis of fidelity for 1989. See Appendix D for a list of species and station groups.

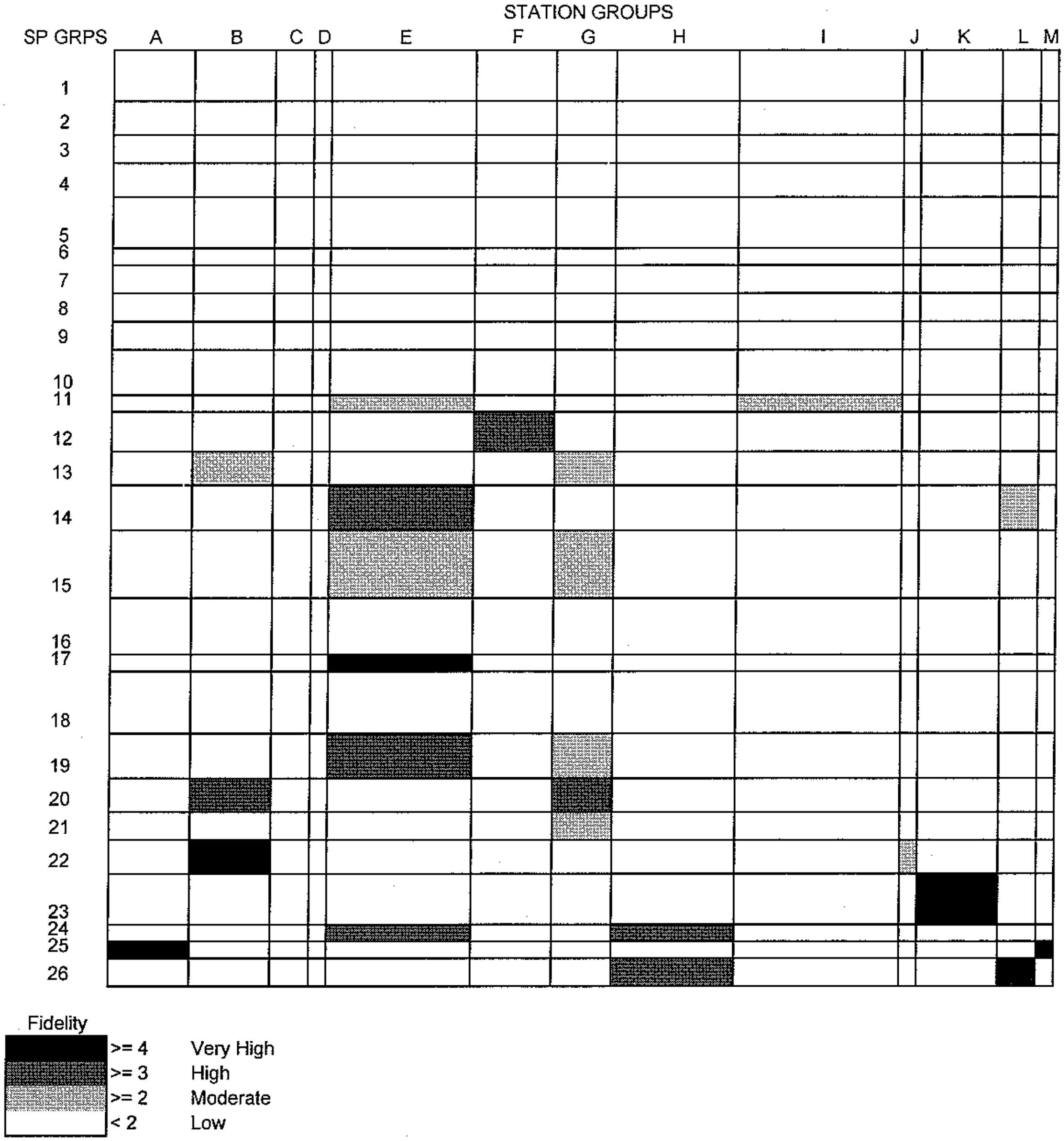



Figure 19. Nodal analysis of fidelity for 1990. See Appendix D for a list of species and station groups.

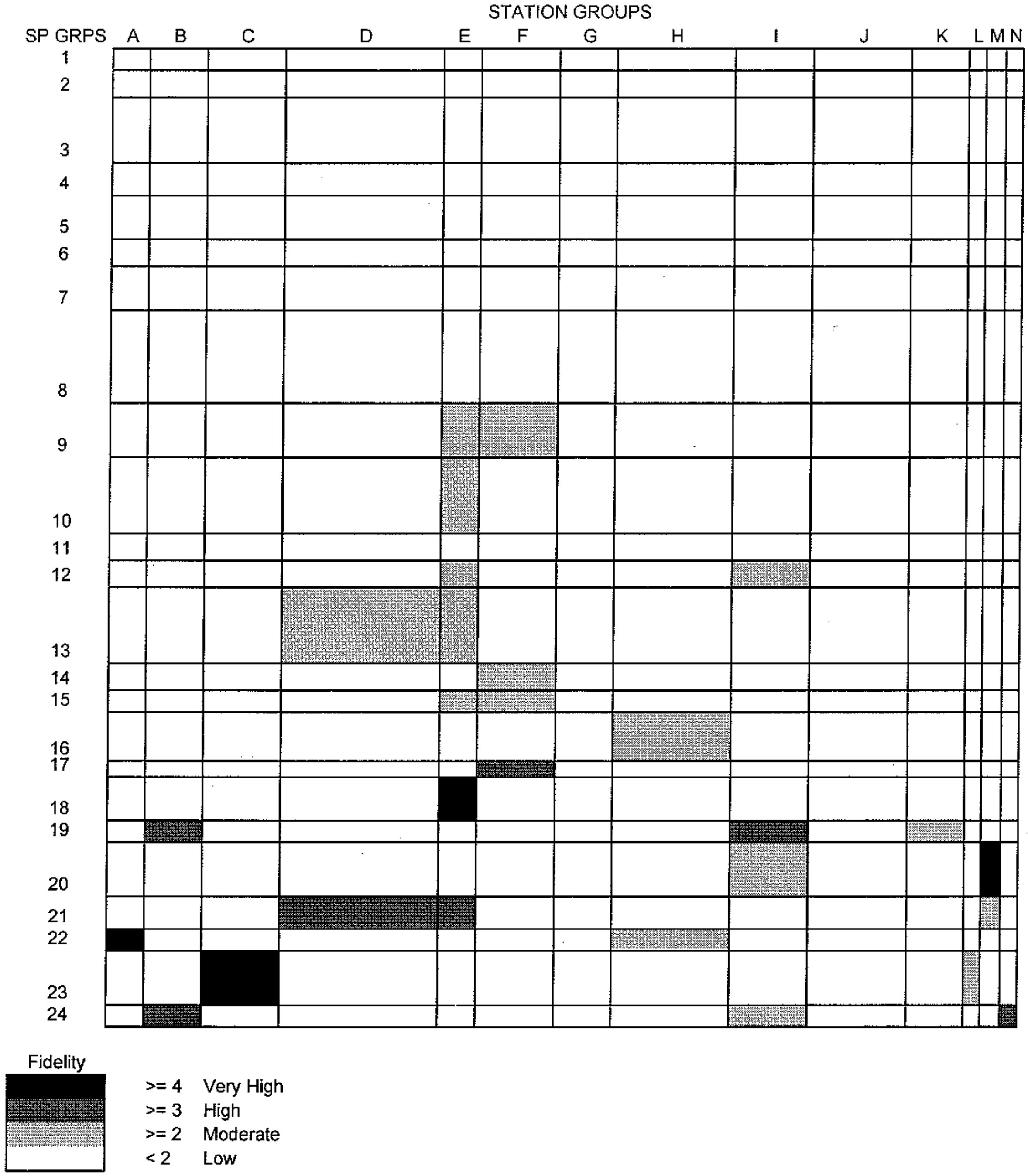



Figure 20. Nodal analysis of fidelity for 1991. See Appendix D for a list of species and station groups.

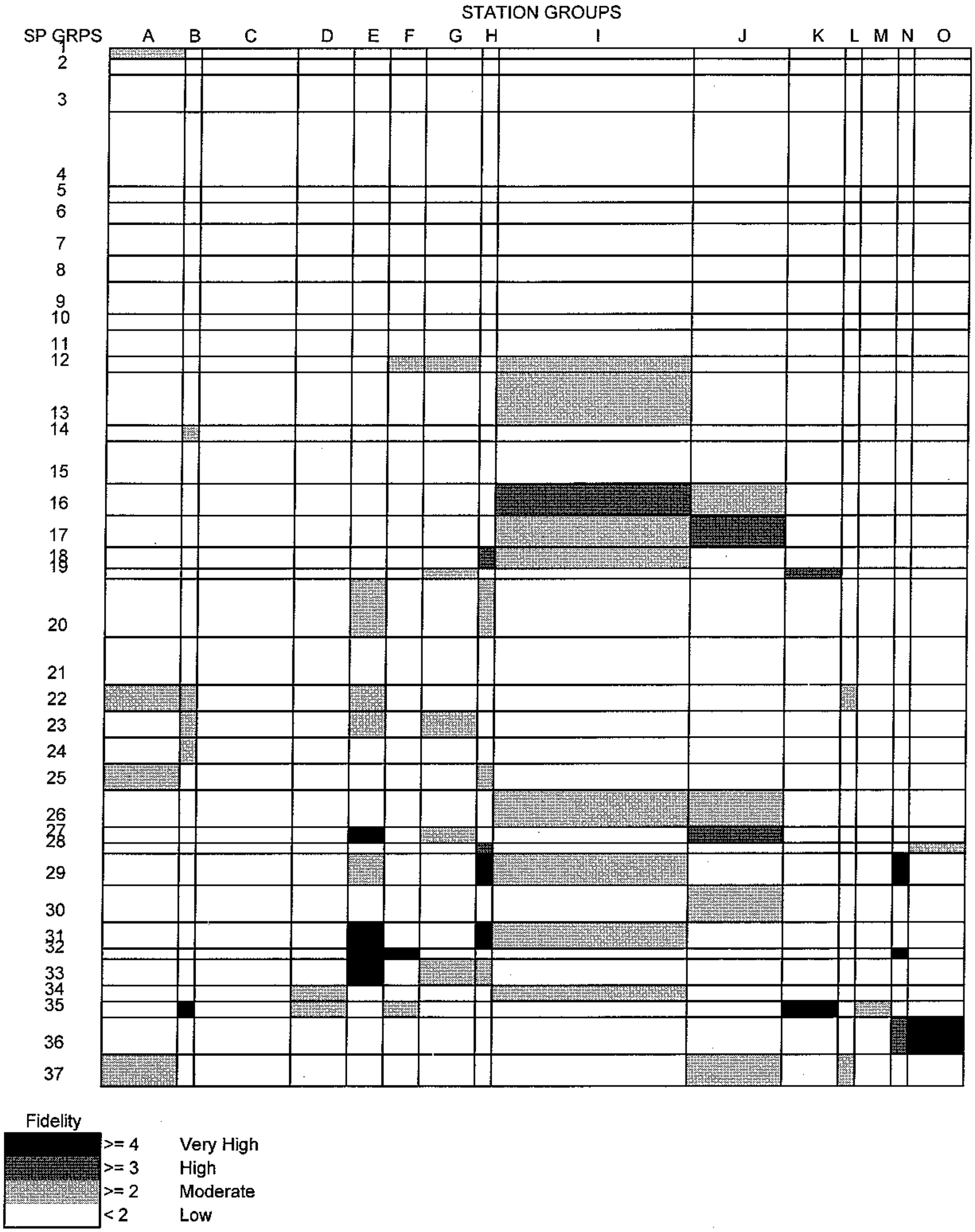



Figure 21. Nodal analysis of fidelity for 1992. See Appendix D for a list of species and station groups.

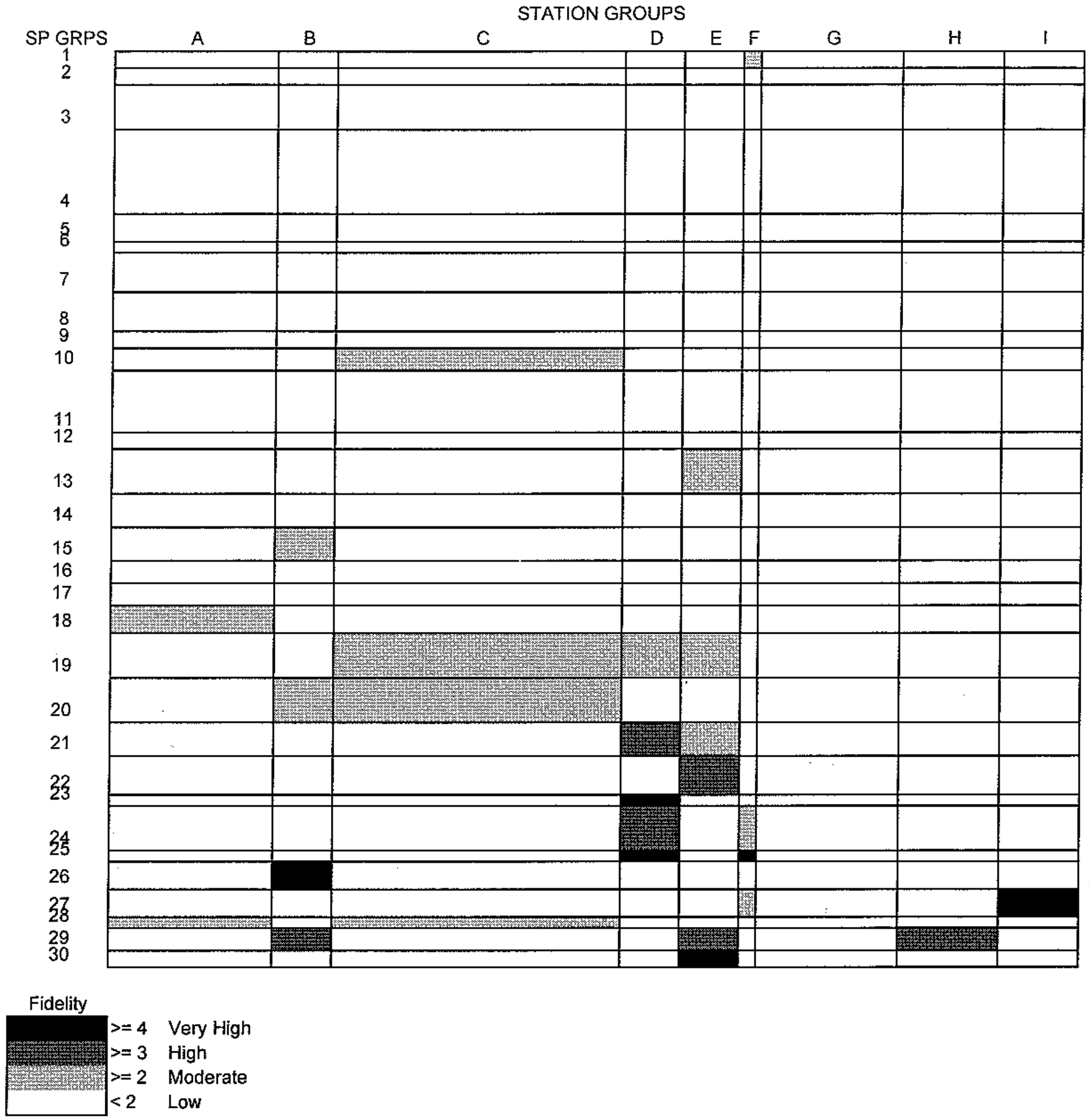



Figure 22. Nodal analysis of fidelity for 1993. See Appendix D for a list of species and station groups.

Table 10. Species used in the classification analysis of MSMP stations categorized according to the type of substrate in which they were numerically dominant. The substrate range in which the species (with two or more individuals) was found is indicated in parenthesis. Also, indicated in parenthesis is whether the species was predominately or strictly found in shallow (< 80 m) or deep (> 80 m) water. See text (Results: Sediment Characteristics) for definition of sediment types. all = all sediment types, cl =clay, de =deep, mx = mixed, sa =sand, sh = shallow, si = silt.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| **All Substrates** | |
| *Alvania compacta* | gastropoda |
| *Ampelisca careyi* | amphipoda |
| *Ampelisca hancocki* | amphipoda |
| *Ampelisca lobata* (sh) | amphipoda |
| *Ampelisca* sp. | amphipoda |
| *Ampharete labrops* (sh) | polychaeta |
| *Amphiodia urtica/periercta* | echinodermata |
| Aoridae/Corophiidae (sh) | amphipoda |
| *Aphelochaeta* sp. | polychaeta |
| *Aricidea (Acmira) catherinae/lopezi* | polychaeta |
| *Aricidea (Allia) ramosa* (sh) | polychaeta |
| *Axinopsida serricata* | bivalvia |
| *Barantolla americana* | polychaeta |
| *Cirratulus cirratus* | polychaeta |
| *Compsomyax subdiaphana* | bivalvia |
| *Corophium* sp. (sh) | amphipoda |
| *Cucumaria piperata* (sa+cl) | echinodermata |
| Cylichnidae | gastropoda |
| *Diastylis* sp. | cumacea |
| *Eteone* sp. | polychaeta |
| *Eudorellopsis longirostris* | cumacea |
| *Eumida longicornuta* | polychaeta |
| *Euphilomedes producta* | ostracoda |
| *Glycera nana* | polychaeta |
| *Glycinde picta* | polychaeta |
| *Glycinde* sp. | polychaeta |
| *Goniada brunnea* | polychaeta |
| *Harpiniopsis/Heterophoxus* | amphipoda |
| *Heterophoxus* sp. | amphipoda |
| *Laonice cirrata* | polychaeta |
| *Leitoscoloplos pugettensis* | polychaeta |
| *Lepidasthenia berkeleyae* | polychaeta |
| *Levinsenia gracilis* | polychaeta |
| Lineidae | nemertina |
| *Lirobittium attenuatum* | gastropoda |
| *Lumbrineris californiensis/cruzensis* | polychaeta |

Table 10. Continued.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| *Lumbrineris cruzensis* | polychaeta |
| *Lumbrineris luti* | polychaeta |
| *Lyonsia californica* | bivalvia |
| *Macoma carlottensis* | bivalvia |
| *Macoma nasuta* | bivalvia |
| *Macoma* sp. | bivalvia |
| *Macoma yoldiformis* (sh) | bivalvia |
| *Malmgreniella* sp. | polychaeta |
| *Mediomastus* sp. | polychaeta |
| *Melita desdichada* | amphipoda |
| *Monoculodes* sp. | amphipoda |
| *Myriochele oculata* | polychaeta |
| *Myriochele* sp | polychaeta |
| *Mysella tumida* | bivalvia |
| *Nassarius mendicus* (sh) | gastropoda |
| Nemertina | |
| *Nephtys discors* | polychaeta |
| *Nephtys signifera* | polychaeta |
| *Nereis procera* (sh) | polychaeta |
| *Nitidella/Mitrella* | gastropoda |
| *Nucula tenuis* | bivalvia |
| *Nuculana minuta* | bivalvia |
| *Odostomia* sp. | gastropoda |
| Oligochaeta | |
| *Onuphis elegans* | polychaeta |
| *Onuphis iridescens* | polychaeta |
| *Ophiodromus pugettensis* | polychaeta |
| *Owenia fusiformis* | polychaeta |
| *Paraprionospio pinnata* | polychaeta |
| *Parvilucina tenuisculpta* | bivalvia |
| *Pectinaria californiensis* | polychaeta |
| *Pholoe minuta* | polychaeta |
| *Photis* sp. | amphipoda |
| *Phyllochaetopterus prolifica* | polychaeta |
| *Pilargis maculata* | polychaeta |
| *Pinnixa occidentalis/schmitti* | decapoda |
| *Pista bansei* | polychaeta |
| *Pista wui* | polychaeta |
| *Polycirrus* sp. | polychaeta |
| *Polydora socialis* | polychaeta |
| *Polydora socialis/cardalia* | polychaeta |
| *Praxillella gracilis* | polychaeta |
| *Praxillella pacifica* | polychaeta |
| *Praxillella* sp. | polychaeta |
| *Prionospio (Minuspio) lighti* | polychaeta |
| *Prionospio jubata* | polychaeta |
| *Protomedeia articulata* | amphipoda |
| *Protomedeia penates/prudens* | amphipoda |
| *Protomedeia prudens* | amphipoda |
| *Protomedeia* sp | amphipoda |

Table 10. Continued.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| *Psephidia lordi* | bivalvia |
| *Rictaxis punctocaelatus* (sh) | gastropoda |
| *Scalibregma inflatum* | polychaeta |
| Scaphopoda | |
| *Spiophanes berkeleyorum* | polychaeta |
| *Terebellides californica* | polychaeta |
| *Terebellides reishi* | polychaeta |
| *Terebellides* sp. | polychaeta |
| *Thyasira flexuosa* | bivalvia |
| *Thysanocardia nigra* | sipuncula |
| *Tubulanus* sp. | nemertina |
| *Turbonilla* sp. | gastropoda |
| *Yoldia hyperborea/scissurata* | bivalvia |
| *Yoldia scissurata* | bivalvia |
| **Sand** | |
| Astartidae (sh) | gastropoda |
| *Cardiomya* sp. (si) | bivalvia |
| *Clymenura gracilis* (sh) | polychaeta |
| *Corophium crassicorne* (sh) | amphipoda |
| *Crenella decussata* | bivalvia |
| *Edwardsia sipunculoides* (si) | cnidaria |
| *Eulima/Balcis* (sh) | gastropoda |
| *Eyakia robusta* (mx) | amphipoda |
| *Foxiphalus obtusidens* (sh) | amphipoda |
| *Hemipodus borealis* (sh) | polychaeta |
| *Hesionura coineaui* (sh) | polychaeta |
| *Heteropodarke heteromorpha* (sh) | polychaeta |
| *Hippomedon* cf *coecus* (sh) (si) | amphipoda |
| *Kurtzia arteaga* (sh) | gastropoda |
| *Lamprops quadriplicata* (sh) | cumacea |
| *Magelona sacculata* (sh) | polychaeta |
| *Micropodarke dubia* (sh) | polychaeta |
| *Nebalia* sp. (sh) | branchiopoda |
| *Neosabellaria cementarium* (sh) (all) | polychaeta |
| *Olivella baetica* (sh) | gastropoda |
| *Pagurus* sp. (sh) (all) | decapoda |
| *Pentamera* sp. (sh) (si) | echinodermata |
| *Polygordius* sp. (sh) | annelida |
| *Rhepoxynius abronius* (sh) (si+mx) | amphipoda |
| *Rhepoxynius abronius/variatus* (sh) (mx) | amphipoda |
| *Scoloplos armiger* (sh) | polychaeta |
| *Tellina nuculoides* (sh) | bivalvia |
| **Sand and Silt** | |
| *Ampelisca pugetica* (sh) (all) | amphipoda |
| *Apistobranchus ornatus* (sh) | polychaeta |
| *Boccardia pugettensis* (sh) | polychaeta |
| *Caulleriella* sp. (sh) | polychaeta |
| *Caulleriella* sp. A (sh) | polychaeta |

Table 10. Continued.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| *Echiurus* sp. (de) (si only) | echiurida |
| *Eulalia (Eulalia) bilineata* | polychaeta |
| *Megacrenella columbiana* (mx) | bivalvia |
| *Mesochaetopterus taylori* (sh) (mx) | polychaeta |
| *Nicomache personata* (sh) | polychaeta |
| *Notomastus latericeus* (sh) | polychaeta |
| *Ophiura sarsi* (de) (si only) | echinodermata |
| *Pholoides asperus* (sh) (all) | polychaeta |
| *Photis lacia* | amphipoda |
| *Polydora* sp. A (si only) | polychaeta |
| *Rutiderma lomae* (sh) (all) | ostracoda |
| *Spiophanes bombyx* | polychaeta |
| *Syllis (Ehlersia) heterochaeta/hyperioni* | polychaeta |
| | |
| **Sand to Mixed** | |
| *Adontorhina cyclia* (all) | bivalvia |
| *Amage anops* (all) | polychaeta |
| *Amphipholis* sp. (all) | echinodermata |
| *Amphipholis squamata* | echinodermata |
| *Anarthruridae/Leptognathiidae* (all) | tanaidacea |
| *Anobothrus gracilis* | polychaeta |
| *Artacama coniferi* (sh) (all) | polychaeta |
| *Asabellides lineata* (all) | polychaeta |
| *Boccardia* sp. (sh) | polychaeta |
| *Boccardiella hamata* | polychaeta |
| *Byblis millsi* | amphipoda |
| *Chaetozone* sp. (all) | polychaeta |
| *Cistenides granulata* (all) | polychaeta |
| *Cyclocardia ventricosa* (sa+mx only) | bivalvia |
| Cylindroleberididae | ostracoda |
| *Decamastus gracilis* (all) | polychaeta |
| *Delectopecten vancouverensis* | bivalvia |
| *Diopatra ornata* (all) | polychaeta |
| *Dorvillea (D.) pseudorubrovittata* (all) | polychaeta |
| *Drilonereis falcata minor* | polychaeta |
| *Eualus pusiolus* (sh) | polychaeta |
| *Euclymene* sp. (all) | polychaeta |
| *Euclymene zonalis* (all) | polychaeta |
| *Euclymeninae* (all) | polychaeta |
| *Euphilomedes carcharodonta* (sh) (all) | ostracoda |
| *Exogone (E.) lourei* | polychaeta |
| *Exogone dwisula* | polychaeta |
| *Eyakia/Paraphoxus/Rhepoxynius* (all) | amphipoda |
| *Foxiphalus similis/cognatus* (sh) (all) | amphipoda |
| *Glycinde armigera* (all) | polychaeta |
| *Lanassa* sp. (sh) (all) | polychaeta |
| *Lanassa venusta* (sh) (all) | polychaeta |
| *Leptochelia savignyi* (sh) (all) | tanaidacea |
| *Leptosynapta transgressor* (all) | echinodermata |
| *Lucinoma annulata* (all) | bivalvia |

Table 10. Continued.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| *Lumbrineris californiensis* (all) | polychaeta |
| *Macoma calcarea* | bivalvia |
| *Macoma calcarea/elimata* (all) | bivalvia |
| *Macoma elimata* (all) | bivalvia |
| *Magelona longicornis* (all) | polychaeta |
| *Musculus* sp. (sh) (sa+mx only) | bivalvia |
| *Myriochele heeri* (all) | polychaeta |
| *Natica clausa* (de) | gastropoda |
| *Nemocardium centifilosum* (all) | bivalvia |
| *Neotrypaea* sp. (all) | decapoda |
| *Notomastus* sp. (all) | polychaeta |
| *Notomastus tenuis* (all) | polychaeta |
| *Odontosyllis phosphorea* | polychaeta |
| *Ophelina acuminata* (all) | polychaeta |
| *Orchomene pacifica* | amphipoda |
| *Parvamussium alaskensis* (sa+mx only) | bivalvia |
| *Pentamera pseudocalcigera* | echinodermata |
| *Petaloproctus tenuis* (sa+mx only) | polychaeta |
| *Pherusa plumosa* (sa+mx only) | polychaeta |
| Phoronida (all) | |
| *Photis brevipes* (sa+mx only) | amphipoda |
| *Phyllodoce* sp. (all) | polychaeta |
| *Platynereis bicanaliculata* (sh) (all) | polychaeta |
| *Polinices pallidus* | gastropoda |
| *Polydora cardalia* (sh) (sa+mx only) | polychaeta |
| *Prionospio (Minuspio) multibranchiata* | polychaeta |
| *Protothaca staminea* (all) | bivalvia |
| *Rhepoxynius* cf *barnardi* | amphipoda |
| *Rhepoxynius variatus* | amphipoda |
| *Rhodine bitorquata* (sh) | polychaeta |
| Sipuncula (all) | |
| *Solen sicarius* (sh) | bivalvia |
| *Spiochaetopterus costarum* (all) | polychaeta |
| *Sthenelais tertiaglabra* (sh) | polychaeta |
| *Streblosoma bairdi* (sh) | polychaeta |
| *Syllis (Typosyllis) harti* (sh) (all) | polychaeta |
| *Synchelidium shoemakeri* (sh) | amphipoda |
| *Synchelidium* sp. (sh) | amphipoda |
| *Tellina modesta* (sh) | bivalvia |
| *Tellina* sp. (sh) | bivalvia |
| *Westwoodilla caecula* (all) | amphipoda |
| | |
| **Silt to Clay** | |
| *Ampelisca unsocalae* | amphipoda |
| *Ampharete acutifrons* (all) | polychaeta |
| *Ampharete* sp. (all) | polychaeta |
| Ceriantharia | cnidaria |
| *Clinocardium* sp. (sh) (mx only) | bivalvia |
| *Cossura* sp. (all) | polychaeta |
| *Euchone incolor* (sh) | polychaeta |

Table 10. Concluded.

| Species/ Taxon | Order, Class or Phylum |
|---|---|
| *Heteromastus filobranchus* (all) | polychaeta |
| *Macroclymene* sp. | polychaeta |
| *Maldane sarsi* (all) | polychaeta |
| *Melinna* sp. (all) | polychaeta |
| *Orchomene* sp. (all) | amphipoda |
| *Pandora* sp. (all) | bivalvia |
| *Pista brevibranchiata* | polychaeta |
| *Sternaspis scutata* (all) | polychaeta |
| *Trochochaeta multisetosa* (mx only) | polychaeta |
| *Yoldia hyperborea* | bivalvia |
| **Mixed and Clay** | |
| *Acila castrensis* (all) | bivalvia |
| *Armandia/Ophelina* (all) | polychaeta |
| *Brada sachalina* (de) (si) | polychaeta |
| *Bylgides macrolepidus* (de) | polychaeta |
| *Crangon alaskensis* | decapoda |
| *Dentalium* sp. (all) | scaphopoda |
| *Eudorella pacifica* (all) | cumacea |
| *Harpiniopsis fulgens* | amphipoda |
| *Heteromastus* sp. (all) | polychaeta |
| *Nephtys cornuta* (all) | polychaeta |
| *Pachycerianthus fimbriatus* | cnidaria |
| *Podarkeopsis glabrus* (all) | polychaeta |
| *Polydora brachycephala* (si) | polychaeta |
| *Polydora* sp. 1 (sh) (all) | polychaeta |
| *Protomedeia grandimana* (all) | amphipoda |
| *Sigambra tentaculata* (all) | polychaeta |
| **Clay** | |
| *Artacamella hancocki* (de) (si+cl) | polychaeta |
| *Bathymedon pumilis* (de) | amphipoda |
| *Brisaster latifrons* (de) | echinodermata |
| *Chaetoderma* sp. (de) (all) | aplacophora |
| *Cirrophorus branchiatus* (de) | polychaeta |
| *Dorvillea (Schistomeringos) annulata* (de) | polychaeta |
| *Eudorellopsis integra* (de) | cumacea |
| *Gattyana treadwelli* | polychaeta |
| *Maera loveni* (de) | amphipoda |
| *Molpadia intermedia* (de) | echinodermata |
| *Nephtys punctata* (de) | polychaeta |
| *Paraphoxus oculatus* (de) (all) | amphipoda |
| *Sarsiella* sp. (sh) | ostracoda |
| Sarsiellidae (sh) | ostracoda |
| *Stylatula elongata* (sh) | cnidaria |
| *Yoldia thraciaeformis* (de) (si+mx) | bivalvia |

Table 11. Fifteen dominant species in Puget Sound by sediment type. Rank values were obtained by assigning rank scores to the ten most abundant species in each station, summing scores over all years, averaging by year, and summing averages over all stations in a group. Maximum possible rank values are shown for each sediment type. Rank values are a reflection of the frequency with which a species is present in the community.

| Species | Rank Value | | Rank Value |
|---|---|---|---|
| **Sand** | | **Mixed** | |
| | max = 300 | | max = 160 |
| *Euphilomedes carcharodonta* | 153.1 | *Axinopsida serricata* | 60.3 |
| *Prionospio jubata* | 141.3 | *Aphelochaeta* sp | 51.9 |
| *Axinopsida serricata* | 64.9 | *Eudorella pacifica* | 49.7 |
| *Rhepoxynius abronius/variatus* | 60.0 | *Amphiodia urtica/periercta* | 40.0 |
| *Amphiodia urtica/periercta* | 57.3 | *Euphilomedes carcharodonta* | 37.9 |
| *Phyllochaetopterus prolifica* | 48.8 | *Lumbrineris luti* | 32.5 |
| *Mediomastus* sp. | 48.7 | *Prionospio jubata* | 32.3 |
| *Spiochaetopterus costarum* | 48.6 | *Psephidia lordi* | 31.1 |
| *Euphilomedes producta* | 46.7 | *Levinsenia gracilis* | 31.0 |
| *Alvania compacta* | 40.1 | *Aricidea ramosa* | 28.5 |
| *Psephidia lordi* | 37.6 | *Macoma carlottensis* | 28.0 |
| *Leitoscoloplos pugettensis* | 34.7 | *Harpinopsis/Heterophoxus* sp | 23.6 |
| *Macoma* sp. | 28.6 | *Parvilucina tenuisculpta* | 23.6 |
| *Lumbrineris californiensis/cruzensis* | 28.1 | *Euphilomedes producta* | 23.0 |
| *Lumbrineris luti* | 26.3 | *Phyllochaetopterus prolifica* | 23.0 |
| **Clay** | | **Deep Clay** | |
| | max = 250 | | max = 70 |
| *Amphiodia urtica/periercta* | 99.5 | *Macoma carlottensis* | 35.6 |
| *Eudorella pacifica* | 93.5 | *Axinopsida serricata* | 34.9 |
| *Sigambra tentaculata* | 87.5 | *Pectinaria californiensis* | 33.8 |
| *Pinnixa occidentalis/schmitti* | 82.8 | *Eudorella pacifica* | 31.5 |
| *Paraprionospio pinnata* | 75.0 | *Euphilomedes producta* | 25.6 |
| *Pholoe minuta* | 51.9 | *Harpinopsis/Heterophoxus* sp. | 25.5 |
| *Aphelochaeta* sp. | 51.3 | *Levinsenia gracilis* | 18.1 |
| *Harpinopsis/Heterophoxus* sp. | 48.8 | *Chaetoderma* sp. | 17.8 |
| *Nephtys cornuta* | 47.9 | *Cylichnidae* | 14.0 |
| *Prionospio (Minuspio) lighti* | 37.6 | *Spiophanes berkeleyorum* | 12.8 |
| *Psephidia lordi* | 36.6 | *Leitoscoloplos pugettensis* | 11.4 |
| *Protomedeia* sp. | 36.4 | *Sigambra tentaculata* | 10.4 |
| *Axinopsida serricata* | 35.8 | *Aricidea catherinae/lopezi* | 10.0 |
| Nemertina | 35.6 | *Thyasira flexuosa* | 10.0 |
| *Parvilucina tenuisculpta* | 31.8 | *Cossura* sp. | 9.4 |

Table 12. Abundance (mean number of individuals per 0.1 $m^2$ grab) and total number of species (five composite 0.1 $m^2$ grabs) of macrobenthos in Puget Sound. Numbers are ranges and averages (±SD) of stations grouped by sediment type and water depth over five years (1989-1993) of sampling.

| | Sediment Type | | | |
|---|---|---|---|---|
| | Sand | Mixed | Clay | Deep Clay |
| Abundance[(a)] | 527.2 (±245.4) | 411.9 (±223.3) | 331.2 (±216.4) | 189.3 (±124.6) |
| Range | 164.0-1489.8 | 57.0-1203.8 | 62.6-1025.6 | 42.0-469.2 |
| Number of species[(b)] | 118.1 (±28.1) | 83.0 (±21.2) | 54.1 (±17.5) | 52.4 (±12.0) |
| Range | 47-187 | 27-128 | 23-103 | 35-76 |

[(a)] Station 41 (mixed) excluded
[(b)] Station 208R (clay) excluded

In addition to the above characterization, we examined similarities and differences in species composition between contaminated and non-contaminated stations. Specifically, we compared Elliott Bay (Station 33) and Commencement Bay (Station 40) to Port Madison (Station 69) because these stations were clustered together 1990 through 1993. The comparison is presented in Table 13.

During the period 1990-1993, Port Madison had 22 more taxa than Elliott Bay, and 56 more taxa than Commencement Bay. However, on average, sediments in Port Madison were sandier (81.8% sand) than sediments in Elliott Bay (71.3% sand) and Commencement Bay (68.5% sand). Thus, the higher number of species recorded in Port Madison relative to the other two stations could be explained on the basis of differences in grain size.

Comparing species lists, 156 taxa (54.9%) were common to Port Madison and Elliott Bay, 53 taxa (18.7%) were restricted to Elliott Bay, and 75 taxa (26.4%) were restricted to Port Madison (Table 13). When Commencement Bay was added to the comparison, the number of taxa restricted to Port Madison was reduced to 54. The data were also compared by taxonomic group. Differences were manifested only through a decrease in the number of crustacea at contaminated stations (Table 13). With the exception of the gastropod *Lirobittium attenuatum* and the amphipod *Rhepoxynius abronius*, the 54 taxa characteristic of Port Madison were only recorded infrequently (Table 14). Because these taxa were not common or abundant, we cannot rule out chance as the determining factor explaining the observed differences. Strong patterns in the composition of common or dominant species distinguishing contaminated stations in Elliott Bay and Commencement Bay from the reference station in Port Madison were not observed.

# Temporal Trends

Temporal patterns of variation in abundance at core stations are presented in Figure 23. The patterns reveal large inter-annual fluctuations in abundance at many stations. No significant trend of increase or decrease in total abundance was detected at 26 of the 33 stations examined (Mann-Kendall Test, $\alpha = 0.10$). At five stations (Oak Harbor, Shilshole, Point Pully, Carr Inlet, and Case Inlet) there was a significant upward trend, and at two stations (Magnolia Bluff and Commencement Bay Station 41) there was a significant downward trend. Commencement Bay Station 41 in particular was associated with high concentrations of sterols.

Examination of Figure 23 also reveals a large variability (large error bars) in abundance around the annual mean at many stations (*e.g.*, Semiahmoo Bay, Port Angeles, Sinclair Inlet, Dyes Inlet, Commencement Bay Station 41). This variability was typically associated with patchiness in a few species, and may confound patterns of temporal variation. For example, *Aphelochaeta* sp. and *Axinopsida serricata* showed spatial variability in abundance that was of the same magnitude or greater than the temporal variability. This is illustrated by the large coefficient of variation frequently observed within years relative to the coefficient of variation computed among years (Figures 24 and 25). Five other dominant species exhibited similar patterns to a more or less degree (Figures 26-30).

To examine if the temporal variation in abundance of some species exhibited a consistent pattern that might be attributed to changes in contaminant concentrations, trends in abundance of fifteen dominant species were compared at four stations. Comparisons were made between pairs of stations differing in chemical contamination. Elliott Bay (Station 33) and Point Pully (Station 38) were each compared to Magnolia Bluff (Station 32) and Shilshole (Station 29), respectively. Elliott Bay and Point Pully showed contamination, while contaminants were no detected in Magnolia Bluff or Shilshole. Each pair of stations shared a common basin.

Species abundance patterns at these stations showed homogeneous trend directions within each comparison (Figures 31-34). For example, the abundance of *Macoma carlottensis* increased with time in both Point Pully and Shilshole. All the species pairs compared exhibited trends that were not significantly different, *i.e.*, the trends were homogeneous (Mann-Kendall Test for homogeneity of stations, $\alpha = 0.05$). The species-specific patterns of temporal variation were basin-wide. Therefore, the patterns were not associated with chemical contamination at the stations examined.

Table 13. Number of species recorded from Elliott Bay (Station 33), Commencement Bay (Station 40), and Port Madison (Station 69), 1990-1993, number of species in common, and number of species unique to each station.

| Taxa | Elliott Bay | Station<br>Commencement Bay | Port Madison |
|---|---|---|---|
| Total number | 209 | 175 | 231 |
| In common with Port Madison | | | |
| All Taxa | 156 | 142 | -- |
| Polychaeta | 95 | 89 | -- |
| Crustacea | 25 | 20 | -- |
| Bivalvia | 21 | 18 | -- |
| Gastropoda | 6 | 7 | -- |
| Echinodermata | 2 | 1 | -- |
| Other Phyla | 6 | 6 | -- |
| Unique | | | |
| All Taxa | 53 | 33 | 54 |
| Polychaeta | 27 | 20 | 27 |
| Crustacea | 8 | 3 | 18 |
| Bivalvia | 5 | 3 | 3 |
| Gastropoda | 9 | 6 | 1 |
| Echinodermata | 3 | 0 | 4 |
| Other Phyla | 1 | 1 | 1 |

Table 14. Species recorded in Port Madison (Station 69), 1990-1993, and absent from Elliott Bay (Station 33) and Commencement Bay (Station 40). B = Bivalvia, C = Crustacea, E = Echinodermata, G = Gastropoda, O = Other Phyla, P = Polychaeta. Maximum possible frequency = 4.

| Species | Frequency of Occurrence | Total Number of Individuals Recorded | Average Density (0.1 $m^2$) When Present |
|---|---|---|---|
| *Ampelisca brevisimulata* (C) | 1 | 2 | 0.4 |
| *Autolytus* sp. (P) | 1 | 1 | 0.2 |
| *Campylaspis hartae* (C) | 1 | 1 | 0.2 |
| *Clymenura columbiana* (P) | 1 | 18 | 3.6 |
| *Cucumaria* sp. (E) | 1 | 1 | 0.2 |
| *Eteone spilotus* (P) | 1 | 1 | 0.2 |
| *Euchone incolor* (P) | 1 | 1 | 0.2 |
| *Eulalia (Eulalia) quadrioculata* (P) | 1 | 2 | 0.4 |
| *Eulalia (Eulalia) viridis* (P) | 2 | 1 | 0.2 |
| *Eupentacta quinquesemita* (E) | 1 | 1 | 0.2 |
| *Eusyllis blomstrandi* (P) | 1 | 4 | 0.8 |
| *Exogone dwisula* (P) | 2 | 2 | 0.2 |
| *Flabelligera affinis* (P) | 1 | 1 | 0.2 |
| *Foxiphalus similis/cognatus* (C) | 1 | 1 | 0.2 |
| *Gattyana cirrosa* (P) | 1 | 1 | 0.2 |
| *Halcampidae* (O) | 2 | 1 | 0.2 |
| *Laonice pugettensis* (P) | 1 | 1 | 0.2 |
| *Leptamphous* sp. (C) | 1 | 2 | 0.4 |
| *Leptostylis villosa* (C) | 1 | 1 | 0.2 |
| *Lirobittium attenuatum* (G) | 4 | 62 | 3.1 |
| *Lyonsia pugettensis* (B) | 1 | 2 | 0.4 |
| *Macoma obliqua* (B) | 1 | 1 | 0.2 |
| *Melita desdichada* (C) | 2 | 3 | 0.3 |
| *Melphisana* sp. A (C) | 1 | 1 | 0.2 |
| *Micropodarke dubia* (P) | 2 | 2 | 0.2 |
| *Myriochele* sp. M (P) | 1 | 1 | 0.2 |
| *Nephtys caeca* (P) | 2 | 2 | 0.2 |
| *Nicomache personata* (P) | 1 | 1 | 0.2 |
| *Notophyllum tectum* (P) | 1 | 1 | 0.2 |
| *Opisa tridentata* (C) | 1 | 1 | 0.2 |
| *Orchomene obtusa* (C) | 1 | 1 | 0.2 |
| *Orchomene pacifica* (C) | 2 | 5 | 0.5 |
| *Orchomene* sp. (C) | 1 | 4 | 0.8 |
| *Pardalisca cuspidata* (C) | 1 | 1 | 0.2 |
| *Pentamera (Cucumaria) populifera* (E) | 1 | 1 | 0.2 |
| *Pentamera pseudopopulifera* (E) | 1 | 3 | 0.6 |
| *Phyllochaetopterus prolifica* (P) | 1 | 9 | 1.8 |
| *Phyllodoce (Anaitides) maculata* (P) | 1 | 1 | 0.2 |
| *Phyllodoce (Anaitides) papillosa* (P) | 1 | 1 | 0.2 |
| *Pilargis maculata* (P) | 1 | 1 | 0.2 |
| *Podocerus* sp. (C) | 2 | 3 | 0.3 |

Table 14. Concluded.

| Species | Frequency of Occurrence | Total Number of Individuals Recorded | Average Density (0.1 m$^2$) When Present |
|---|---|---|---|
| *Polydora* sp. 1 (P) | 1 | 3 | 0.6 |
| *Pontogeneia inermis* (C) | 1 | 1 | 0.2 |
| *Pontogeneia intermedia* (C) | 1 | 1 | 0.2 |
| *Proceraea cornuta* (P) | 1 | 1 | 0.2 |
| *Protothaca staminea* (B) | 1 | 1 | 0.2 |
| *Pterocirrus macroceros* (P) | 1 | 3 | 0.6 |
| *Rhepoxynius abronius* (C) | 3 | 14 | 0.9 |
| *Sige macrocirrus* (P) | 1 | 1 | 0.2 |
| *Sphaerodorum papillifer* (P) | 1 | 1 | 0.2 |
| *Spiophanes missionensis* (P) | 1 | 1 | 0.2 |
| *Spirontocaris snyderi* (C) | 1 | 1 | 0.2 |
| *Tanais* sp. (C) | 1 | 1 | 0.2 |
| *Travisia brevis* (P) | 1 | 1 | 0.2 |

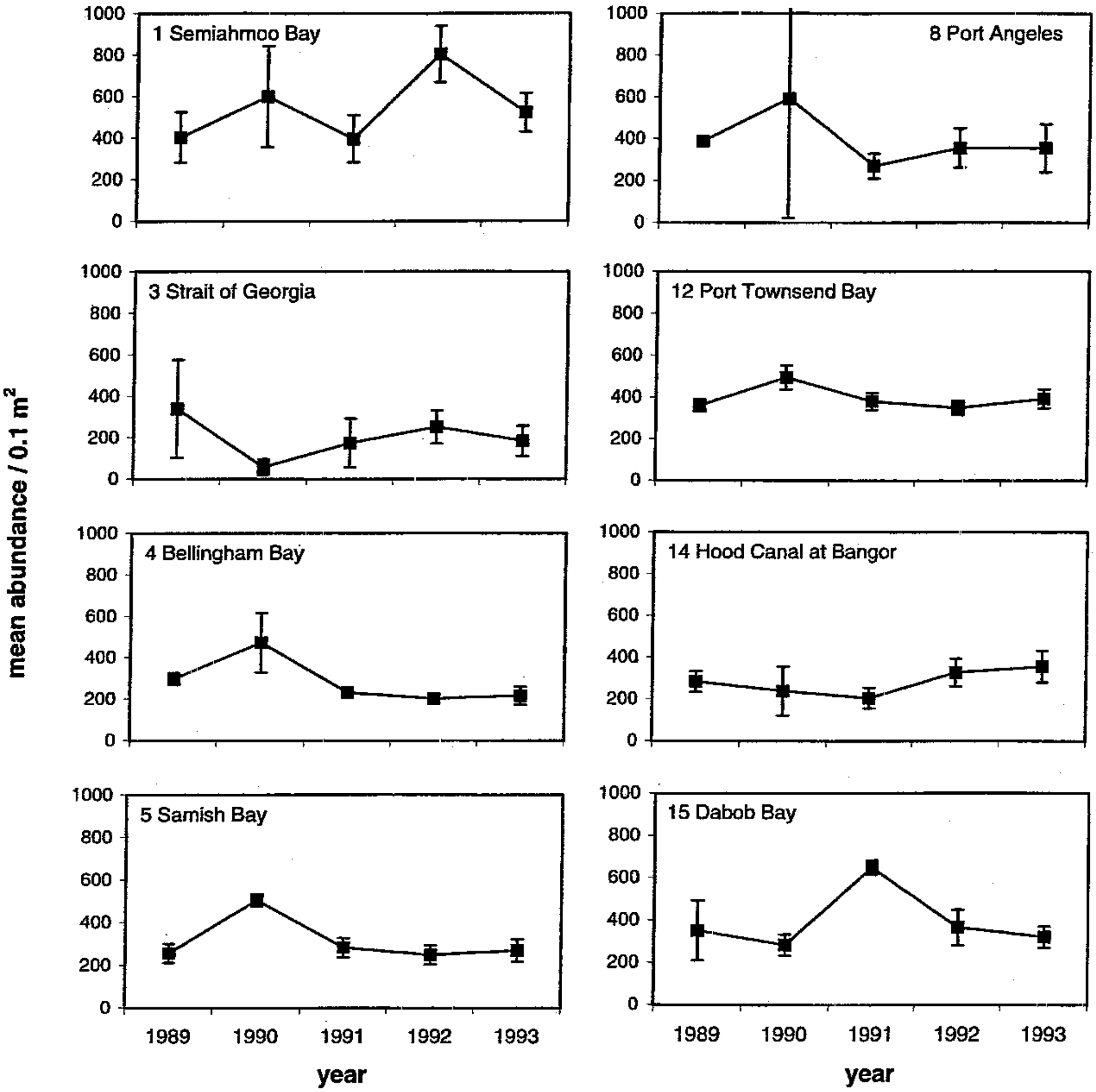



Figure 23. Temporal changes in mean (± SD) total abundance of benthic macrofauna at core stations.

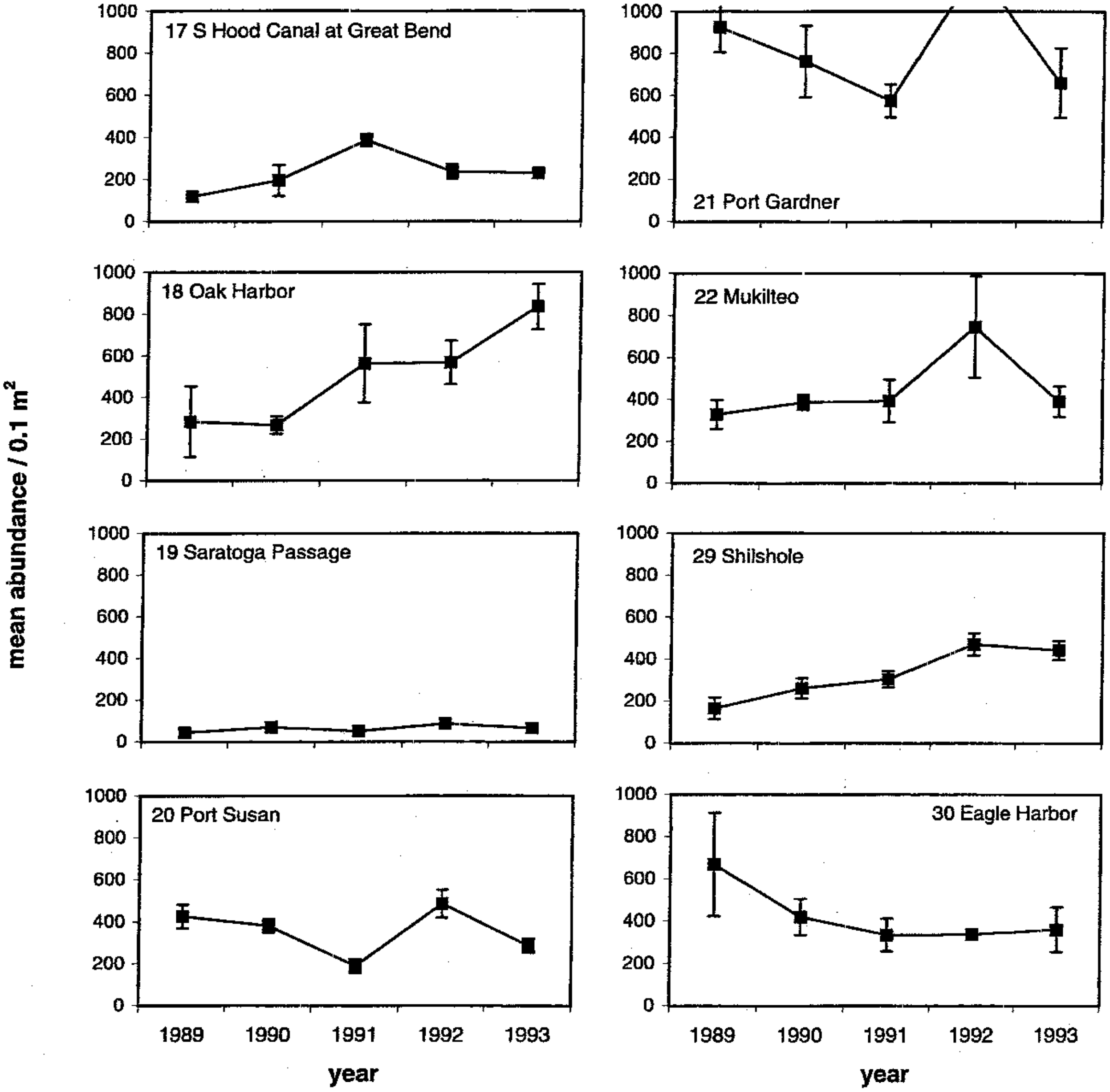



Figure 23 Continued

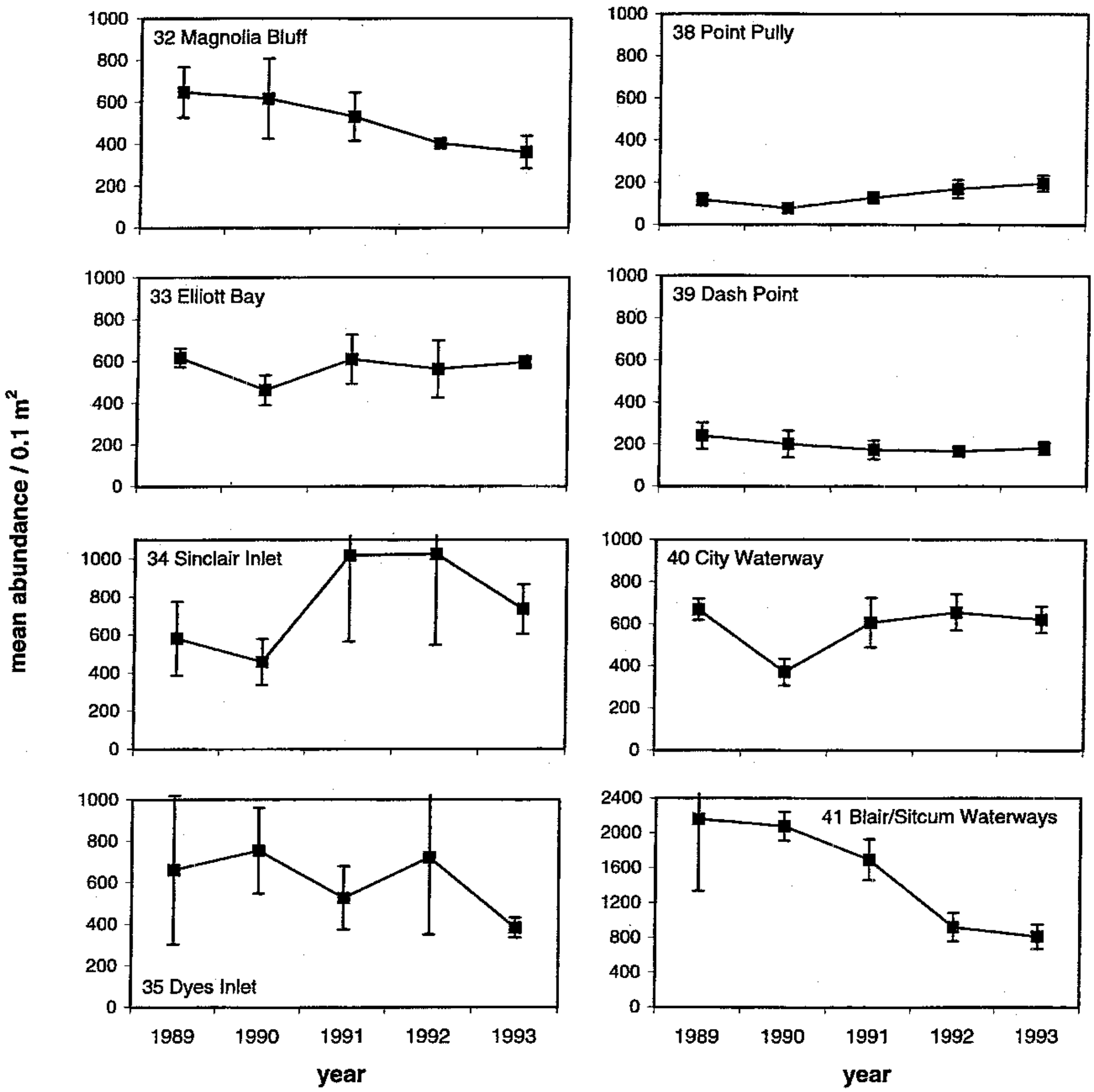



Figure 23. Continued.

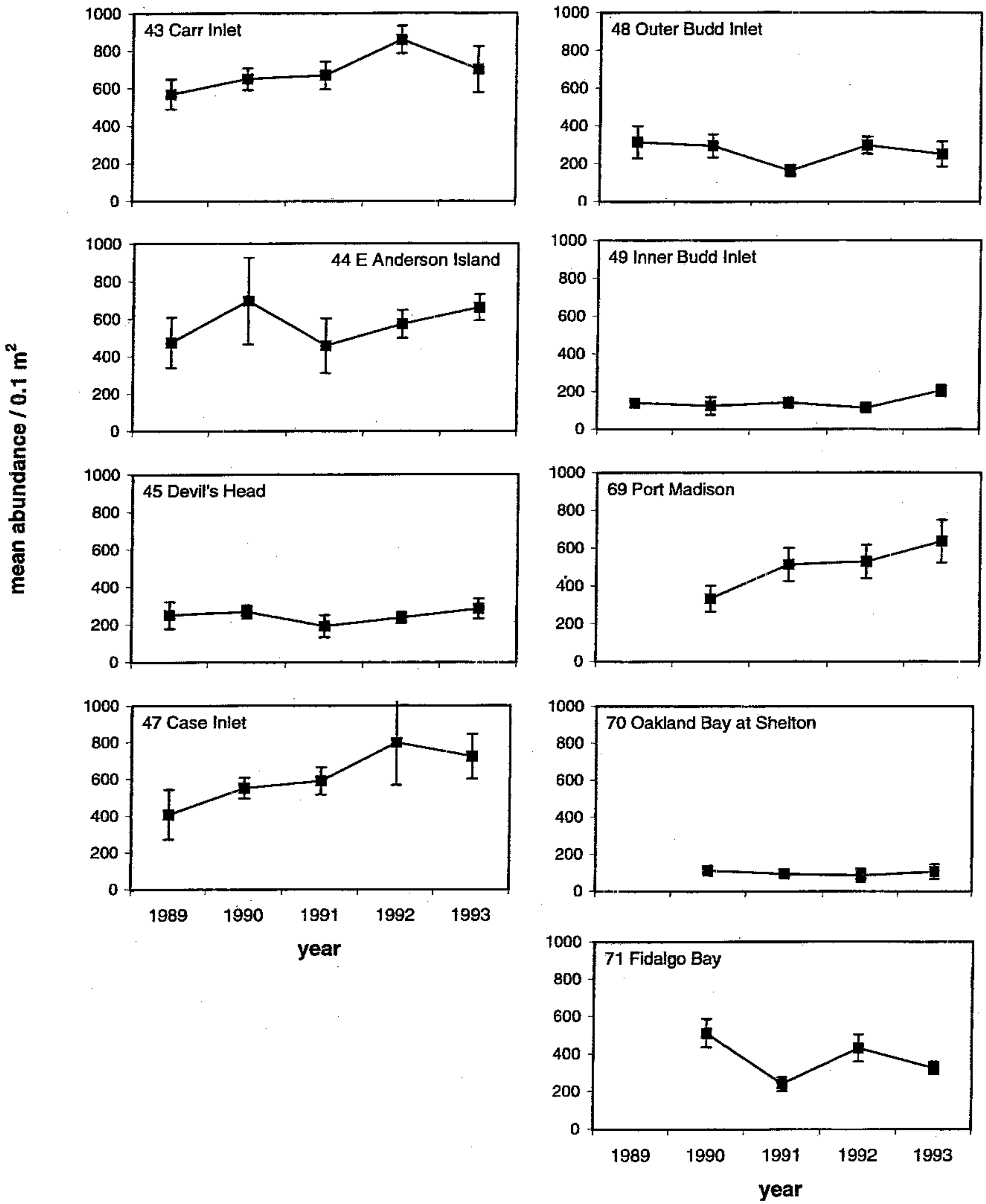



Figure 23. Concluded.

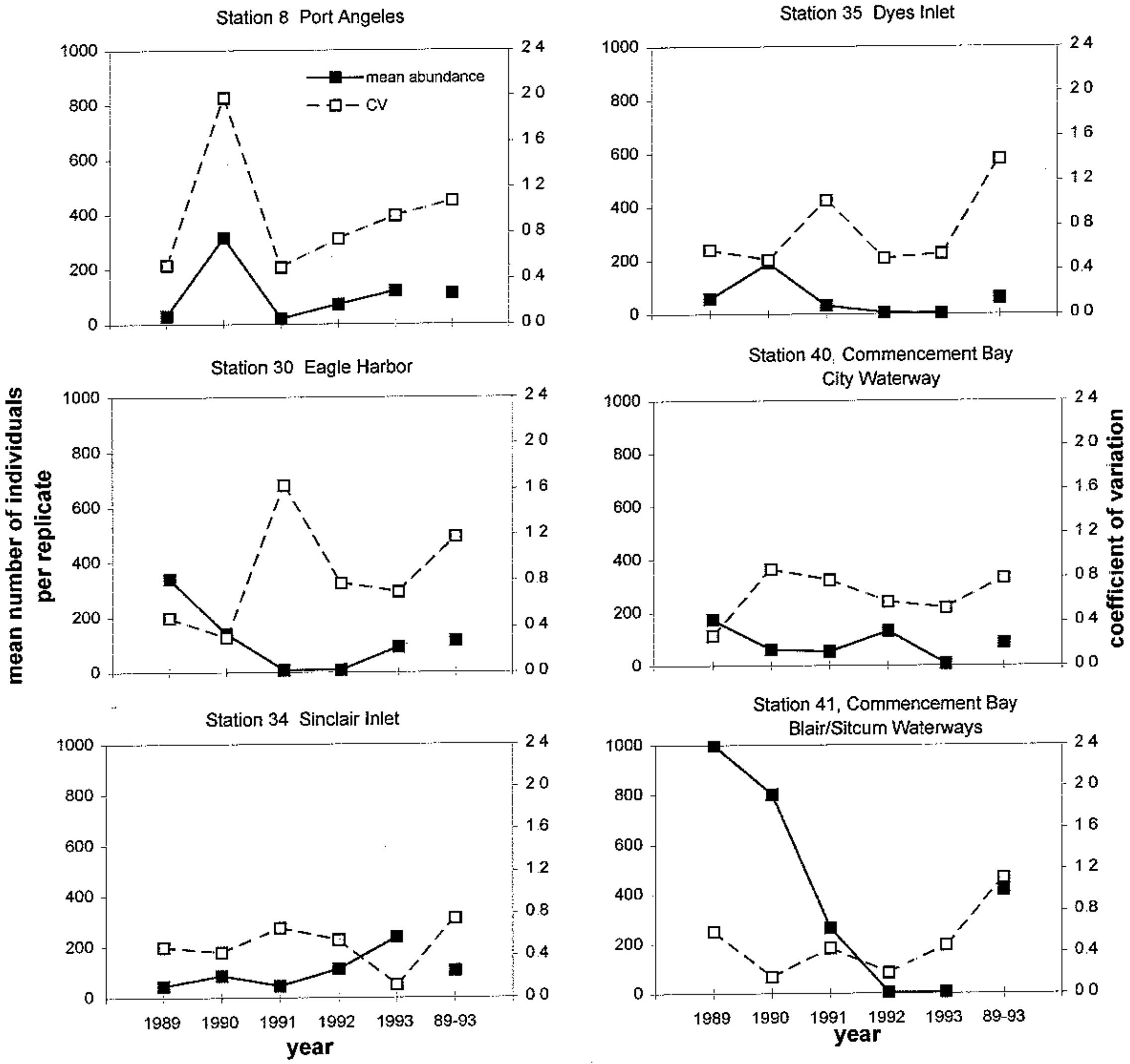



Figure 24. Temporal changes in mean abundance of *Aphelochaeta* sp. (Annelida: Polychaeta) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

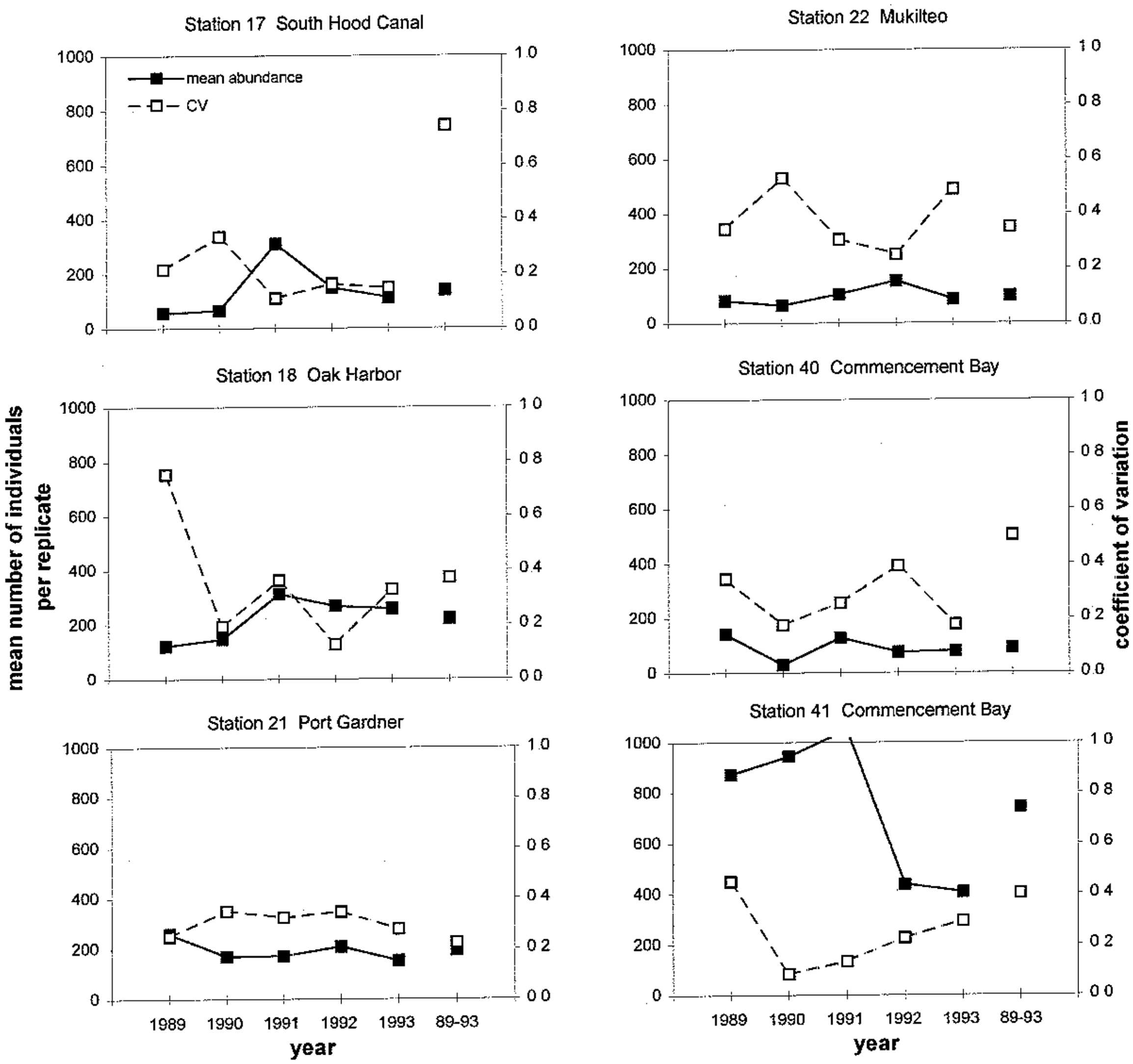



Figure 25. Temporal changes in mean abundance of *Axinopsida serricata* (Mollusca: Bivalvia) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

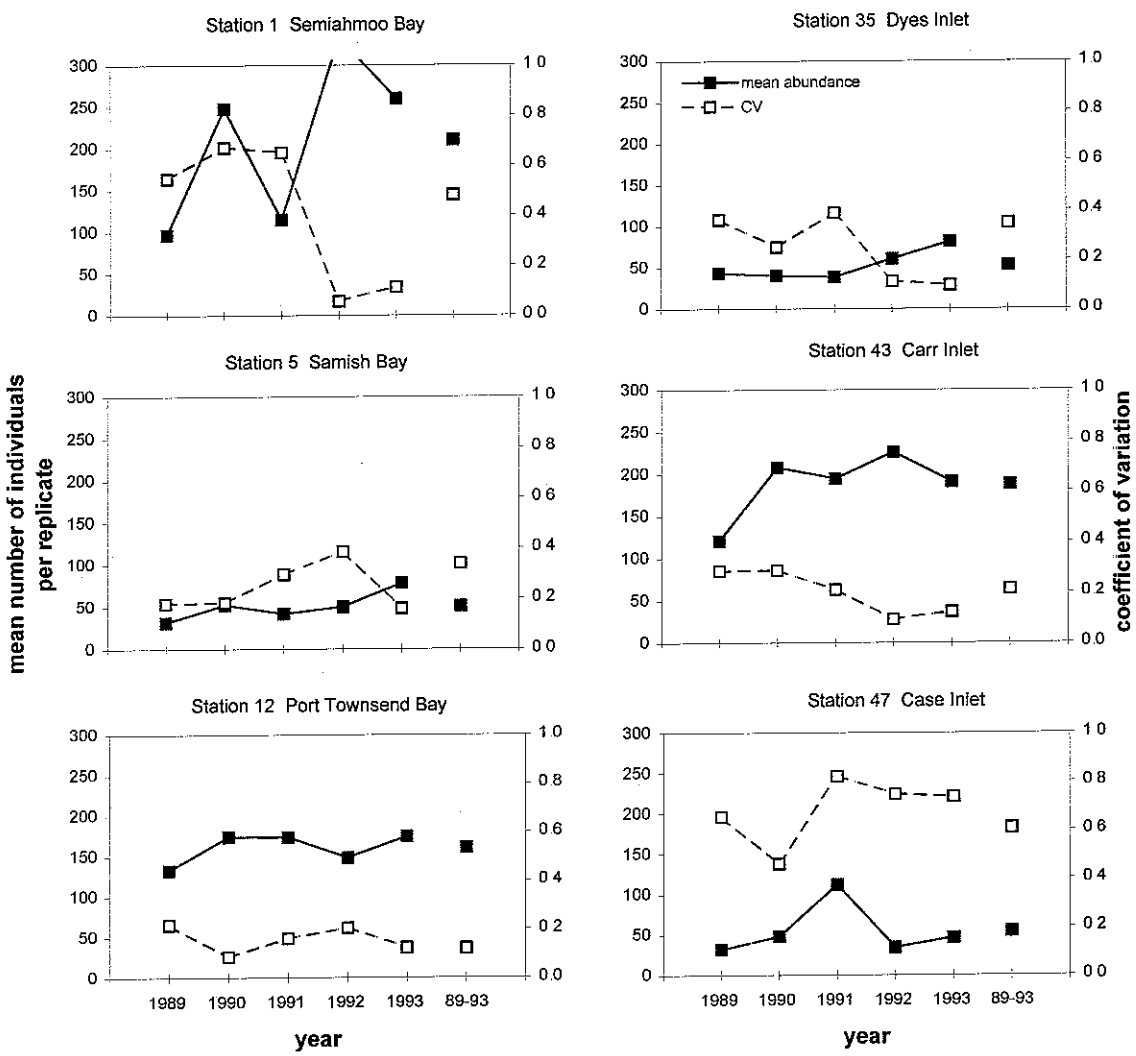



Figure 26. Temporal changes in mean abundance of *Amphiodia urtica/periercta* (Echinodermata: Ophiuroidea) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

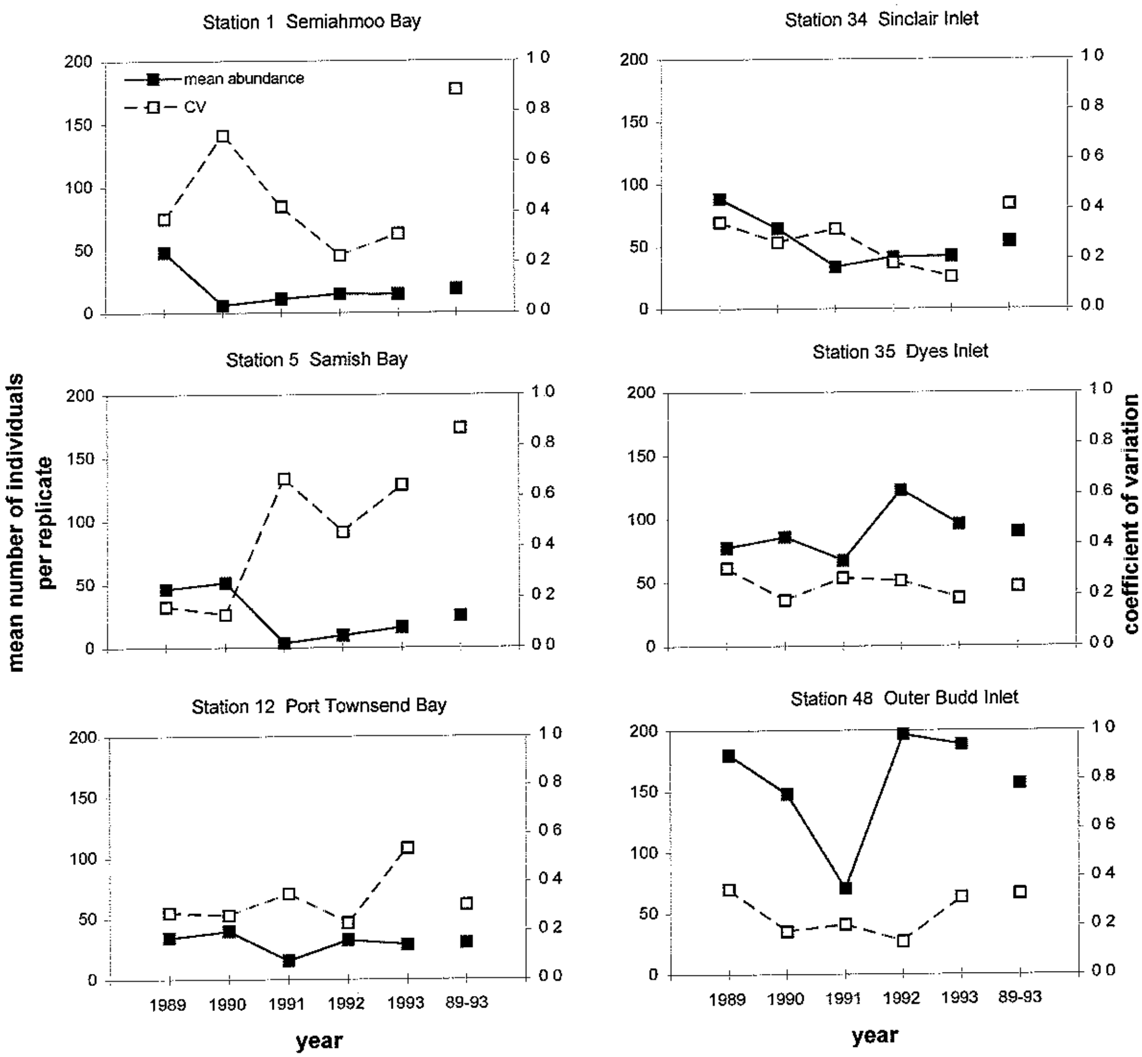



Figure 27. Temporal changes in mean abundance of *Eudorella pacifica* (Crustacea: Cumacea) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

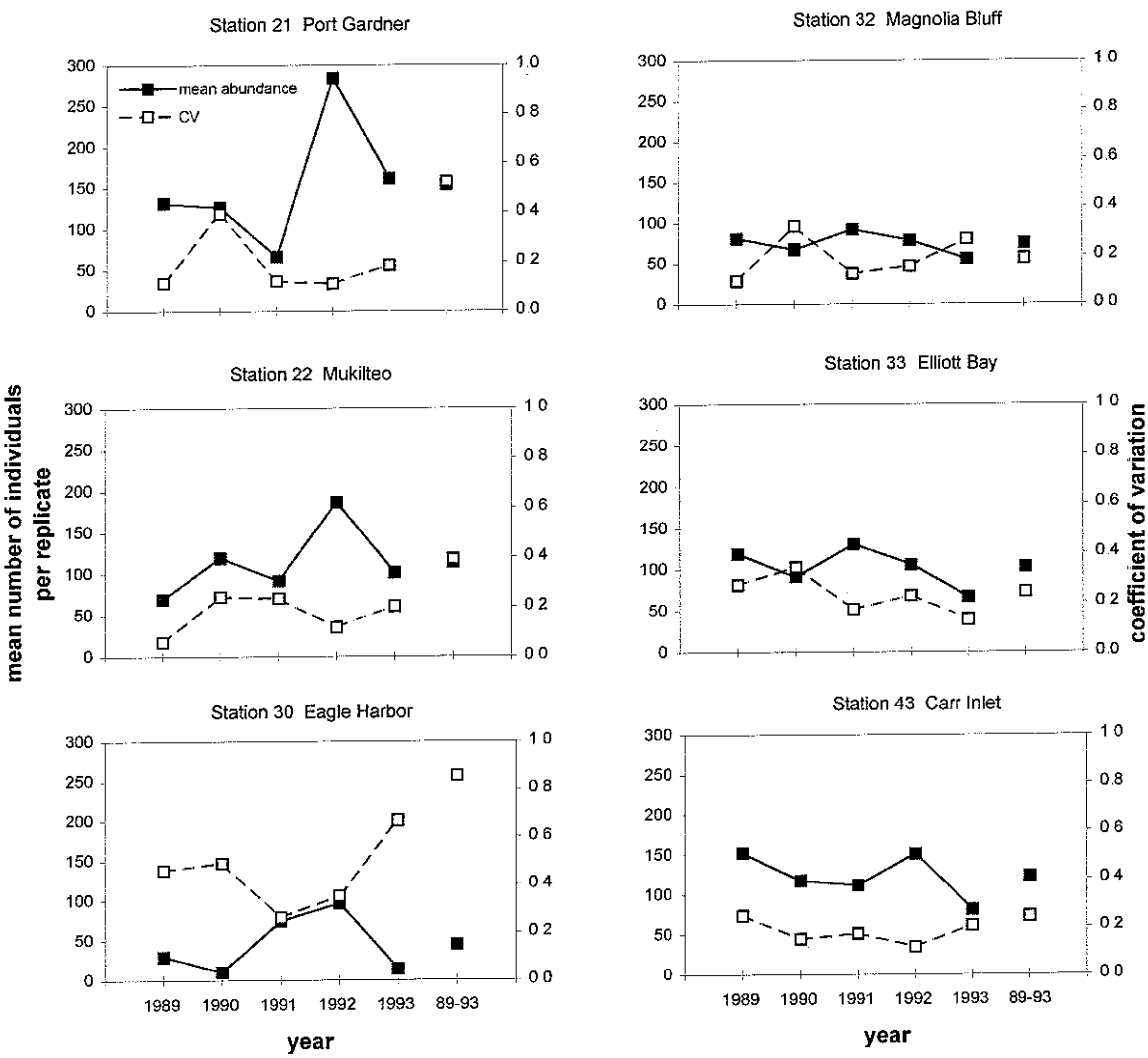



Figure 28. Temporal changes in mean abundance of *Euphilomedes carcharodonta* (Crustacea: Ostracoda) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

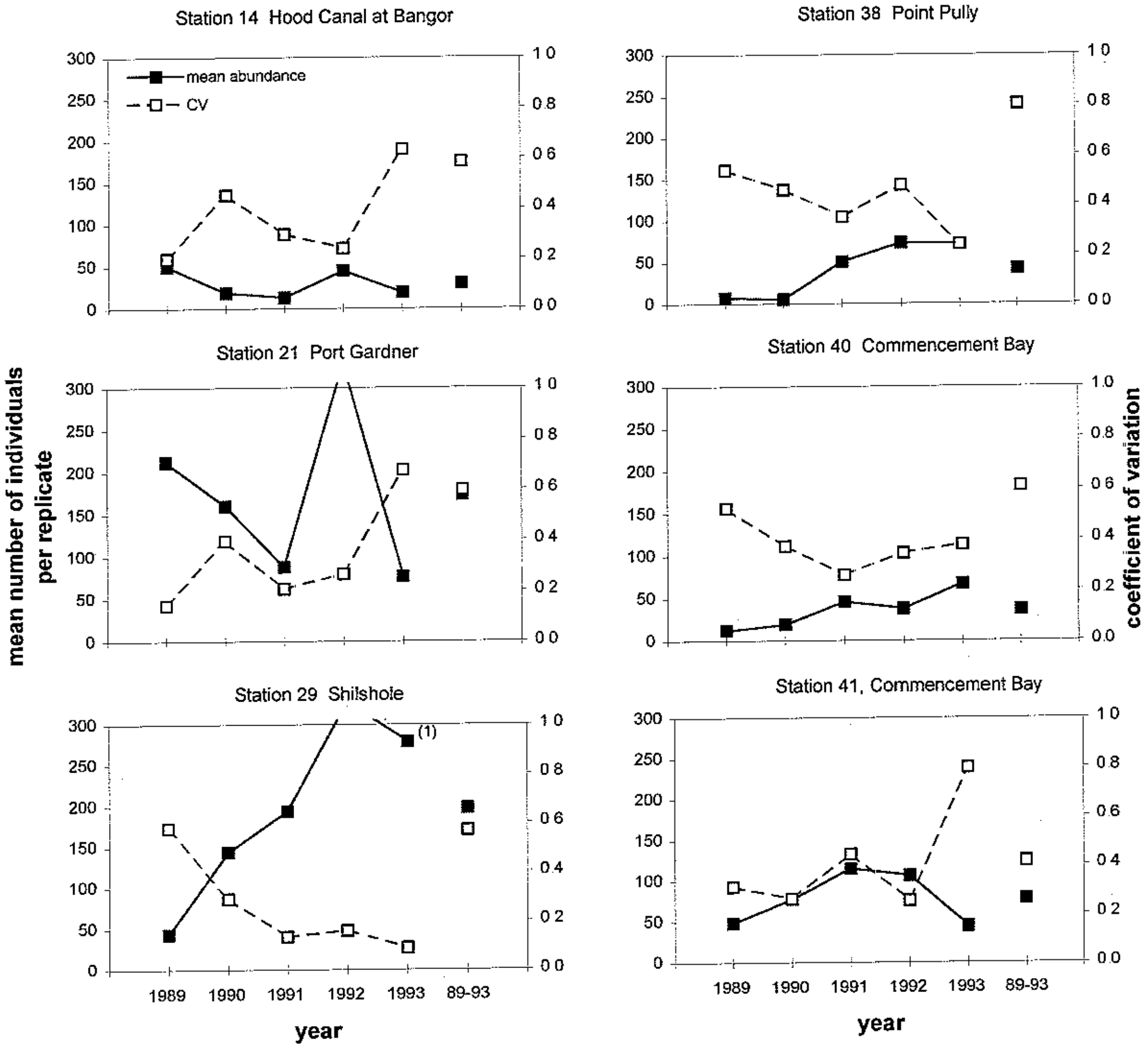



Figure 29. Temporal changes in mean abundance of *Macoma* spp. (Mollusca: Bivalvia) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993. The value indicated with (1) is a mean of 4 replicates. All other values are means of 5 replicates. The vast majority of individuals at Stations 21, 29 and 38 are *Macoma carlottensis*. Stations 14, 40 and 41 include various species of *Macoma*.

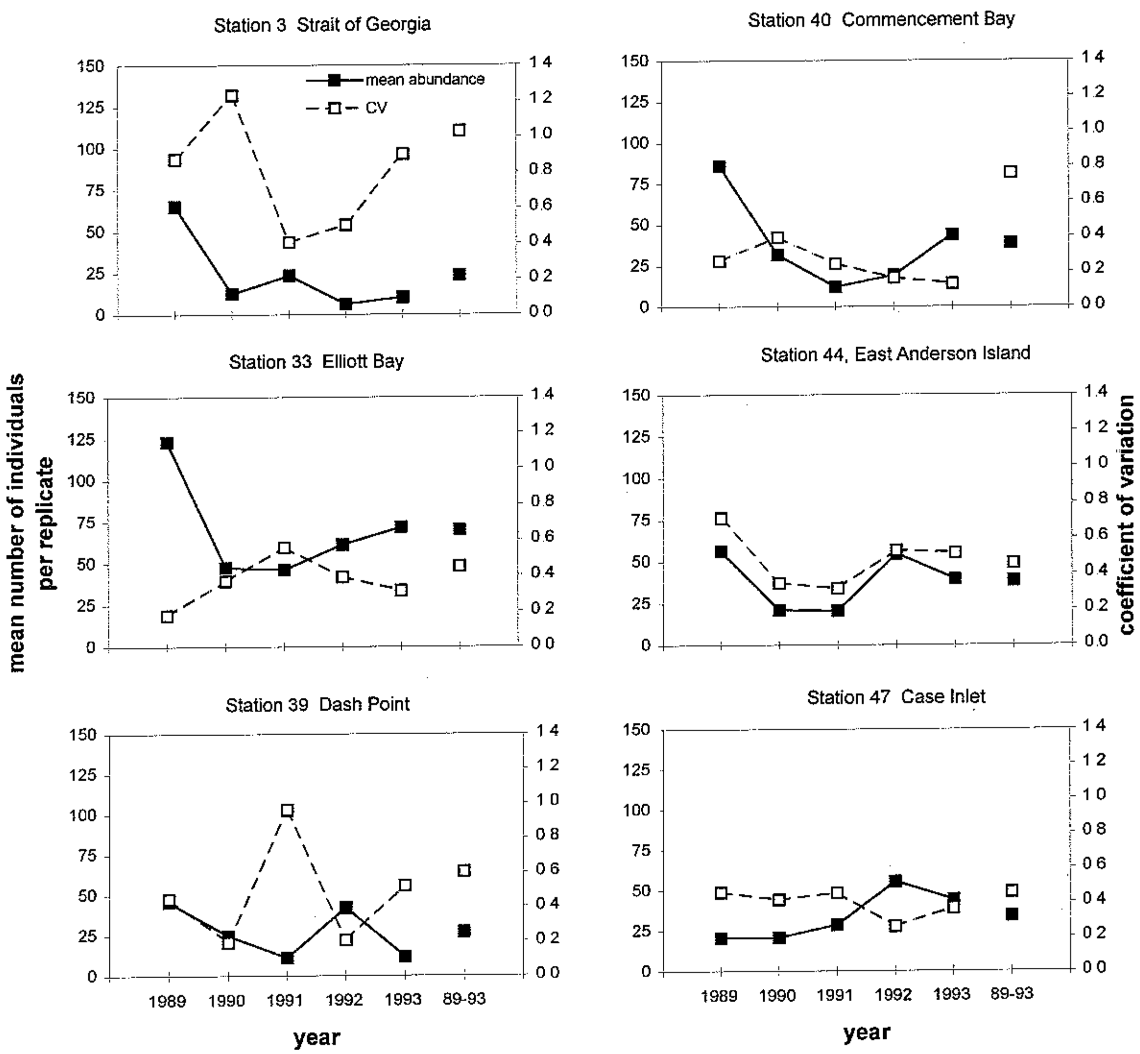



Figure 30. Temporal changes in mean abundance of *Prionospio jubata* (Annelida: Polychaeta) at six stations in Puget Sound. The coefficient of variation is shown for each year and for the period 1989-1993.

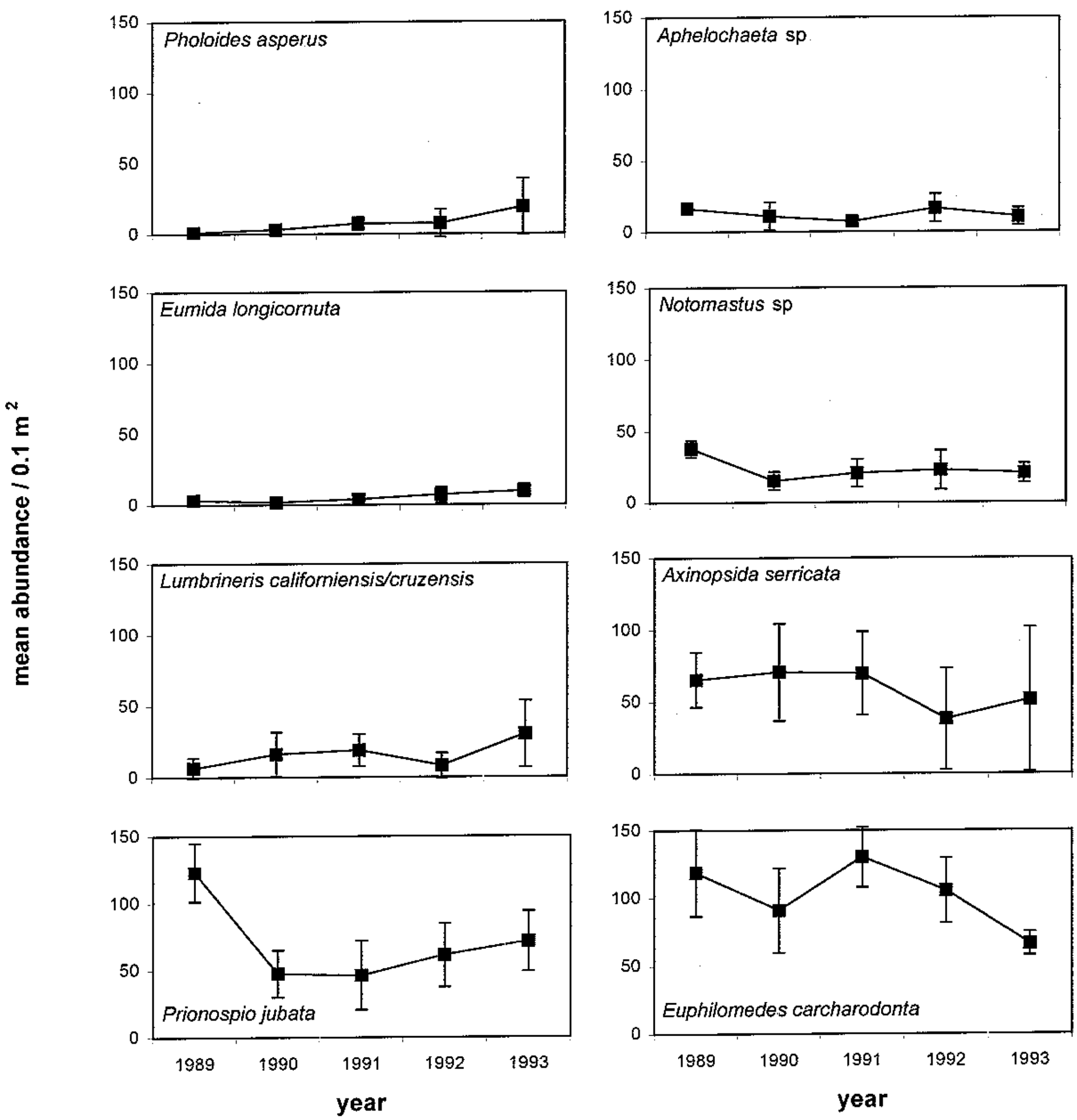



Figure 31. Temporal changes in mean abundance (± SD) of eight species in Elliott Bay (Station 33).

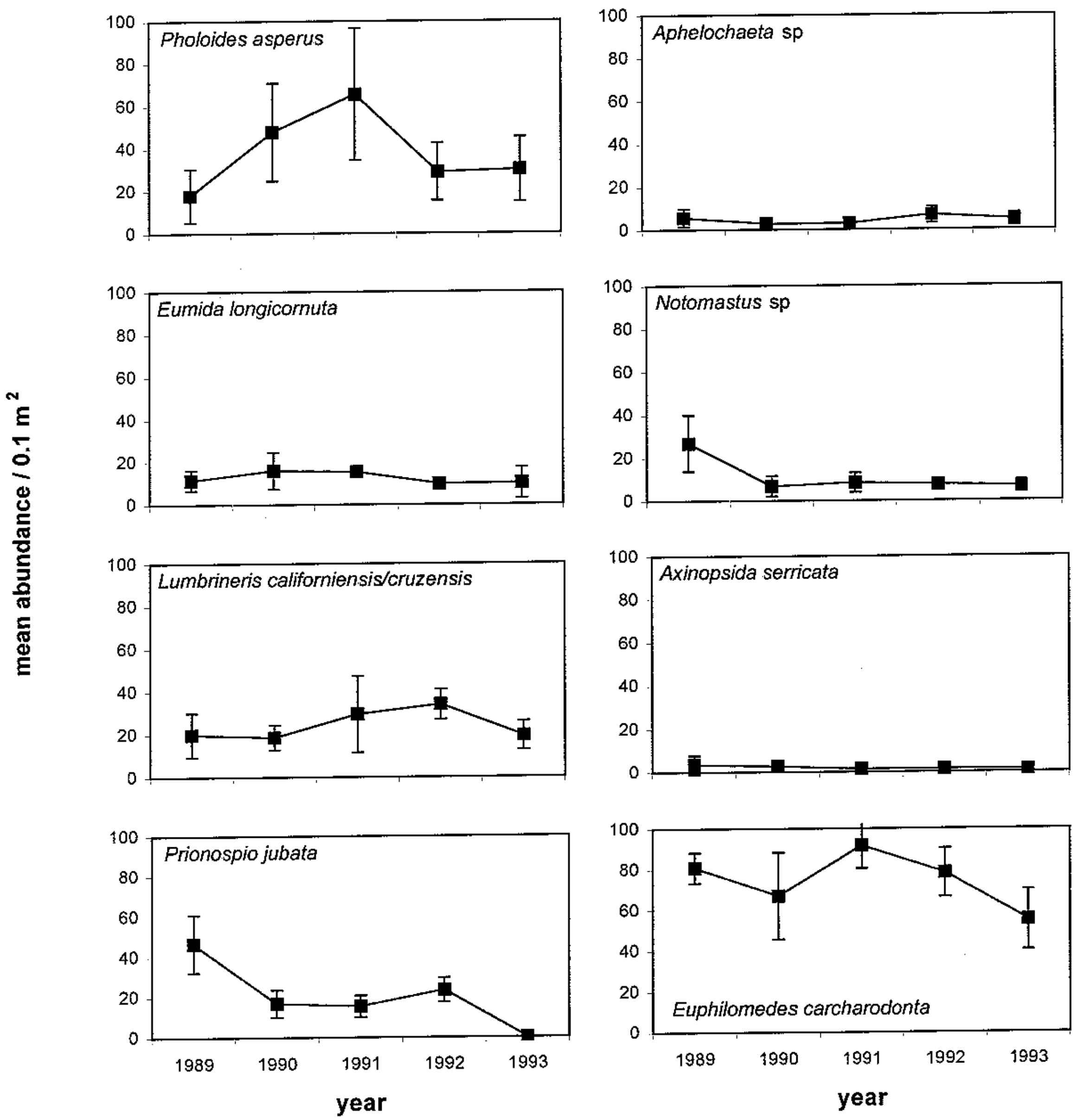



Figure 32. Temporal changes in mean abundance (± SD) of eight species in Magnolia Bluff (Station 32).

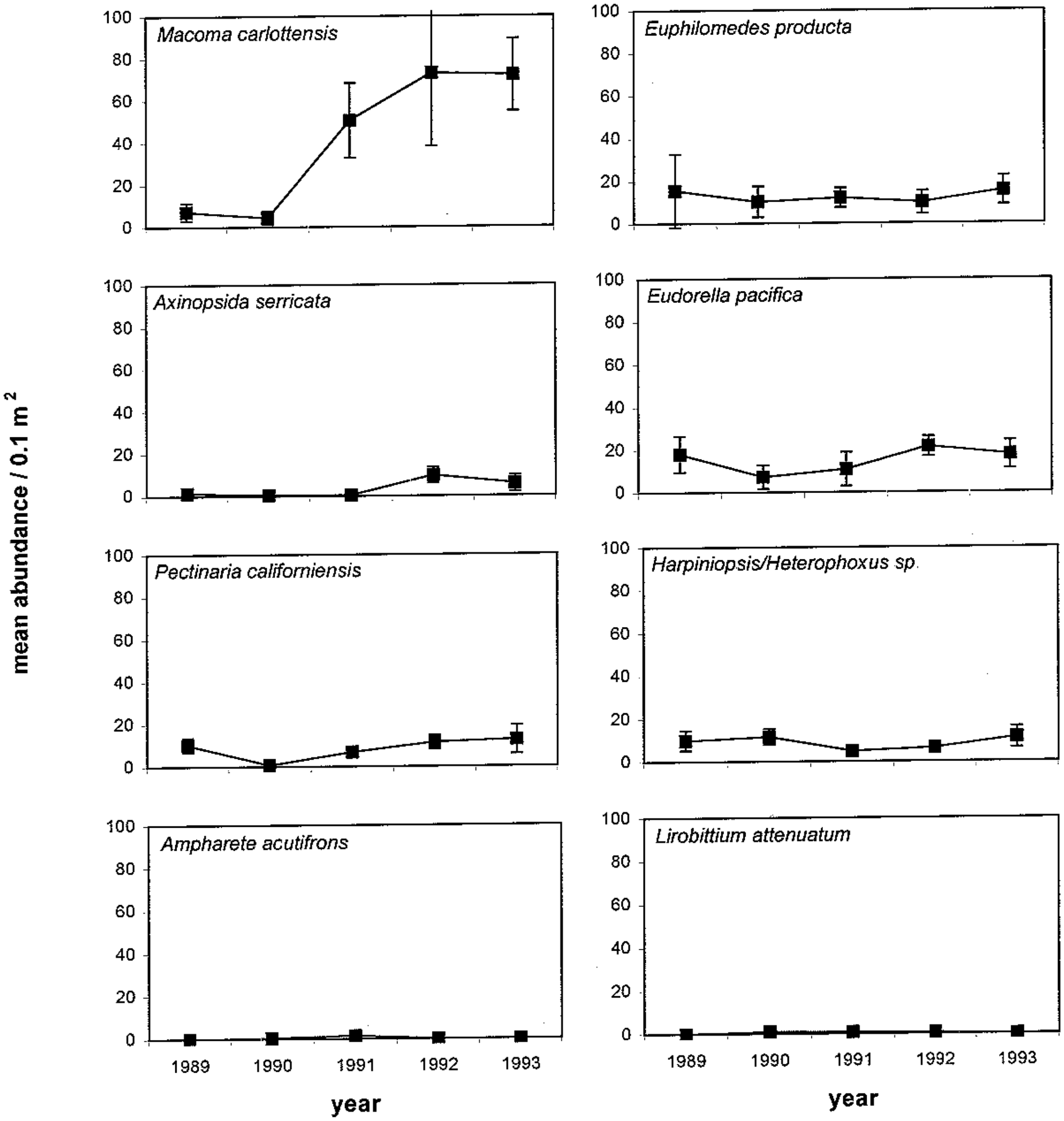



Figure 33. Temporal changes in mean abundance (± SD) of eight species in Point Pully (Station 38).

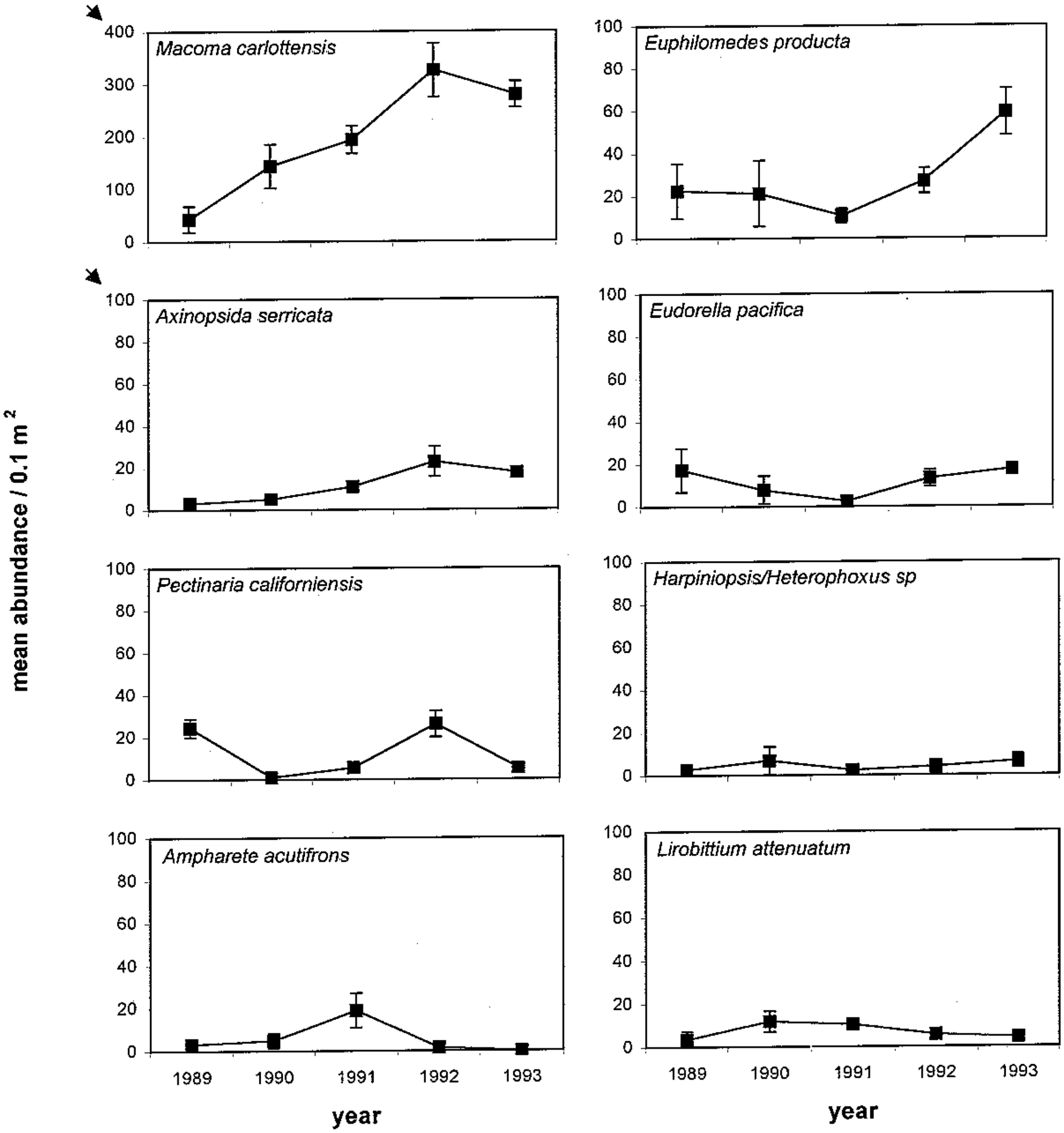



Figure 34. Temporal changes in mean abundance (± SD) of eight species in Shilshole (Station 29). Note change in scale indicated by arrows.

# Discussion

## Correspondence with Contamination

Overall, there was no correspondence between benthic community measures and the low to moderate sediment contamination found at MSMP stations. For example, relatively high total abundance and species number of benthic macro-invertebrates were identified in both urban and rural sites. Thus, total abundance and species number were not predictors of sediment contamination at monitoring stations. The absence of clear effects is probably due to the generally low contaminant concentrations recorded in the MSMP. Even so, and as presented in Volume 1 of this report, concentrations above threshold levels (ER-L, AET) indicative of acute biological effects were identified at several stations.

The lack of correspondence between those stations exceeding contaminant threshold concentrations and benthic infaunal measures of abundance and diversity may be explained in several ways. First of all, the Effects Range-Low (ER-L, Long *et al.*, 1995) are incipient levels often based on the determination of mortality in sensitive organisms such as bacteria, larvae, and amphipods. Secondly, some Apparent Effect Thresholds (AET) are based on measures of benthic "effects" that have been derived from studies with small ranges of chemical concentrations. These effects may have been caused solely or in part by other factors or natural stresses related to physical sediment properties, high sulfide concentrations, or low dissolved oxygen in the overlaying water column. Lastly, benthic abundance and diversity may not be sensitive measures of toxic effects.

Nonetheless, some of the highest concentrations of hydrocarbons and metals measured in the MSMP are potentially toxic. Substrate physicochemical characteristics, however, may have contributed to a reduction of the toxicity. For example, silts, clays and the organic carbon content of sediments are known to influence the relative availability of organic contaminants to organisms (Plesha *et al.*, 1988). At similar contaminant concentrations, sands with low organic content can be substantially more toxic than clay sediments. Also, the bioavailability of some compounds such as metals can be influenced by factors such as the Redox potential of sediments and the pH of interstitial water (Arjonilla *et al.*, 1994). For example, Johnston (1993) measured high concentrations of acid volatile sulfides (AVS) in sediments from Sinclair Inlet, and suggested that most metals were bound to sulfides and were therefore unavailable to organisms. Sinclair Inlet (Station 34) exhibited the largest concentrations of metals in the MSMP, and high concentrations of sulfides (100 mg/kg) were also measured at this station in one year.

Abundance and diversity measures may overlook changes in dominance from one group of organisms to another. Therefore, the analysis of species composition is essential to unravel changes in species distributions that may be related to pollution effects. Our results suggest that the presence of a few species at some monitoring stations may have been related to contamination. In the MSMP, the polychaete *Aphelochaeta* sp. (mostly sp. C) was a dominant member of the community at urban stations where organic enrichment and/or moderate contamination were identified. For example, *Aphelochaeta* was numerically dominant near the City of Tacoma WWTP outfall in Commencement Bay. However, elevated densities of this species were not found in any residential or rural areas, as illustrated in Figure 35. Other monitoring programs in Puget Sound have found high densities of *Aphelochaeta* in severely contaminated areas, such as the Hylebos Waterway and the Harbor Island Superfund sites (Figure 35). Also, this species (which has been previously reported as *Tharyx* sp. A) is numerically dominant near sewage outfalls in California (Swartz *et al.*, 1986). In addition, the polychaete *Capitella capitata* has been found in high densities near sources of pollution in Puget Sound (Armstrong *et al.*, 1981; PTI, 1993). The association of these species with organic pollution could be useful as an indicator of environmental conditions in Puget Sound.

The presence of species in contaminated areas constitutes a reflection of their physiology and life history. Some species are tolerant to the effects of pollutants in the environment, while other species respond to organically-enriched material through high reproductive and recruitment potential (Pearson and Rosenberg, 1978). Organic enrichment effects on benthos in Puget Sound may turn out to be relatively common in shallow bays where log transport, storage, and processing are occurring. For example, sediments from Port Angeles Harbor (Station 8) in the vicinity of wood processing industries, contained large amounts of wood chips; they also exhibited some of the highest concentrations of organic carbon measured in the MSMP. Benthic assemblages at this station predominantly comprised deposit-feeding polychaete species (60%-80% of the species), some of which (*e.g.*, cirratulids) exhibit high reproductive potential.

Organic enrichment may also result from effluents discharged by sewage treatment facilities or from leaking septic tanks. Effects from these sources were clearly manifested in sediments of Commencement Bay (Station 41), where high concentrations of β-coprostanol (a sewage tracer) were correlated with high abundance of the polychaete *Aphelochaeta* sp. (discussed above) and of the bivalve *Axinopsida serricata*. Large inter-annual fluctuations in the abundance of these species at this station were also observed, and remain unexplained. Changes in the abundance of opportunistic species, however, are common and can vary dramatically with time.

Organic detritus such as wood debris increases biochemical oxygen demand. This process will lead to decreased oxygen levels, and may lead to the accumulation of hydrogen sulfide in sediments. Puget Sound is already affected by coastal upwelling that cause low oxygen water masses to intrude into the estuary during summer

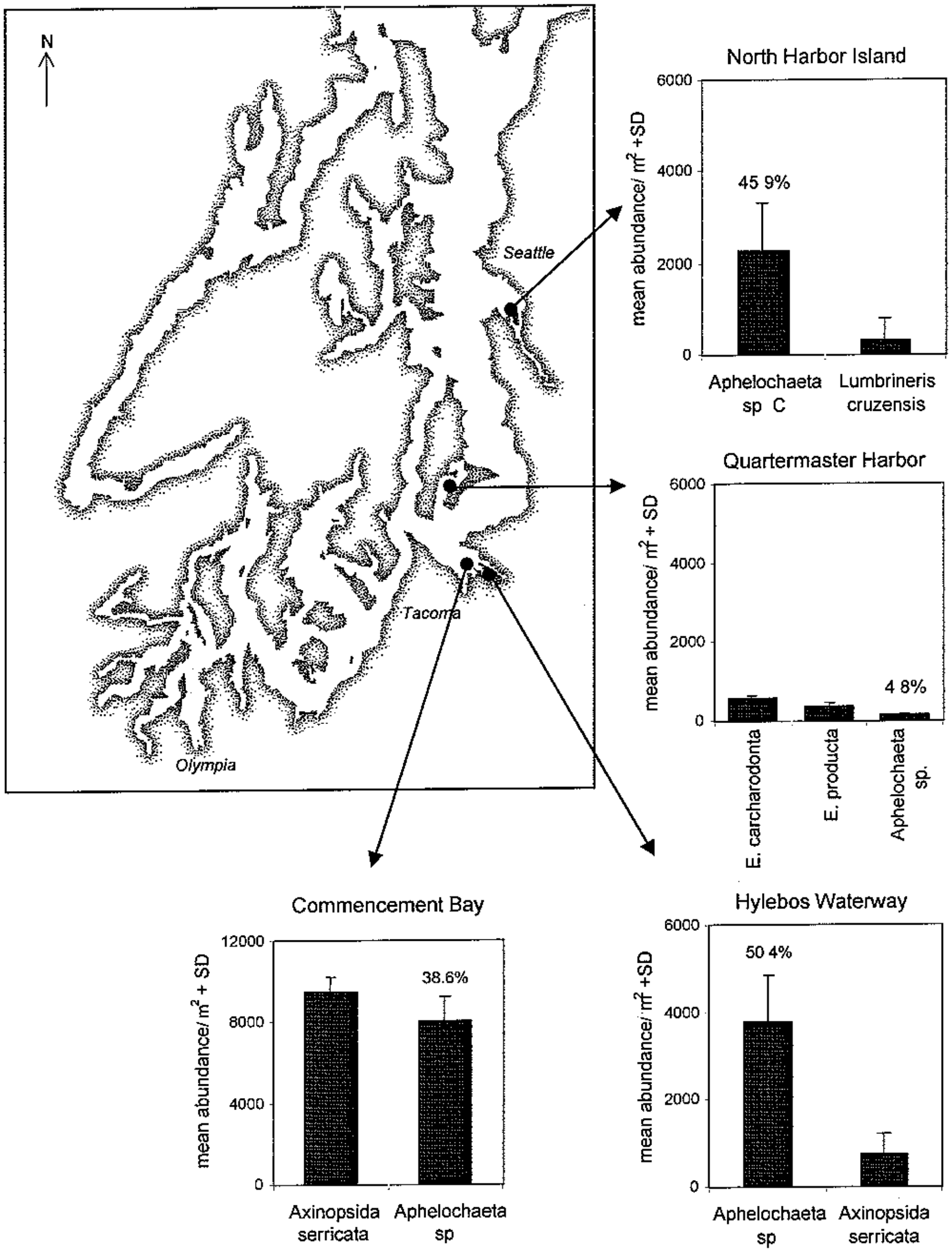



Figure 35. Top 2-3 numerically dominant species (1.0-mm mesh screen) at four sites in Puget Sound. The percent contribution of the polychaete *Aphelochaeta* sp. to the total station abundance is indicated in the plots. Quartermaster Harbor Station 303R is a rural/residential area. Commencement Bay Station 41 is located near the outfall of Tacoma Central Waste Water Treatment Plant. Hylebos Waterway Station 12 and North Harbor Island Station NH-08 are located in heavily contaminated areas. Selected stations have sediments with similar grain-size composition. Hylebos Waterway data collected by NOAA in 1994; North Harbor Island data collected by EPA's Elliott Bay Action Program in 1985. *Axinopsida serricata* is a bivalve, *Euphilomedes carcharodonta* and *Euphilomedes producta* are ostracods, and *Lumbrineris cruzensis* is a polychaete.

(Newton *et al.*, 1994). The low dissolved oxygen problem may be exacerbated by the accumulation of organic matter in shallow bays of restricted water circulation For example, the upper reaches of Sequim Bay (Station 208R) exhibited high organic content in sediments resulting mostly from accumulation of wood debris from log storage operations. In combination with low dissolved oxygen concentrations in the water column (Hannach *et al.*, in preparation), the sediments accumulated high sulfide concentrations. Correlative effects on benthos were manifested through a dramatic reduction in abundance, where only few organisms, mostly belonging to the polychaete species *Nephtys cornuta*, were found to have established a population (this study; Hannach *et al.*, in preparation). *Nephtys cornuta* may have value as an indicator species, since other *Nephtys* species have been commonly observed in proximity to benthic disturbance (Grant *et al.*, 1995; Pearson *et al.*, 1983).

Conversely, hydrogen sulfide in sediments of Dyes Inlet (Station 35), and to a lesser extent in Sinclair Inlet (Station 34), may have fostered the proliferation of mats of the polychaete *Phyllochaetopterus prolifica*. *Phyllochaetopterus* was very abundant at stations in Sinclair Inlet and Dyes Inlet. In Sinclair Inlet, *Phyllochaetopterus* accounted for a large proportion of the organisms collected there. Abbiati *et al.* (1994) have found that a sibling species, *P. socialis*, is associated with sulfide-rich substrates, and suggest that the reason for this association is the presence of sulfur bacteria, which may constitute a major food component in the diet of these worms. The relationships between sulfide concentrations and high densities of *Phyllochaetopterus* in Sinclair and Dyes Inlets or in other bays of Puget Sound remain to be investigated.

Relationships between sediment contamination and species composition at MSMP stations other than those described above could not be identified. A close examination of species presence/absence at two contaminated stations (Elliott Bay and Commencement Bay Station 40) and one reference clean station (Port Madison) did not reveal significant differences that could be attributed to chemical contamination. In addition, close examination of temporal patterns in abundance at four stations in Puget Sound sharing common dominant species and differing in sediment quality indicated that species increases or decreases in abundance are homogeneous within a basin, and thus unrelated to contamination. A caveat to these findings is that the MSMP was not designed to evaluate the areas of highest contaminant concentrations in Puget Sound (see Volume 1). For example, severely contaminated locations in Elliott Bay and Commencement Bay were not sampled. Differences in community measures may exist along stronger gradients of pollution. Such differences in species composition, for example, have been found between contaminated sites in Everett Harbor and reference areas in Port Susan, and have been attributed to pollution (PTI, 1993).

## Community Structure

The analysis of MSMP stations revealed rich and diverse species assemblages of organisms that were mainly associated with sediment type and water depth, reinforcing results from previous studies (Lie, 1974). The majority of species in Puget Sound were not restricted to one substrate, but were broadly distributed in different types of sediment with peaks of abundance in sand, mixed sediment, or mud. This result is in agreement with previous findings (Lie, 1968), which suggest that infaunal assemblages in Puget Sound represent a continuum along the environmental gradient. Therefore, benthic infaunal communities could only be loosely classified according to the type of substrate or water depth in which the species were dominant.

In addition to substrate, some assemblages were separated secondarily by geographical location. Clay stations in south Puget Sound consistently clustered together, and were separated from clay stations in the north Puget Sound region. In particular, Blaine (Station 1), Bellingham Bay (Station 4), Samish Bay (Station 5), and Port Townsend Bay (Station 12) formed a distinct group in the north.

One group of stations consisted of inlet ends in south Puget Sound. Inlet ends were characterized by low species richness relative to other locations in Puget Sound. Although there was a tendency for stations with finer substrates to have a lower number of species than stations with coarser substrates, clay stations in south Puget Sound generally supported fewer species than many shallow clay locations elsewhere. In addition, stations in south Hood Canal (Stations 17, 304R, and 305R), Sequim Bay (Station 208R), Holmes Harbor (Station 305R), and the Strait of Georgia (Station 3) exhibited impoverished assemblages (low abundance and species richness) and were separated in cluster analysis.

One characteristic common to most of the above locations is their relative physical isolation from main basins that allow water exchange between the Puget Sound region and the continental shelf. Locations of restricted water circulation are prone to the development of seasonal episodes of low dissolved oxygen (DO). If in addition these locations are associated with major inputs of freshwater, the likelihood is for the formation of seasonal density stratification of the water column, which exacerbates the low DO problem with increasing depth. Both Holmes Harbor and the Strait of Georgia are influenced by the extensive fresh water plumes of the Skagit and the Fraser rivers, respectively. Also, Saratoga Passage (Station 19) is directly influenced by the freshwater plume of the Skagit River (Newton *et al.*, 1997), and showed very low abundance.

The occurrence of low DO in south Hood Canal, Holmes Harbor, Sequim Bay, and Budd Inlet has been identified by Ecology's Marine Waters Monitoring Program (Newton *et al.*, 1997) and in previous studies (Collias *et al.*, 1974; Chapman, 1988). Additional data collected by the MSMP in south Hood Canal on two dates in September 1994, suggest an association between low DO ($<2$ $mgl^{-1}$) and reduced benthic abundance, with the greatest reduction in the crustacea (Figure 36).

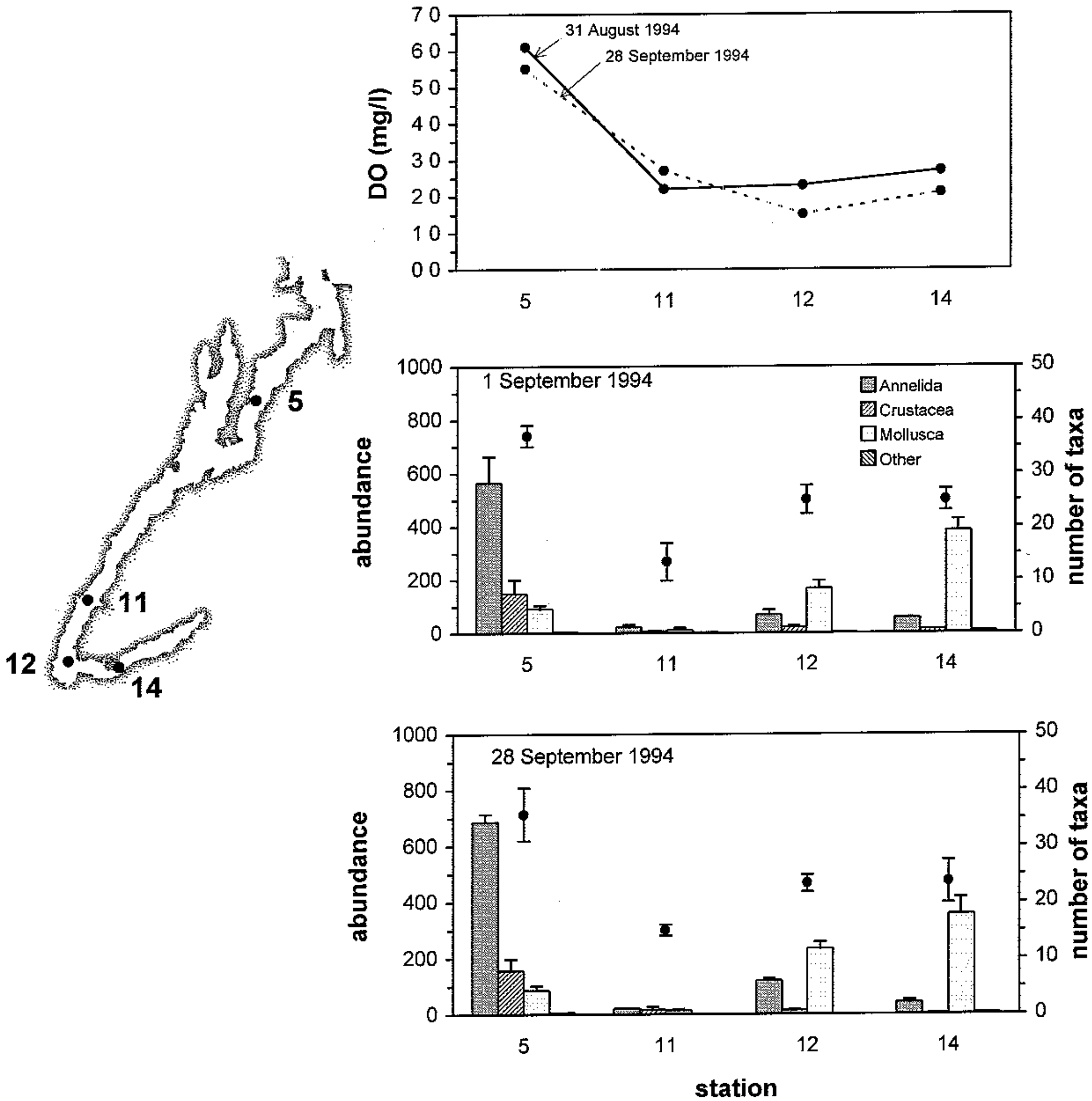



Figure 36. Abundance (mean + SD; bars) and number of taxa (mean ± SD; circles) of benthic macro-invertebrates at four stations in Hood Canal. The top diagram shows the near-bottom dissolved oxygen record. Benthic organisms were sampled 1 and 28 September 1994. Three van Veen garbs (0.1 $m^2$) were taken at each station. Organisms (1.0-mm mesh screen) were consistently identified to family level (annelids and molluscs) or higher (all other phyla). Water depth, silt-clay (s-c) and total organic carbon (toc) (top 2 centimeters of sediment) were as follows. Station 5, 116 m, 56% s-c, 1% toc; Station 11, 136 m, 98% s-c, 2.7% toc; Station 12, 82 m, 98% s-c, 2.1% toc; Station 14, 53 m, 51% s-c, 1.6% toc. Note the high abundance of molluscs and the low abundance of crustacea at hypoxic stations. The bivalve *Axinopsida serricata* accounted for 57%-61% of all organisms at Station 12, and 49%-55% of all organisms at Station 14.

South Hood Canal stations exhibited some of the lowest abundances recorded in the MSMP. In addition, south Hood Canal at Great Bend (Station 17) was strongly dominated by *Axinopsida serricata*. This was also shown in the short-term study conducted in September 1994 (Figure 36). Changes in benthic macro-invertebrate abundance and composition in Hood Canal in relation to DO are in general agreement with findings from the ecological and physiological literature which suggest that polychaetes are more tolerant of hypoxia than crustaceans, and that bivalves are variously affected (Theede *et al.*, 1969; Harper *et al.*, 1981; Gaston, 1985). Some species exhibit physiological and behavioral adaptations to low DO and hydrogen sulfide (Llansó, 1991; 1992). Most bivalves of the family Thyasiridae, to which *Axinopsida serricata* belongs, form a symbiosis with sulfur-oxidizing bacteria (Southward, 1986). It is possible that *Axinopsida* harbors chemosynthetic bacteria, but bacterial associations in *Axinopsida* have not been investigated.

Of course, low DO can only be hypothesized as one factor structuring benthic infaunal communities in Puget Sound. Further monitoring in susceptible areas is needed. A gradual decline in species number is expected to occur along the estuarine gradient as natural factors such as changes in water circulation, salinity, temperature, and sedimentation rates impose physiological and ecological barriers to the establishment of species populations. High sedimentation rates and organic input, for example, would be expected in quiescent regions of south Puget Sound. Elevated concentrations of total organic carbon, relative to other stations in the MSMP, were generally measured in inlet ends of south Puget Sound.

Data presented in this report suggest that low DO may be an important but overlooked factor structuring some benthic assemblages in Puget Sound. Also, other factors such as reduced interstitial salinity at ground water seeps may be important (Jack Word, Battelle Marine Sciences Laboratory, pers. comm.) and remain to be investigated. The identification of natural stresses in monitoring programs should constitute a priority because these factors may confound interpretation of pollution effects. Because contaminants tend to accumulate in fine sediments in urban areas typically associated with river mouths and bays, benthic communities in these areas are likely to be exposed to a variety of stresses, both natural and anthropogenic. Alterations to community structure cannot be unambiguously attributed to pollution without at least a rudimentary understanding of the natural processes that regulate benthic species abundance and composition in soft-sediments.

# Evaluation of the MSMP and Recommendations

## Design

In association with concurrent measures of sediment chemistry and toxicity, the benthic component of the MSMP provides valuable information on the general condition of benthic assemblages in Puget Sound. This information is essential to discern and evaluate potential anthropogenic influences. The information also may be useful in establishing criteria and reference ranges to which data from polluted sites can be compared. In the following sections, we evaluate the design of the benthic monitoring component of the MSMP, suggest improvements, and provide recommendations

- The information generated by the present design of the MSMP was successful at characterizing benthic communities in Puget Sound. Also, the data were useful to evaluate community health at specific locations, *i.e.*, those stations sampled by the MSMP. However, the health of the community could not be evaluated on a system-wide basis because of limited spatial coverage and the non-random nature of the sampling design. To overcome these limitations, we recommend the use of a probabilistic design (*e.g.*, stratified random sampling) and increased spatial extent (see Volume 1).

- In general, the benthic data set may be used to calculate benthic community reference values representative of uncontaminated soft-bottom habitats in Puget Sound (*e.g.*, Striplin, 1996), with the following caveats. First, it must be kept in mind that the stations are not representative of the full range of biological, physical, chemical, and hydrodynamic characteristics of Puget Sound sediments. Bias may be introduced if stations that do not integrate a variety of oceanographic conditions are grouped on the basis of, say, one or two substrate characteristics. Classification analyses became essential to establishing groups of stations and elucidating which environmental factors were most strongly related to group separation. However, additional physical, chemical and biological parameters should be measured and included in the analysis.

  Second, we should remember that benthic communities respond to multiple stressors, acting separately or in combination. For example, in this report we have identified water-column low DO and possibly hydrogen sulfide in sediments as potentially important natural factors affecting community structure. Therefore, variability due to natural factors is an integral part of the data set. Depressions in benthic measures should not be automatically equated with pollution effects. There is no reason to exclude this variability from the data set unless that natural stressors are measured and there is an explicit desire to partition the variability due to these stressors.

- One of the limitations of the present monitoring design is that it does not allow for the discrimination of the effects of pollution from the effects of natural phenomena. Should the program be expanded to cover gradients of pollution in urban sediments, the importance of natural stressors should be specifically evaluated. This will ensure that differences in the presence of human impacts are not merely due to environmental attributes differing between two areas.

- We need to discriminate between the effects of different types of human-induced stresses on benthic communities. Responses to organic enrichment may differ substantially from those to chemical toxicity. For example, some species respond to organic enrichment through high reproductive output. While organic enrichment often elicits shifts in the dominance patterns of opportunistic species, chemical toxicity induces mortality of the most sensitive species in the community. The degree of tolerance to toxic compounds varies among species (*e.g.*, Eisler and Hennekey, 1977), depending on the presence or absence of physiological or behavioral adaptations to adverse sediment quality conditions. Sensitive species may disappear from the community in affected areas, resulting in a shift in favor of tolerant species.

- Changes in the abundance of opportunist species can vary dramatically with time. Environmental monitoring programs should therefore include a temporal component, where both reference and putatively impacted areas are sampled at appropriate small (e.g., months) to large (e.g., years) temporal scales. Estimating population size from samples taken at one sampling location once a year may result in differences in abundance between two areas that are due to intrinsic factors of variation in the population of a species, seasonal changes, or time lags, rather than to sediment quality. Results presented in this report suggest that species composition in Puget Sound is relatively stable, but that large fluctuations in abundance may be associated with the top dominant species.

  Obtaining accurate density estimates is important to avoid confounding temporal patterns of variation in species abundance with spatial variation. For example, in the MSMP the spatial variation of some species was of similar or larger magnitude than the temporal variation. For these species, we cannot exclude the possibility that the observed annual trends in abundance are in fact artifacts associated with the choice of sampler or with the number of samples collected.

- Ecological processes structuring benthic communities are complex. To begin to understand the myriad of interactions between the benthic organisms and the environment, we first need to describe the community. In this context, the absence of especially sensitive species in areas affected by pollution may provide the first indication of impacts at the community level. The nodal analysis data presented in this report should be useful as a first step towards the identification of sensitive and tolerant species in the Puget Sound region. In the future, benthic data collected along stronger gradients of pollution should be compared to data in this report to delineate sensitive/tolerant species lists.

## Sieve Size and Taxonomic Resolution

Benthic samples were collected with a van Veen grab and the sediments were sieved through a 1.0-mm screen. The animal size fraction investigated is important because it generally influences the sensitivity of community measures, especially diversity indices. Taxa with small, opportunistic members tend to dominate in contaminated sediments. Therefore, differences in community measures between contaminated and uncontaminated sites may become more evident when smaller macrofauna (0.25 or 0.5-mm sieve) are included in the samples.

Ferraro and Cole (1992) have assessed the taxonomic level and the mesh size sufficient for detecting impacts on benthic communities in Puget Sound. Overall, moderate benthic impacts could be detected with 5-7 0.06-$m^2$ box-corers, samples sieved through a 1.0-mm mesh, and identification to family. Sampling unit area (*i.e.*, 0.06-$m^2$ box corer vs. 0.1-$m^2$ van Veen) appeared to have little effect on taxonomic sufficiency. For number of taxa, identification to family level and 1.0-mm mesh sieve were sufficient to identify pollution effects. However, species-level identification was required for diversity indices. Also, taxonomic identity may be useful when interpreting diversity indices because diversity is influenced by many additional factors.

Recent studies (Warwick and Clarke, 1993) also have shown that disturbance effects are detectable with multivariate methods at higher taxonomic levels than species. However, species-level data may be necessary to detect subtle changes in community measures in response to small pollution increases.

- We recommend that species-level identifications be continued, but that exploratory analyses be conducted to determine optimum cost-efficient sampling designs. Adopting a comprehensive approach to sediment monitoring will increase the range of contaminant concentrations. Differences between stations may then change from subtle or moderate to large impacts. With a stronger gradient of pollution, identification to higher taxonomic levels may be sufficient for detecting impacts. Nonetheless, designs that are sensitive to detecting small changes in community measures will be able to detect pollution effects before major changes in the community occur.

## Replication

Based on data collected by the MSMP, we calculated the theoretical number of samples necessary to achieve a precision of 0.2 (the allowable size of the ratio of the standard error to the mean) in the estimate of total abundance. For most stations, the theoretical number of samples needed was less than four. Fifty-nine percent of the stations had a precision smaller than 0.10, 35% had a precision of 0.10-0.19, and only 6% achieved a precision larger than 0.2. Therefore, five replicates appear to be adequate to characterize total population density. However, as suggested by data presented in this report, precise estimates of species abundances are likely to require increased sampling effort.

- The number of replicates will ultimately depend on the objectives and questions formulated in the revised program. If the aim of a monitoring program is to statistically identify changes in some community parameter along a gradient of pollution, the minimum sample size should be estimated from preliminary data collected along the gradient, and will depend on the minimum detectable difference desired, the population variance, and the power of the test. Another objective may be to describe diversity patterns and monitor trends over time. In this case, we recommend that diversity curves be constructed to estimate the number of samples necessary to ensure that a majority of species are collected. Data presented in this report suggest that benthic communities in Puget Sound consist of many rare species. Therefore, diversity is probably underestimated with the current level of replication effort.

## Biomass

Communities in Puget Sound are species-rich and comprise many organisms that are considered indicators of equilibrium conditions, such as terebellid and maldanid polychaetes, cerianthid anthozoans, and echinoderms. Because these are relatively large invertebrates and may not be adequately sampled, their contribution to the community may be overlooked if only densities of organisms are examined.

- We recommend that the use of biomass measures (*e.g.*, ash-free dry weights in major taxonomic groups) be explored as an indicator of community health. Abundance-biomass comparisons such as those described by Warwick (1986) may prove to be useful tools for the detection of changes along the pollution gradient.

# Conclusions

- Puget Sound exhibits rich infaunal assemblages that are primarily associated with sediment type and water depth, and secondarily with geographical location.
- In general, patterns in species abundance and composition appeared to be unrelated to low or moderate contaminant concentrations at sampling locations. Instead, there was an association between low abundance or species number and locations prone to the development of low dissolved oxygen (DO) episodes.
- The identification of natural stresses such as low DO in monitoring programs should be made a priority because these factors may confound interpretation of pollution effects.
- Twenty species showed large increases or decreases in abundance. The association of one of these species (the polychaete *Aphelochaeta* sp.) with sediment contamination and organic enrichment may be useful as indication of pollution. Other tolerant/sensitive species in the Puget Sound region should be identified from more comprehensive monitoring programs with increased spatial coverage.
- The study initiated in this report represents the first system-wide effort to characterize benthic assemblages in the Puget Sound region (Olympia to the Canadian border and west to Port Angeles), and constitutes a first step toward the development of reference standards for assessing benthic environmental conditions in Puget Sound.

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# Appendix A

## Sediment Composition

Appendix A. Percent gravel (Gr), sand (Sa), silt (Si), clay (Cl), and sediment class at MSMP stations, 1989-1993. Replicate samples are averaged, and values rounded. For sediment class criteria see text. Dominance of sand or silt in mixed sediments is indicated in parenthesis. Blanks denote stations not sampled in a given year. For station location, see Table 1.

| | 1989 | | | | | 1990 | | | | | 1991 | | | | | 1992 | | | | | 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class |
| 1 | 0 | 7 | 70 | 23 | clay | 0 | 3 | 71 | 26 | clay | 0 | 4 | 70 | 26 | clay | 0 | 6 | 68 | 27 | clay | 0 | 6 | 66 | 28 | clay |
| 2R | 0 | 50 | 38 | 12 | mixed (sa) | | | | | | 0 | 42 | 41 | 17 | mixed (sa+si) | | | | | | | | | | |
| 3 | 34 | 34 | 26 | 7 | mixed (sa+gr) | 24 | 31 | 31 | 14 | mixed (s+s+g) | 8 | 29 | 43 | 21 | mixed (si) | 16 | 33 | 34 | 17 | mixed (s+s+g) | 7 | 34 | 36 | 23 | mixed (s+s+g) |
| 4 | 0 | 7 | 71 | 23 | clay | 0 | 2 | 56 | 42 | clay | 0 | 2 | 52 | 46 | clay | 0 | 3 | 54 | 43 | clay | 0 | 2 | 50 | 48 | clay |
| 5 | 0 | 4 | 71 | 25 | clay | 0 | 3 | 66 | 32 | clay | 0 | 4 | 60 | 35 | clay | 0 | 5 | 61 | 33 | clay | 0 | 4 | 63 | 34 | clay |
| 8 | 1 | 33 | 49 | 17 | mixed (si) | 0 | 36 | 45 | 19 | mixed (si) | 0 | 36 | 46 | 17 | mixed (si) | 0 | 28 | 51 | 21 | mixed (si) | 2 | 30 | 47 | 21 | mixed (si) |
| 9R | | | | | | | | | | | 3 | 96 | 0 | 1 | sand+gravel | | | | | | | | | | |
| 10R | 0 | 63 | 26 | 12 | mixed (sa) | | | | | | 0 | 67 | 23 | 10 | silty sand | | | | | | | | | | |
| 11R | 0 | 75 | 15 | 9 | silty sand | | | | | | 0 | 71 | 18 | 11 | silty sand | | | | | | | | | | |
| 12 | 0 | 9 | 66 | 24 | clay | 0 | 7 | 65 | 28 | clay | 0 | 8 | 65 | 27 | clay | 0 | 7 | 65 | 28 | clay | 0 | 8 | 63 | 29 | clay |
| 13R | 0 | 90 | 6 | 3 | sand | | | | | | 0 | 90 | 7 | 3 | sand | | | | | | | | | | |
| 14 | 0 | 72 | 17 | 10 | silty sand | 0 | 63 | 23 | 14 | mixed (sa) | 0 | 62 | 24 | 14 | mixed (sa) | 0 | 52 | 31 | 17 | mixed (sa) | 0 | 75 | 16 | 9 | silty sand |
| 15 | 0 | 91 | 5 | 3 | sand | 0 | 95 | 3 | 2 | sand | 0 | 94 | 3 | 3 | sand | 0 | 95 | 3 | 2 | sand | 0 | 93 | 3 | 4 | sand |
| 17 | 1 | 7 | 63 | 29 | clay | 0 | 2 | 68 | 30 | clay | 0 | 6 | 62 | 32 | clay | 0 | 3 | 65 | 32 | clay | 0 | 5 | 62 | 33 | clay |
| 18 | 0 | 40 | 38 | 22 | mixed (sa+si) | 0 | 8 | 54 | 38 | clay | 0 | 58 | 21 | 21 | mixed (sa) | 0 | 57 | 21 | 22 | mixed (sa) | 0 | 68 | 16 | 16 | mixed (sa) |
| 19 | 0 | 19 | 34 | 48 | clay | 0 | 17 | 37 | 46 | clay | 0 | 18 | 33 | 49 | clay | 0 | 19 | 32 | 50 | clay | 0 | 19 | 32 | 49 | clay |
| 20 | 0 | 6 | 73 | 21 | clay | 0 | 3 | 66 | 31 | clay | 0 | 4 | 61 | 36 | clay | 0 | 4 | 64 | 31 | clay | 0 | 8 | 62 | 30 | clay |
| 21 | 0 | 48 | 46 | 6 | mixed (sa+si) | 0 | 39 | 49 | 12 | mixed (si) | 0 | 20 | 63 | 18 | mixed (si) | 0 | 38 | 48 | 14 | mixed (si) | 0 | 33 | 53 | 14 | mixed (si) |
| 22 | 0 | 96 | 3 | 2 | sand | 1 | 94 | 3 | 3 | sand | 0 | 87 | 6 | 7 | sand | 0 | 92 | 2 | 6 | sand | 0 | 94 | 2 | 4 | sand |
| 23R | 2 | 96 | 1 | 1 | sand | | | | | | | | | | | 1 | 96 | 1 | 2 | sand | | | | | |
| 24R | 0 | 13 | 48 | 39 | clay | | | | | | | | | | | 0 | 10 | 52 | 38 | clay | | | | | |
| 25R | 0 | 98 | 0 | 1 | sand | | | | | | | | | | | 0 | 97 | 1 | 3 | sand | | | | | |
| 26 | 0 | 84 | 9 | 7 | (1) | 0 | 79 | 11 | 10 | (1) | 53 | 30 | 9 | 8 | (1) | 0 | 73 | 14 | 13 | silty sand | 0 | 76 | 13 | 11 | silty sand |
| 27R | 0 | 97 | 1 | 2 | sand | | | | | | | | | | | 0 | 97 | 1 | 2 | sand | | | | | |
| 29 | 0 | 17 | 69 | 14 | mixed | 0 | 7 | 59 | 34 | clay | 0 | 16 | 51 | 33 | clay | 0 | 12 | 55 | 33 | clay | 0 | 21 | 49 | 30 | clay |
| 30 | 0 | 44 | 48 | 8 | mixed (sa+si) | 0 | 38 | 46 | 16 | mixed (si) | 0 | 77 | 17 | 6 | silty sand | 0 | 64 | 25 | 11 | mixed (sa) | 0 | 49 | 37 | 14 | mixed (sa) |
| 32 | 0 | 93 | 3 | 4 | sand | 0 | 93 | 3 | 5 | sand | 0 | 87 | 9 | 5 | sand | 0 | 94 | 3 | 3 | sand | 0 | 94 | 2 | 4 | sand |
| 33 | 1 | 75 | 19 | 5 | silty sand | 4 | 62 | 23 | 11 | silty sand | 0 | 93 | 3 | 4 | sand | 2 | 65 | 24 | 9 | silty sand | 6 | 65 | 21 | 8 | silty sand+gr |
| 34 | 0 | 8 | 72 | 20 | clay | 0 | 5 | 62 | 33 | clay | 0 | 7 | 59 | 34 | clay | 1 | 10 | 59 | 31 | clay | 8 | 10 | 54 | 28 | clay |
| 35 | 0 | 21 | 69 | 10 | mixed (si) | 0 | 18 | 53 | 30 | clay | 0 | 20 | 48 | 32 | clay | 0 | 19 | 51 | 29 | clay | 0 | 20 | 51 | 29 | clay |
| 36R | 0 | 98 | 1 | 2 | sand | | | | | | | | | | | 0 | 97 | 1 | 2 | sand | | | | | |

Appendix A. Continued.

| Station | 1989 Gr | 1989 Sa | 1989 Si | 1989 Cl | 1989 Class | 1990 Gr | 1990 Sa | 1990 Si | 1990 Cl | 1990 Class | 1991 Gr | 1991 Sa | 1991 Si | 1991 Cl | 1991 Class | 1992 Gr | 1992 Sa | 1992 Si | 1992 Cl | 1992 Class | 1993 Gr | 1993 Sa | 1993 Si | 1993 Cl | 1993 Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37R | 1 | 93 | 4 | 2 | sand | | | | | | | | | | | 16 | 81 | 1 | 2 | sand+gravel | | | | | |
| 38 | 0 | 7 | 50 | 42 | clay | 0 | 2 | 48 | 51 | clay | 0 | 5 | 44 | 51 | clay | 0 | 7 | 47 | 46 | clay | 0 | 3 | 47 | 50 | clay |
| 39 | 0 | 98 | 0 | 1 | sand | 0 | 98 | 1 | 1 | sand | 0 | 97 | 1 | 2 | sand | 0 | 97 | 1 | 2 | sand | 0 | 96 | 1 | 3 | sand |
| 40 | 1 | 84 | 11 | 4 | sand | 0 | 72 | 21 | 7 | silty sand | 0 | 67 | 24 | 9 | silty sand | 1 | 67 | 22 | 10 | silty sand | 0 | 68 | 21 | 11 | silty sand |
| 41 | 0 | 19 | 69 | 12 | mixed (si) | 0 | 34 | 56 | 10 | mixed (si) | 0 | 30 | 60 | 10 | mixed (si) | 0 | 25 | 59 | 16 | mixed (si) | 0 | 15 | 66 | 19 | mixed (si) |
| 43 | 0 | 94 | 3 | 3 | sand | 0 | 93 | 3 | 4 | sand | 0 | 94 | 3 | 3 | sand | 0 | 94 | 3 | 3 | sand | 0 | 93 | 3 | 4 | sand |
| 44 | 1 | 84 | 10 | 5 | sand | 1 | 85 | 8 | 7 | sand | 0 | 83 | 9 | 8 | sand | 0 | 82 | 8 | 9 | sand | 1 | 82 | 9 | 9 | sand |
| 45 | 1 | 44 | 46 | 9 | mixed (sa+si) | 0 | 40 | 38 | 22 | mixed (si) | 0 | 40 | 41 | 19 | mixed (sa+si) | 0 | 44 | 39 | 17 | mixed (sa) | 0 | 48 | 36 | 16 | mixed (sa) |
| 46R | 7 | 83 | 8 | 2 | sand | 0 | 81 | 13 | 6 | sand | | | | | | | | | | | 0 | 78 | 16 | 6 | silty sand |
| 47 | 0 | 77 | 16 | 8 | silty sand | 4 | 84 | 6 | 6 | sand+gravel | 26 | 64 | 5 | 5 | sand+gravel | 13 | 73 | 7 | 6 | sand+gravel | 22 | 63 | 8 | 7 | sand+gravel |
| 48 | 3 | 16 | 45 | 36 | clay | 0 | 8 | 37 | 55 | clay | 0 | 10 | 55 | 35 | clay | 0 | 11 | 56 | 33 | clay | 0 | 10 | 60 | 30 | clay |
| 49 | 0 | 12 | 58 | 30 | clay | 0 | 3 | 62 | 35 | clay | 0 | 16 | 50 | 34 | clay | 0 | 12 | 55 | 33 | clay | 0 | 16 | 50 | 34 | clay |
| 69 | | | | | | 0 | 85 | 10 | 5 | sand | 0 | 79 | 15 | 6 | silty sand | 0 | 82 | 12 | 6 | sand | 0 | 81 | 13 | 6 | sand |
| 70 | | | | | | 0 | 36 | 40 | 24 | clay | 0 | 32 | 43 | 24 | clay | 0 | 33 | 41 | 26 | clay | 0 | 50 | 29 | 21 | mixed (sa) |
| 71 | | | | | | 0 | 54 | 27 | 19 | mixed (sa) | 0 | 44 | 38 | 18 | mixed (sa) | 0 | 47 | 33 | 21 | mixed (sa) | 0 | 46 | 35 | 19 | mixed (sa) |
| 101R | | | | | | 0 | 10 | 63 | 27 | clay | | | | | | | | | | | 0 | 14 | 58 | 28 | clay |
| 102R | | | | | | 0 | 12 | 54 | 34 | clay | | | | | | | | | | | 12 | 26 | 37 | 25 | clay |
| 103R | | | | | | 0 | 92 | 3 | 5 | sand | | | | | | | | | | | 0 | 91 | 4 | 5 | sand |
| 104R | | | | | | 0 | 2 | 59 | 39 | clay | | | | | | | | | | | 0 | 9 | 57 | 34 | clay |
| 105R | | | | | | 1 | 24 | 46 | 29 | clay | | | | | | | | | | | 0 | 29 | 44 | 27 | clay |
| 106R | | | | | | 1 | 13 | 55 | 31 | clay | | | | | | | | | | | 0 | 7 | 59 | 34 | clay |
| 109R | | | | | | 1 | 8 | 65 | 26 | clay | | | | | | | | | | | 0 | 16 | 62 | 22 | clay |
| 110R | | | | | | 0 | 9 | 58 | 33 | clay | | | | | | | | | | | 4 | 21 | 50 | 25 | clay |
| 111R | | | | | | 0 | 64 | 19 | 17 | mixed (sa) | | | | | | | | | | | 0 | 33 | 41 | 26 | clay |
| 112R | | | | | | 0 | 99 | 0 | 1 | sand | | | | | | | | | | | 0 | 97 | 0 | 3 | sand |
| 113R | | | | | | 0 | 80 | 13 | 7 | sand | | | | | | | | | | | 0 | 84 | 10 | 6 | sand |
| 114R | | | | | | 0 | 13 | 66 | 21 | clay | | | | | | | | | | | 0 | 14 | 63 | 23 | clay |
| 115R | | | | | | 0 | 28 | 53 | 19 | mixed (si) | | | | | | | | | | | 0 | 25 | 57 | 18 | mixed (si) |
| 201R | | | | | | | | | | | 0 | 78 | 14 | 8 | silty sand | | | | | | | | | | |
| 202R | | | | | | | | | | | 0 | 75 | 17 | 8 | silty sand | | | | | | | | | | |
| 203R | | | | | | | | | | | 0 | 1 | 54 | 45 | clay | | | | | | | | | | |
| 204R | | | | | | | | | | | 0 | 6 | 59 | 35 | clay | | | | | | | | | | |
| 205R | | | | | | | | | | | 1 | 37 | 43 | 19 | mixed (si) | | | | | | | | | | |
| 206R | | | | | | | | | | | 0 | 64 | 23 | 12 | mixed (sa) | | | | | | | | | | |

Appendix A. Concluded.

| | 1989 | | | | | 1990 | | | | | 1991 | | | | | 1992 | | | | | 1993 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class | Gr | Sa | Si | Cl | Class |
| 207R | | | | | | | | | | | 0 | 26 | 48 | 26 | clay | | | | | | | | | | |
| 208R | | | | | | | | | | | 1 | 9 | 51 | 39 | clay | | | | | | | | | | |
| 209R | | | | | | | | | | | 0 | 66 | 27 | 7 | silty sand | | | | | | | | | | |
| 301R | | | | | | | | | | | | | | | | 7 | 87 | 3 | 3 | sand | | | | | |
| 302R | | | | | | | | | | | | | | | | 0 | 31 | 47 | 21 | mixed (si) | | | | | |
| 303R | | | | | | | | | | | | | | | | 0 | 23 | 57 | 19 | mixed (si) | | | | | |
| 304R | | | | | | | | | | | | | | | | 0 | 3 | 43 | 54 | clay | | | | | |
| 305R | | | | | | | | | | | | | | | | 0 | 6 | 54 | 40 | clay | | | | | |
| 306R | | | | | | | | | | | | | | | | 0 | 91 | 4 | 5 | sand | | | | | |
| 307R | | | | | | | | | | | | | | | | 0 | 4 | 47 | 49 | clay | | | | | |
| 308R | | | | | | | | | | | | | | | | 0 | 89 | 5 | 6 | sand | | | | | |

(1) Station 26 not used in classification analysis 1989-1991.

# Appendix B

## Taxonomic Listing of Macro-invertebrates

Appendix B. Taxonomic listing of macro-invertebrates found in the MSMP, 1989-1993. Unid. = unidentified to genus or species level. The hierarchical arrangement of phyla and classes follows Kozloff's (1987) "Marine Invertebrates of the Pacific Northwest". Families and species are listed alphabetically. Species names and authorship are based primarily on SCAMIT's "Taxonomic Listing of Soft Bottom Macro- and Megainvertebrates" (Third Edition, June 1998), but other sources have also been used. Synonyms are given only in the case of names that have recently been changed and the new name was not included in database files at the time of report preparation.

| Phylum/Class/Family | Species | |
|---|---|---|
| **PORIFERA** | | |
| **Calcarea** | | |
| Leucosoleniidae | | |
| | *Leucosolenia* sp. | |
| **Demospongiae** (unid.) | | |
| **CNIDARIA** | | |
| **Hydrozoa** | | |
| Aglaopheniidae | | |
| | *Aglaophenia* sp. | |
| Bougainvilliidae | | |
| | *Perigonimus* sp | Sars, 1846 |
| | *Perigonimus yoldiarcticae* | Birula, 1897 |
| Campanulariidae | | |
| | *Campanularia* sp | Lamarck, 1816 |
| | *Obelia bidentata* | Clark, 1875 |
| | *Obelia dichotoma* | (Linnaeus, 1758) |
| Campanulinidae (unid.) | | |
| Cladonematidae | | |
| | *Cladonema* sp. A | |
| Corymorphidae | | |
| | *Euphysa ruthae* | Norenburg & Morse, 1983 |
| Corynidae | | |
| | *Coryne* sp | Gaertner, 1774 |
| Eudendriidae | | |
| | *Eudendrium* sp | Ehrehberg, 1834 |
| Haleciidae | | |
| | *Halecium* sp | Oken, 1815 |
| Hydractiniidae | | |
| | *Hydractinia aggregata* | Fraser, 1922 |
| | *Stylactis* sp | Allman, 1864 |

| Phylum/Class/Family | Species | |
|---|---|---|
| Lafoeidae | | |
| | *Grammaria* sp. | |
| | *Lafoea* sp. | Lamouroux, 1821 |
| | *Lafoea fruticosa* | Sars, 1863 |
| Sertulariidae | | |
| | *Abietinaria* sp. | Kirchenpauer, 1884 |
| | *Hydrallmania* sp. | |
| | *Hydrallmania distans* | Nutting, 1899 |
| | *Selaginopsis mirabilis* | (Verrill, 1872) |
| | *Sertularella* sp | Gray, 1848 |
| | *Thuiaria* sp. | Fleming, 1828 |
| Tubulariidae | | |
| | *Tubularia* sp. | Linnaeus, 1758 |
| **Anthozoa** | | |
| Actiniidae | | |
| | *Urticina coriacea* | (Cuvier, 1798) |
| Cerianthidae | | |
| | *Pachycerianthus fimbriatus* | McMurrich, 1910 |
| | *Ceriantharia* sp | |
| | *Ceriantharia* sp E | Swainson, 1840 |
| Diadumenidae | | |
| | *Diadumene* sp. | Stephenson, 1920 |
| Edwardsiidae | | |
| | *Edwardsia* sp | Quatrefages, 1842 |
| | *Edwardsia sipunculoides* | (Stimpson, 1853) |
| Halcampidae | | |
| | *Halcampa* sp. | |
| | *Halcampa decemtentaculata* | Hand, 1954 |
| | *Halcampoides purpurea* | (Studer, 1878) |
| Limnactiniidae | | |
| | Limnactiniidae sp. A | SCAMIT, 1989 |
| Metridiidae | | |
| | *Metridium* sp. | Oken, 1815 |
| | *Metridium senile* | (Linnaeus, 1767) |
| Pennatulidae | | |
| | *Ptilosarcus gurneyi* | (Gray, 1860) |
| Virgulariidae | | |
| | *Acanthoptilum* sp. | Kolliker, 1870 |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Stylatula elongata* | (Gabb, 1862) |
| | *Stylatula* sp. A | Ljubenkov, 1991 |
| | *Virgularia* sp | Lamarck, 1816 |
| | *Virgularia bromleyi* | Kolliker, 1880 |
| **PLATYHELMINTHES** | | |
| **Turbellaria** | | |
| Euryleptidae | | |
| | *Acerotisa alba* | (Freeman, 1933) |
| Leptoplanidae (unid.) | | |
| Notoplanidae | | |
| | *Notoplana* sp. | Laidlaw, 1903 |
| Planoceridae | | |
| | Planoceridae sp. A | |
| Stylochidae | | |
| | *Stylochus exiguus* | Hyman, 1953 |
| **NEMERTINA** | | |
| **Anopla** | | |
| Carinomidae | | |
| | *Carinoma* sp. | Oudemans, 1885 |
| | *Carinoma mutabilis* | Griffin, 1898 |
| Lineidae | | |
| | *Cerebratulus* sp. | Renier, 1804 |
| | *Lineus* sp. | Sowerby, 1806 |
| | *Micrura* sp | Ehrenberg, 1831 |
| Tubulanidae | | |
| | *Tubulanus* sp. | Renier, 1804 |
| | *Tubulanus capistratus* | (Coe, 1901) |
| | *Tubulanus frenatus* | (Coe, 1904) |
| | *Tubulanus nothus* | (Berger, 1892) |
| | *Tubulanus polymorphus* | (Renier, 1804) |
| **Enopla** | | |
| Amphiporidae | | |
| | *Amphiporus* sp. | Ehrenberg, 1831 |
| | *Zygonemertes* sp. | Montgomery |
| | *Zygonemertes virescens* | (Verrill, 1879) |

| Phylum/Class/Family | | Species | |
|---|---|---|---|
| | Emplectonematidae | | |
| | | *Paranemertes* sp. | Coe, 1901 |
| | | *Paranemertes californica* | Coe, 1904 |
| | | *Paranemertes peregrina* | Coe, 1901 |
| | Prosorhochmidae | | |
| | | *Oerstedia dorsalis* | (Abildgaard, 1806) |
| | | *Prosorhochmus albidus* | (Coe, 1905) |
| | Tetrastemmatidae | | |
| | | *Tetrastemma* sp. | Ehrenberg, 1831 |
| | | *Tetrastemma nigrifrons* | Coe, 1904 |
| **PRIAPULIDA** | | | |
| | Priapulidae | | |
| | | *Priapulus* sp | |
| | | *Priapulus caudatus* | Lamarck, 1816 |
| **ANNELIDA** | | | |
| **Polychaeta** | | | |
| | Ampharetidae | | |
| | | *Amage* sp. | Malmgren, 1866 |
| | | *Amage anops* | (Johnson, 1901) |
| | | *Ampharete* sp. | Malmgren, 1866 |
| | | *Ampharete acutifrons* | (Grube, 1860) |
| | | *Ampharete arctica* | Malmgren, 1866 |
| | | *Ampharete finmarchica* | (M. Sars, 1865) |
| | | *Ampharete goesi* | Malmgren, 1866 |
| | | *Ampharete labrops* | Hartman, 1961 |
| | | Ampharetinae (unid.) | |
| | | *Amphicteis* sp. | Grube, 1850 |
| | | *Amphicteis glabra* | Moore, 1905 |
| | | *Amphicteis mucronata* | Moore, 1923 |
| | | *Amphicteis scaphobranchiata* | Moore, 1906 |
| | | *Anobothrus gracilis* | (Malmgren, 1866) |
| | | *Asabellides* sp. | Annenkova, 1929 |
| | | *Asabellides lineata* | (Berkeley & Berkeley, 1943) |
| | | *Asabellides sibirica* | (Wiren, 1883) |
| | | *Lysippe* sp. | Malmgren, 1866 |
| | | *Lysippe labiata* | Malmgren, 1866 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Melinna* sp. | Malmgren, 1866 |
| | *Melinna elisabethae* (= *M. cristata*) | McIntosh, 1922 |
| | *Melinna oculata* | Hartman, 1969 |
| | *Mooresamytha bioculata* | (Moore, 1906) |
| | *Samytha californiensis* | Hartman, 1969 |
| | *Schistocomus hiltoni* | Chamberlin, 1919 |
| Aphroditidae | | |
| | *Aphrodita* sp. | Linnaeus, 1758 |
| | *Aphrodita japonica* | Marenzeller, 1879 |
| | *Aphrodita parva* | Moore, 1905 |
| Apistobranchidae | | |
| | *Apistobranchus ornatus* | Hartman, 1965 |
| Capitellidae | | |
| | *Barantolla americana* | Hartman, 1963 |
| | *Capitella capitata* | (Fabricius, 1780) |
| | *Decamastus gracilis* | Hartman, 1963 |
| | *Heteromastus* sp. | Eisig, 1887 |
| | *Heteromastus filiformis* | (Claparède, 1864) |
| | *Heteromastus filobranchus* | Berkeley & Berkeley, 1932 |
| | *Mediomastus* sp. | Hartman, 1944 |
| | *Mediomastus ambiseta* | (Hartman, 1947) |
| | *Mediomastus californiensis* | Warren & Hutchings, 1994 |
| | *Notomastus* sp. | M. Sars, 1851 |
| | *Notomastus latericeus* | M. Sars, 1851 |
| | *Notomastus tenuis* | Moore, 1909 |
| | *Notomastus variegatus* | Berkeley & Berkeley, 1950 |
| Chaetopteridae | | |
| | *Chaetopterus* sp. | Cuvier, 1827 |
| | *Chaetopterus variopedatus* | (Renier, 1804) |
| | *Mesochaetopterus taylori* | Potts, 1914 |
| | *Phyllochaetopterus* sp. | Grube, 1863 |
| | *Phyllochaetopterus prolifica* | Potts, 1914 |
| | *Spiochaetopterus costarum* | (Claparède, 1870) |
| Chrysopetalidae | | |
| | *Paleanotus bellis* | (Johnson, 1897) |
| Cirratulidae | | |
| | *Aphelochaeta* spp. | |
| | *Aphelochaeta monilaris* | (Hartman, 1960) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Caulleriella* sp. | Chamberlin, 1919 |
| | *Caulleriella pacifica* (= *C. alata*) | |
| | *Caulleriella* sp. A | |
| | *Chaetozone* spp. | |
| | *Cirratulus* sp. | Lamarck, 1801 |
| | *Cirratulus cirratus* | (O. F. Müller, 1776) |
| | *Cirratulus spectabilis* | (Kinberg, 1866) |
| | *Cirriformia spirabranchia* | (Moore, 1904) |
| | *Monticellina* sp | Laubier, 1961 |
| | *Monticellina dorsobranchialis* | (Kirkegaard, 1959) |
| | *Monticellina tesselata* | (Hartman, 1960) |
| Cossuridae | | |
| | *Cossura* sp. | Webster & Benedict, 1887 |
| | *Cossura bansei* [as *C. modica* in files] | Hilbig, 1996 |
| | *Cossura longocirrata* | Webster & Benedict, 1897 |
| | *Cossura pygodactylata* | Jones, 1956 |
| Dorvilleidae | | |
| | *Dorvillea (D.)* sp | |
| | *Dorvillea (D.) pseudorubrovittata* | E. Berkeley, 1927 |
| | *Dorvillea (Schistomeringos) annulata* | (Moore, 1906) |
| | *Dorvillea (Schistomeringos) rudolphi* | (delle Chiaje, 1828) |
| | Dorvilleidae sp. Z | |
| | *Parougia caeca* | (Webster & Benedict, 1884) |
| | *Protodorvillea gracilis* | (Hartman, 1938) |
| Flabelligeridae | | |
| | *Brada* sp. | Stimpson, 1854 |
| | *Brada sachalina* | Annenkova, 1922 |
| | *Brada villosa* | (Rathke, 1843) |
| | *Flabelligera affinis* | M. Sars, 1829 |
| | *Pherusa* sp. | Oken, 1807 |
| | *Pherusa plumosa* | (O. F. Müller, 1776) |
| Glyceridae | | |
| | *Glycera* sp. | Savigny, 1818 |
| | *Glycera americana* | Leidy, 1855 |
| | *Glycera nana* | Johnson, 1901 |
| | *Glycera oxycephala* | Ehlers, 1887 |
| | *Glycera robusta* | Ehlers, 1868 |
| | *Glycera* sp. 1 | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Hemipodus borealis* | Johnson, 1901 |
| Goniadidae | | |
| | *Glycinde* sp. | F. Müller, 1858 |
| | *Glycinde armigera* | Moore, 1911 |
| | *Glycinde picta* | E. Berkeley, 1927 |
| | *Glycinde polygnatha* | Hartman, 1950 |
| | *Goniada* sp. | Audouin & Milne-Edwards, 1833 |
| | *Goniada annulata* | Moore, 1905 |
| | *Goniada brunnea* | Treadwell, 1906 |
| | *Goniada maculata* | Ørsted, 1843 |
| | *Goniada zonata* | |
| Hesionidae | | |
| | *Gyptis* sp. | |
| | Hesionidae sp. 1 | |
| | *Heteropodarke heteromorpha* | Hartmann-Schröder, 1962 |
| | *Kefersteinia cirrata* | (Keferstein, 1862) |
| | *Microphthalmus* sp. | Mecznikow, 1865 |
| | *Microphthalmus aberrans* | |
| | *Microphthalmus sczelkowii* | Metschnikow, 1865 |
| | *Micropodarke dubia* | (Hessle, 1925) |
| | *Ophiodromus pugettensis* | (Johnson, 1901) |
| | *Podarkeopsis glabrus* | (Hartman, 1961) |
| Lumbrineridae | | |
| | *Lumbrineris* sp. | De Blainville, 1828 |
| | *Lumbrineris bicirrata* | Treadwell, 1929 |
| | *Lumbrineris californiensis* | Hartman, 1944 |
| | *Lumbrineris cruzensis* | Hartman, 1944 |
| | *Lumbrineris inflata* | Moore, 1911 |
| | *Lumbrineris lagunae* | Fauchald, 1970 |
| | *Lumbrineris latreilli* | Audouin & Milne-Edwards, 1834 |
| | *Lumbrineris limicola* | Hartman, 1944 |
| | *Lumbrineris luti* | Berkeley & Berkeley, 1945 |
| | *Lumbrineris pallida* | Hartman, 1944 |
| | *Lumbrineris zonata* | (Johnson, 1901) |
| | *Ninoe gemmea* | Moore, 1911 |
| | *Ninoe palmata* | |
| | *Scoletoma fragilis* | |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| Magelonidae | | |
| | *Magelona* sp | F. Müller, 1858 |
| | *Magelona berkeleyi* | Jones, 1971 |
| | *Magelona longicornis* | Johnson, 1901 |
| | *Magelona sacculata* | Hartman, 1961 |
| | *Magelona* sp. 1 | |
| Maldanidae | | |
| | *Axiothella* sp. | Verrill, 1900 |
| | *Axiothella rubrocincta* | (Johnson, 1901) |
| | *Chirimia* sp. | Light, 1991 |
| | *Chirimia biceps* | (Sars, 1861) |
| | *Chirimia similis* | (Moore, 1906) |
| | *Clymenella* sp. | Verrill, 1873 |
| | *Clymenella complanata* | Hartman, 1969 |
| | *Clymenella torquata* | (Leidy, 1855) |
| | *Clymenura* sp. | Verrill, 1900 |
| | *Clymenura columbiana* | (E. Berkeley, 1929) |
| | *Clymenura gracilis* | Hartman, 1969 |
| | *Euclymene* sp. | Verrill, 1900 |
| | *Euclymene reticulata* | Moore, 1923 |
| | *Euclymene zonalis* | (Verrill, 1874) |
| | Euclymeninae (unid.) | |
| | *Isocirrus longiceps* | (Moore, 1923) |
| | *Macroclymene* sp. | Verrill, 1900 |
| | *Maldane* sp. | Grube, 1840 |
| | *Maldane sarsi* | Malmgren, 1865 |
| | *Maldanella robusta* | Moore, 1906 |
| | *Metasychis disparidenta* | (Moore, 1904) |
| | Nicomachinae (unid.) | |
| | *Nicomache* sp. | Malmgren, 1865 |
| | *Nicomache lumbricalis* | (Fabricius, 1780) |
| | *Nicomache personata* | Johnson, 1901 |
| | *Notoproctus* sp. | |
| | *Notoproctus pacificus* | (Moore, 1906) |
| | *Petaloproctus* sp. | Quatrefages, 1865 |
| | *Petaloproctus tenuis* | (Théel, 1879) |
| | *Petaloproctus tenuis borealis* | Arwidsson, 1907 |
| | *Praxillella gracilis* | (M. Sars, 1861) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Praxillella pacifica* | E. Berkeley, 1929 |
| | *Praxillella* sp. A | |
| | *Rhodine bitorquata* | Moore, 1923 |
| Nephtyidae | | |
| | *Nephtys* sp. | Cuvier, 1917 |
| | *Nephtys assignis* | Hartman, 1950 |
| | *Nephtys brachycephala* | Moore, 1903 |
| | *Nephtys caeca* | (Fabricius, 1780) |
| | *Nephtys caecoides* | Hartman, 1938 |
| | *Nephtys californiensis* | Hartman, 1938 |
| | *Nephtys ciliata* | (O. F. Müller, 1776) |
| | *Nephtys cornuta* | Berkeley & Berkeley, 1945 |
| | *Nephtys discors* | Ehlers, 1868 |
| | *Nephtys glabra* | Hartman, 1950 |
| | *Nephtys longosetosa* | Ørsted, 1843 |
| | *Nephtys punctata* | Hartman, 1938 |
| | *Nephtys signifera* | Hilbig, 1992 |
| | *Nephtys* sp. A (Commenc. Bay only) | |
| Nereidae | | |
| | *Cheilonereis cyclurus* | (Harrington, 1897) |
| | *Eunereis wailesi* | Berkeley & Berkeley, 1954 |
| | *Neanthes brandti* | (Malmgren, 1866) |
| | *Neanthes virens* | (M. Sars, 1835) |
| | *Nereis* sp. | Linnaeus, 1758 |
| | *Nereis procera* | Ehlers, 1868 |
| | *Nereis vexillosa* | Grube, 1851 |
| | *Platynereis bicanaliculata* | (Baird, 1863) |
| Oenonidae | | |
| | *Drilonereis* sp. | Claparède, 1870 |
| | *Drilonereis falcata* | Moore, 1911 |
| | *Drilonereis falcata minor* | Hartman, 1956 |
| | *Drilonereis longa* | Webster, 1879 |
| | *Drilonereis nuda* | Moore, 1909 |
| | *Notocirrus californiensis* | Hartman, 1944 |
| Onuphidae | | |
| | *Diopatra* sp. | Audouin & Milne-Edwards, 1833 |
| | *Diopatra ornata* | Moore, 1911 |
| | *Epidiopatra* sp. | Augener, 1918 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Epidiopatra hupferiana* | Berkeley, 1956 |
| | *Nothria* sp | Malmgren, 1867 |
| | *Nothria occidentalis* | Fauchald, 1968 |
| | *Onuphis* sp. | Audouin & Milne-Edwards, 1833 |
| | *Onuphis elegans* | (Johnson, 1901) |
| | *Onuphis geophiliformis* | Moore, 1903 |
| | *Onuphis iridescens* | Johnson, 1901 |
| Opheliidae | | |
| | *Armandia brevis* | (Moore, 1906) |
| | *Ophelia limacina* | (Rathke, 1843) |
| | *Ophelina acuminata* | Ørsted, 1843 |
| | *Ophelina breviata* | (Ehlers, 1913) |
| | *Travisia* sp | Johnston, 1840 |
| | *Travisia brevis* | Moore, 1923 |
| | *Travisia pupa* | Moore, 1906 |
| Orbiniidae | | |
| | *Leitoscoloplos panamensis* | (Monro, 1933) |
| | *Leitoscoloplos pugettensis* | (Pettibone, 1957) |
| | *Naineris quadricuspida* | (Fabricius, 1780) |
| | *Naineris uncinata* | Hartman, 1957 |
| | *Orbinia* sp. | |
| | *Phylo felix* | Kinberg, 1866 |
| | *Scoloplos* sp | Blainville, 1828 |
| | *Scoloplos acmeceps* | Chamberlin, 1919 |
| | *Scoloplos armiger* | (O. F. Müller, 1776) |
| Oweniidae | | |
| | *Galathowenia oculata* (= *M. oculata*) | (Zachs, 1923) |
| | *Myriochele* sp. | Malmgren, 1867 |
| | *Myriochele heeri* | Malmgren, 1867 |
| | *Myriochele* sp. M | SCAMIT, 1985 |
| | *Owenia fusiformis* | delle Chiaje, 1841 |
| Paraonidae | | |
| | *Aricidea* sp. | Webster, 1879 |
| | *Aricidea (Acmira) catherinae* | (Laubier, 1967) |
| | *Aricidea (Acmira) lopezi* | Berkeley & Berkeley, 1956 |
| | *Aricidea (Allia) nolani* | Webster & Benedict, 1887 |
| | *Aricidea (Allia) quadrilobata* | Webster & Benedict, 1887 |
| | *Aricidea (Allia) ramosa* | Annenkova, 1934 |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Aricidea (Aricidea) minuta* | Southward, 1956 |
| | *Aricidea neosuecica* | Hartman, 1965 |
| | *Aricidea wassi* | Pettibone, 1965 |
| | *Cirrophorus branchiatus* | Ehlers, 1908 |
| | *Levinsenia gracilis* | (Tauber, 1879) |
| | *Levinsenia oculata* | (Hartman, 1957) |
| | *Paradoneis lyra* | (Southern, 1914) |
| | *Paraonella platybranchia* | (Hartman, 1961) |
| Pectinariidae | | |
| | *Cistenides granulata* | (Linnaeus, 1767) |
| | *Pectinaria* sp. | Savigny, 1818 |
| | *Pectinaria californiensis* | Hartman, 1941 |
| Pholoidae | | |
| | *Pholoides asperus* | (Johnson, 1897) |
| Phyllodocidae | | |
| | *Bergstroemia nigrimaculata* | (Moore, 1909) |
| | *Eteone* sp. | Savigny, 1822 |
| | *Eteone californica* | Hartman, 1936 |
| | *Eteone pacifica* | Hartman, 1936 |
| | *Eteone pigmentata* | Blake, 1992 |
| | *Eteone spilotus* | Kravitz & Jones, 1979 |
| | *Eulalia (Eulalia)* sp | Savigny, 1822 |
| | *Eulalia (Eulalia)* sp. undescribed [as *E. levicornuta* in files] | |
| | *Eulalia (Eulalia) bilineata* | (Johnston, 1840) |
| | *Eulalia (Eulalia) quadrioculata* | Moore, 1906 |
| | *Eulalia (Eulalia) viridis* | (Linnaeus, 1767) |
| | *Eumida* sp. | Malmgren, 1865 |
| | *Eumida longicornuta* | (Moore, 1906) |
| | *Hesionura coineaui difficilis* | (Banse, 1963) |
| | *Nereiphylla* sp. | |
| | *Nereiphylla castanea* | (Marenzeller, 1879) |
| | *Notophyllum tectum* | (Chamberlin, 1919) |
| | *Paranaitis* sp | Southern, 1914 |
| | *Paranaitis polynoides* | (Moore, 1909) |
| | *Paranaitis wahlbergi* | |
| | *Phyllodoce* sp. | Lamarck, 1818 |
| | *Phyllodoce (Anaitides) cuspidata* | McCammon & Montagne, 1979 |
| | *Phyllodoce (Anaitides) groenlandica* | Ørsted, 1843 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Phyllodoce (Anaitides) longipes* | Kinberg, 1866 |
| | *Phyllodoce (Anaitides) maculata* | (Linnaeus, 1767) |
| | *Phyllodoce (Anaitides) medipapillata* | Moore, 1909 |
| | *Phyllodoce (Anaitides) mucosa* | Ørsted, 1843 |
| | *Phyllodoce (Anaitides) papillosa* | Uschakov & Wu, 1959 |
| | *Phyllodoce (Anaitides) williamsi* | (Hartman, 1936) |
| | *Phyllodoce (Aponaitides) hartmanae* | Blake & Walton, 1977 |
| | *Pterocirrus macroceros* | (Grube, 1860) |
| | *Sige bifoliata* | Moore, 1909 |
| | *Sige macrocirrus* | |
| | *Steggoa* sp. 1 | |
| Pilargidae | | |
| | *Parandalia fauveli* | (Berkeley & Berkeley, 1941) |
| | *Pilargis maculata* | Pettibone, 1966 |
| | *Sigambra tentaculata* | (Treadwell, 1941) |
| Pisionidae | | |
| | *Pisione* sp. | |
| | *Pisione* sp. 1 | |
| Polygordiidae | | |
| | *Polygordius* sp | |
| Polynoidae | | |
| | *Arcteobia anticostiensis* | (McIntosh, 1874) |
| | *Arctonoe* sp. | Chamberlin, 1920 |
| | *Arctonoe pulchra* | (Johnson, 1897) |
| | *Bylgides macrolepidus* | (Moore, 1905) |
| | *Eunoe* sp. | Malmgren, 1865 |
| | *Eunoe depressa* | Moore, 1905 |
| | *Eunoe uniseriata* | Banse & Hobson, 1968 |
| | *Gattyana* sp. | Mcintosh, 1900 |
| | *Gattyana ciliata* | Moore, 1902 |
| | *Gattyana cirrosa* | (Pallas, 1766) |
| | *Gattyana treadwelli* | Pettibone, 1949 |
| | *Grubeopolynoe tuta* | (Grube, 1855) |
| | Harmothoinae sp. A | |
| | *Harmothoe* sp. | Kinberg, 1855 |
| | *Harmothoe extenuata* | (Grube, 1840) |
| | *Harmothoe fragilis* | Moore, 1910 |
| | *Harmothoe imbricata* | (Linnaeus, 1767) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Harmothoe multisetosa* | (Moore, 1902) |
| | *Harmothoe* sp. A | |
| | *Hesperonoe* sp. | Chamberlin, 1919 |
| | *Hesperonoe adventor* | (Skogsberg, 1928) |
| | *Hesperonoe complanata* | (Johnson, 1901) |
| | *Hesperonoe laevis* | Hartman, 1961 |
| | *Lepidasthenia* sp | Malmgren, 1867 |
| | *Lepidasthenia berkeleyae* | Pettibone, 1948 |
| | *Lepidasthenia longicirrata* | E. Berkeley, 1923 |
| | *Lepidonotus squamatus* | (Linnaeus, 1767) |
| | *Malmgreniella* sp | Hartman, 1967 |
| | *Malmgreniella bansei* | Pettibone, 1993 |
| | *Malmgreniella liei* | Pettibone, 1993 |
| | *Malmgreniella macginitiei* | Pettibone, 1993 |
| | *Malmgreniella nigralba* | (E. Berleley, 1923) |
| | *Malmgreniella scriptoria* | (Moore, 1910) |
| | *Tenonia priops* | (Hartman, 1961) |
| Sabellariidae | | |
| | *Idanthyrsus saxicavus* | (Baird, 1863) |
| | *Neosabellaria cementarium* | (Moore, 1906) |
| Sabellidae | | |
| | *Chone* sp. | Kröyer, 1856 |
| | *Chone duneri* | Malmgren, 1867 |
| | *Chone ecaudata* | (Moore, 1923) |
| | *Chone magna* | (Moore, 1923) |
| | *Chone minuta* | Hartman, 1944 |
| | *Chone mollis* | (Bush, 1904) |
| | *Demonax* sp | Kinberg, 1867 |
| | *Demonax medius* | (Bush, 1904) |
| | *Demonax pacifica* | |
| | *Euchone incolor* | Hartman, 1965 |
| | *Euchone limnicola* | Reish, 1959 |
| | *Eudistylia* sp. | Bush, 1905 |
| | *Eudistylia catherinae* | Banse, 1979 |
| | *Eudistylia vancouveri* | (Kinberg, 1867) |
| | *Laonome kroyeri* | Malmgren, 1866 |
| | *Megalomma* sp. | Johansson, 1927 |
| | *Megalomma pigmentum* | Reish, 1963 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Megalomma splendida* | (Moore, 1905) |
| | *Myxicola infundibulum* | (Renier, 1804) |
| | *Potamethus* sp. | |
| | *Potamethus* sp. A | SCAMIT, 1986 |
| | *Potamilla* sp | Malmgren, 1866 |
| | *Potamilla intermedia* | Moore, 1905 |
| | *Potamilla myriops* | Marenzeller, 1884 |
| | *Potamilla neglecta* | (M. Sars, 1851) |
| | *Potamilla* nr. *neglecta* | |
| | *Potamilla occelata* | Moore, 1905 |
| | *Sabellastarte* sp. A | |
| | *Sabellastarte* sp. B | |
| | Sabellinae (unid.) | |
| Saccocirridae | | |
| | *Saccocirrus eroticus* | Gray, 1969 |
| Scalibregmidae | | |
| | *Asclerocheilus beringianus* | Ushakov, 1955 |
| | *Scalibregma inflatum* | Rathke, 1843 |
| Serpulidae | | |
| | *Hyalopomatus biformis* | (Hartman, 1960) |
| | *Pseudochitinopoma occidentalis* | (Bush, 1904) |
| | *Serpula* sp. | Linnaeus, 1767 |
| | *Serpula vermicularis* | Linnaeus, 1767 |
| Sigalionidae | | |
| | *Pholoe minuta* | (Fabricius, 1780) |
| | *Sigalion mathildae* | Audouin & Milne-Edwards, 1830 |
| | *Sthenelais* sp. | Kinberg, 1855 |
| | *Sthenelais berkeleyi* | Pettibone, 1971 |
| | *Sthenelais tertiaglabra* | Moore, 1910 |
| | *Thalenessa spinosa* | |
| Sphaerodoridae | | |
| | *Sphaerodoropsis minuta* | (Webster & Benedict, 1887) |
| | *Sphaerodoropsis sphaerulifer* | (Moore, 1909) |
| | *Sphaerodorum papillifer* | Moore, 1909 |
| Spionidae | | |
| | *Aonides oxycephala* | (Sars, 1862) |
| | *Aonides* sp. 1 | |
| | *Boccardia* sp. | Carazzi, 1893 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Boccardia pugettensis* | Blake, 1979 |
| | *Boccardiella hamata* | (Webster, 1879) |
| | *Carazziella* sp. | |
| | *Laonice* sp. | Malmgren, 1867 |
| | *Laonice cirrata* | (M. Sars, 1851) |
| | *Laonice pugettensis* | Banse & Hobson, 1968 |
| | *Malacoceros (Rhynchospio) glutaeus* | (Ehlers, 1897) |
| | *Microspio pigmentata* | (Reish, 1959) |
| | *Paraprionospio pinnata* | (Ehlers, 1901) |
| | *Polydora sp.* | Bosc, 1802 |
| | *Polydora aggregata* | |
| | *Polydora armata* | Langerhans, 1880 |
| | *Polydora armillaris* | |
| | *Polydora brachycephala* | Hartman, 1936 |
| | *Polydora cardalia* | E. Berkeley, 1927 |
| | *Polydora cornuta* | Bosc, 1802 |
| | *Polydora limicola* | Annenkova, 1934 |
| | *Polydora pygidialis* | Blake & Woodwick, 1972 |
| | *Polydora quadrilobata* | Jacobi, 1883 |
| | *Polydora socialis* | (Schmarda, 1861) |
| | *Polydora* sp. 1 | |
| | *Polydora* sp. A | |
| | *Polydora* sp. G | |
| | *Polydora spongicola* | Berkeley & Berkeley, 1950 |
| | *Prionospio* sp | Malmgren, 1867 |
| | *Prionospio (Minuspio) lighti* | Maciolek, 1985 |
| | *Prionospio (Minuspio) multibranchiata* | E. Berkeley, 1927 |
| | *Prionospio pygmaea* | Hartman, 1961 |
| | *Prionospio jubata* | Blake, 1996 |
| | *Pseudopolydora kempi japonica* | Imajima & Hartman, 1964 |
| | *Pseudopolydora paucibranchiata* | (Okuda, 1937) |
| | *Pygospio elegans* | Claparède, 1863 |
| | *Scolelepis squamata* | (O. F. Müller, 1806) |
| | *Spio* sp. | Fabricius, 1785 |
| | *Spio butleri* | Berkeley & Berkeley, 1954 |
| | *Spio cirrifera* | (Banse & Hobson, 1968) |
| | *Spio filicornis* | (O. F. Müller, 1766) |
| | *Spio* sp. 1 | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Spiophanes* sp. | Grube, 1860 |
| | *Spiophanes berkeleyorum* | Pettibone, 1962 |
| | *Spiophanes bombyx* | (Claparède, 1870) |
| | *Spiophanes missionensis* | Hartman, 1941 |
| | *Streblospio benedicti* | Webster, 1879 |
| Spirorbidae | | |
| | *Circeis* sp | Saint-Joseph, 1894 |
| | *Circeis armoricana* | Saint-Joseph, 1894 |
| | *Spirorbis* sp. | Daudin, 1800 |
| Sternaspidae | | |
| | *Sternaspis scutata* | (Renier, 1807) |
| Syllidae | | |
| | *Autolytus* sp | Grube, 1850 |
| | *Eusyllis* sp. | Malmgren, 1867 |
| | *Eusyllis assimilis* | Marenzeller, 1875 |
| | *Eusyllis blomstrandi* | Malmgren, 1867 |
| | *Eusyllis habei* | Imajima, 1966 |
| | *Eusyllis japonica* | Imajima & Hartman, 1964 |
| | *Exogone* sp. | Ørsted, 1845 |
| | *Exogone (E.) lourei* | Berkeley & Berkeley, 1938 |
| | *Exogone (Parexogone) molesta* | Banse, 1972 |
| | *Exogone dwisula* | Kudenov & Harris, 1995 |
| | *Odontosyllis* sp. | Claparède, 1863 |
| | *Odontosyllis phosphorea* | Moore, 1909 |
| | *Pionosyllis* sp. | Malmgren, 1867 |
| | *Pionosyllis gigantea* | Moore, 1908 |
| | *Pionosyllis* sp. 1 | |
| | *Pionosyllis uraga* | Imajima, 1966 |
| | *Proceraea* sp. | Ehlers, 1864 |
| | *Proceraea cornuta* | (Agassiz, 1863) |
| | *Sphaerosyllis brandhorsti* | Hartmann-Schröder, 1965 |
| | *Sphaerosyllis californiensis* | Hartman, 1966 |
| | *Sphaerosyllis* sp. F | |
| | *Streptosyllis* sp A | |
| | *Syllides longocirrata* | Ørsted, 1845 |
| | *Syllis* sp I (Commenc Bay only) | |
| | *Syllis* sp II (Commenc. Bay only) | |
| | *Syllis (Ehlersia) heterochaeta* | Moore, 1909 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Syllis (Ehlersia) hyperioni* | Dorsey & Phillips, 1987 |
| | *Syllis (Ehlersia)* sp. 1 | |
| | *Syllis (Typosyllis) armillaris* | (O. F. Müller, 1771) |
| | *Syllis (Typosyllis) harti* | Berkeley & Berkeley, 1942 |
| | *Syllis (Typosyllis) hyalina* | Grube, 1863 |
| | *Syllis (Typosyllis) stewarti* | Berkeley & Berkeley, 1942 |
| | *Syllis (Typosyllis) variegata* | Grube, 1860 |
| | *Trypanosyllis* sp. | Claparède, 1864 |
| Terebellidae | | |
| | *Amaeana occidentalis* | (Hartman, 1944) |
| | *Amphitrite* sp. | O. F. Müller, 1771 |
| | *Amphitrite cirrata* | O. F. Müller, 1776 |
| | Amphitritinae (unid.) | |
| | Amphitritinae sp. 1 | |
| | *Artacama coniferi* | Moore, 1905 |
| | *Artacamella hancocki* | Hartman, 1955 |
| | *Eupolymnia* sp. | Verrill, 1900 |
| | *Eupolymnia heterobranchia* | (Johnson, 1901) |
| | *Lanassa nordenskioldi* | Malmgren, 1865 |
| | *Lanassa* sp. | Malmgren, 1866 |
| | *Lanassa venusta* | (Malm, 1874) |
| | *Lanice conchilega* | (Pallas, 1776) |
| | *Laphania boecki* | Malmgren, 1866 |
| | *Amphitrite edwardsi* | (Quatrefages, 1865) |
| | *Amphitrite robusta* | Johnson, 1901 |
| | *Neoamphitrite* sp. | Hessle, 1917 |
| | *Nicolea* sp. | Malmgren, 1866 |
| | *Nicolea* sp. A | |
| | *Nicolea zostericola* | (Ørsted, 1844) |
| | *Pista* sp. | Malmgren, 1866 |
| | *Pista bansei* | Safronova, 1988 |
| | *Pista brevibranchiata* | Moore, 1923 |
| | *Pista elongata* | Moore, 1909 |
| | *Pista moorei* | Berkeley & Berkeley, 1942 |
| | *Pista pacifica* | Berkeley & Berkeley, 1943 |
| | *Pista paracristata* | |
| | *Pista* sp. A | |
| | *Pista* sp. B | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Pista* sp. I | |
| | *Pista wui* | Safronova, 1988 |
| | Polycirrinae (unid.) | |
| | *Polycirrus* sp. | Grube, 1850 |
| | *Polycirrus californicus* | Moore, 1909 |
| | *Polycirrus* sp. A | SCAMIT, 1995 |
| | *Polycirrus* sp. I | Banse, 1980 |
| | *Polycirrus* sp. III | Banse, 1980 |
| | *Polycirrus* sp. V | Banse, 1980 |
| | *Proclea graffii* | (Langerhans, 1880) |
| | *Scionella japonica* | Moore, 1903 |
| | *Streblosoma* sp. | Sars, 1872 |
| | *Streblosoma bairdi* | (Malmgren, 1866) |
| | *Thelepus* sp. | Leuckart, 1849 |
| | *Thelepus crispus* | Johnson, 1901 |
| | *Thelepus setosus* | (Quatrefages, 1865) |
| Trichobranchidae | | |
| | *Terebellides* sp. | M. Sars, 1835 |
| | *Terebellides californica* | Williams, 1984 |
| | *Terebellides horikoshii* | |
| | *Terebellides japonica* | |
| | *Terebellides kobei* | Hessle, 1917 |
| | *Terebellides reishi* | Williams, 1984 |
| | *Terebellides stroemi* | M. Sars, 1835 |
| | *Trichobranchus glacialis* | Malmgren, 1866 |
| Trochochaetidae | | |
| | *Trochochaeta multisetosa* | (Ørsted, 1844) |
| **Oligochaeta** | | |
| Enchytraeidae | | |
| | Enchytraeidae sp. B | |
| Tubificidae | | |
| | *Limnodriloides victoriensis* | Brinkhurst & Baker, 1979 |
| | *Tubificoides* sp. | Lastockin, 1937 |
| | *Tubificoides brownae* | Brinkhurst & Baker, 1979 |
| | *Tubificoides* sp. A | |
| | *Tubificoides* sp. B | |
| **Hirudinea** (unid.) | | |

| Phylum/Class/Family | Species | |
|---|---|---|
| **ECHIURA** | | |
| **Echiurida** | | |
| Bonelliidae | | |
| | *Nellobia eusoma* | Fisher, 1946 |
| Echiuridae | | |
| | *Echiurus* sp. | |
| | *Echiurus echiurus* | Fisher, 1946 |
| Thalassematidae | | |
| | *Arhynchite pugettensis* | Fisher, 1949 |
| **SIPUNCULA** | | |
| **Phascolosomida** | | |
| Phascolosomatidae | | |
| | *Phascolosoma agassizii* | Keferstein, 1867 |
| **Sipunculida** | | |
| Golfingiidae | | |
| | *Golfingia margaritacea* | (M. Sars, 1851) |
| | *Golfingia vulgaris* | (Blainville, 1827) |
| | *Nephasoma* sp | Pergament, 1946 |
| | *Nephasoma diaphanes* | (Gerould, 1913) |
| | *Thysanocardia nigra* | (Ikeda, 1904) |
| Sipunculidae (unid.) | | |
| **MOLLUSCA** | | |
| **Aplacophora** | | |
| Chaetodermatidae | | |
| | *Chaetoderma* sp | Lovén, 1844 |
| **Polyplacophora** | | |
| Lepidochitonidae | | |
| | *Lepidochitona dentiens* | (Gould, 1846) |
| **Gastropoda: Prosobranchia** | | |
| Acmaeidae | | |
| | *Collisella* sp. | Dall, 1871 |
| Batillariidae | | |
| | *Cerithidea* sp | |
| Buccinidae | | |
| | *Buccinum* sp. | Linnaeus, 1758 |
| | *Buccinum plectrum* | Stimpson, 1865 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Searlesia dira* | (Reeve, 1846) |
| Caecidae (unid.) | | |
| Calyptraeidae | | |
| | *Calyptraea fastigiata* | Gould, 1846 |
| | *Crepidula* sp. | Lamarck, 1799 |
| | *Crepidula* sp. A | |
| | *Crepipatella* sp | Lesson, 1830 |
| | *Crepipatella dorsata* (= *C. lingulata*) | (Broderip, 1834) |
| Cancellariidae | | |
| | *Admete gracilior* | (Carpenter, 1869) |
| Cerithiidae | | |
| | *Lirobittium attenuatum* | (Carpenter, 1864) |
| | *Lirobittium munitum* | (Carpenter, 1864) |
| Cerithiopsidae | | |
| | *Cerithiopsis* sp | Forbes & Hanley, 1849 |
| | *Cerithiopsis signa* | Bartsch, 1921 |
| Columbellidae | | |
| | *Alia carinata* | (Hinds, 1844) |
| | *Amphissa* sp. | H. & A. Adams, 1853 |
| | *Amphissa columbiana* | Dall, 1916 |
| | *Astyris gausapata* (= *Nitidella gouldi*) | (Gould, 1850) |
| | *Mitrella tuberosa* | (Carpenter, 1864) |
| Epitoniidae | | |
| | *Epitonium* sp. (= *Nitidiscala* sp.) | |
| | *Epitonium caamanoi* (= *N. caamanoi*) | (Dall & Bartsch, 1910) |
| | *Epitonium indianorum* (= *Nitidiscala indianorum*) | (Carpenter, 1864) |
| | *Epitonium tinctum* (= *N. tincta*) | (Carpenter, 1864) |
| Eulimidae | | |
| | *Balcis* sp. | Leach, 1847 |
| | *Eulima* sp. | Risso, 1926 |
| | *Melanella* sp. | Bowdish, 1822 |
| Fasciolariidae | | |
| | *Fusinus* sp. | Rafinesque, 1815 |
| Lacunidae | | |
| | *Lacuna* sp | Turton, 1827 |
| Littorinidae | | |
| | *Littorina* sp | Ferussac, 1822 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| Muricidae | | |
| | *Ocenebra* sp. | Gray, 1847 |
| Nassariidae | | |
| | *Nassarius mendicus* | (Gould, 1849) |
| Naticidae | | |
| | *Amauropsis* sp. | Morch, 1857 |
| | *Cryptonatica affinis* (= *Natica clausa*) | (Gmelin, 1791) |
| | *Euspira pallida* (= *Polinices pallidus*) | (Broderip & Sowerby, 1829) |
| | *Polinices* sp. | Montfort, 1810 |
| | *Polinices lewisii* | (Gould, 1847) |
| Neptuneidae | | |
| | *Colus halli* | Dall, 1873 |
| | *Mohnia* sp. | Friele, 1878 |
| | *Mohnia freilei* | (Dall, 1891) |
| | *Neptunea phoenicia* | (Dall, 1891) |
| | *Pyrulofusus harpa* | Mörch, 1858 |
| Olividae | | |
| | *Olivella baetica* | Carpenter, 1864 |
| | *Olivella biplicata* | (G. B. Sowerby I, 1825) |
| Rissoidae | | |
| | *Alvania compacta* | (Carpenter, 1864) |
| Trichotropididae | | |
| | *Trichotropis cancellata* | Hinds, 1843 |
| Trochidae | | |
| | *Margarites* sp. | Gray, 1847 |
| | *Margarites pupillus* | (Gould, 1841) |
| | *Solariella* sp. | S. V. Wood, 1842 |
| | *Solariella obscura* | (Couthouy, 1838) |
| | *Solariella vancouverensis* | (E. A. Smith, 1887) |
| | *Solariella varicosa* | (Mighels & C. B. Adams, 1842) |
| Turridae | | |
| | cf. *Elaeocyma* sp. | |
| | *Kurtzia* sp. | Bartsch, 1944 |
| | *Kurtzia arteaga* | (Dall & Bartsch, 1910) |
| | *Kurtziella* sp. | Dall, 1918 |
| | *Kurtziella plumbea* | (Hinds, 1843) |
| | *Oenopota* sp. | Morch, 1852 |
| | *Oenopota viridula* | (O. Fabricius, 1780) |

| Phylum/Class/Family | Species | |
|---|---|---|
| Vermetidae | | |
| | *Petaloconchus* sp. | H. C. Lea, 1843 |
| | *Petaloconchus compactus* | (Carpenter, 1864) |
| Vitrinellidae | | |
| | *Vitrinella* sp. | C. B. Adams, 1850 |
| | *Vitrinella columbiana* | (Bartsch, 1921) |
| **Gastropoda: Opisthobranchia** | | |
| Acteonidae | | |
| | *Rictaxis punctocaelatus* | (Carpenter, 1864) |
| Aeolidiidae | | |
| | *Aeolidea* sp | |
| Aglajidae | | |
| | *Aglaja* sp. | Renier, 1807 |
| | *Aglaja ocelligera* | (Bergh, 1893) |
| | *Melanochlamys diomedea* | (Bergh, 1894) |
| Arminidae | | |
| | *Armina californica* | (J. G. Cooper, 1863) |
| Atyidae | | |
| | *Haminoea* sp. | Turton & Kingston, 1830 |
| | *Haminoea vesicula* | Gould, 1855 |
| Bullidae | | |
| | *Bulla* sp. | Linnaeus, 1758 |
| | *Bulla gouldiana* | Pilsbry, 1895 |
| | *Bullomorpha* sp. | |
| | *Bullomorpha* sp. A | Ljubenkov, 1994 |
| | Cephalaspidea sp. A | |
| Corambidae | | |
| | *Corambe thompsoni* | Millen & Nybakken, 1991 |
| Cylichnidae | | |
| | *Acteocina* sp. | Gray, 1847 |
| | *Acteocina culcitella* | (Gould, 1853) |
| | *Cylichna* sp. | Loven, 1846 |
| | *Cylichna alba* | (Carpenter, 1864) |
| | *Cylichna attonsa* | (Brown, 1827) |
| Dendronotidae | | |
| | *Dendronotus* sp. | Alder & Hancock, 1845 |
| Diaphanidae | | |
| | *Diaphana* sp. | Brown, 1837 |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Diaphana californica* | Dall, 1919 |
| Dotoidae | | |
| | *Doto* sp | Oken, 1815 |
| Fionidae | | |
| | *Fiona pinnata* | (Eschscholtz, 1831) |
| Flabellinidae (unid.) | | |
| Gastropteridae | | |
| | *Gastropteron pacificum* | Bergh, 1893 |
| Goniodorididae | | |
| | *Ancula* sp. | Loven, 1846 |
| | *Okenia* sp. | Menke, 1830 |
| Onchidorididae | | |
| | *Onchidoris hystricina* | (Bergh, 1878) |
| Philinidae | | |
| | *Philine* sp. | Ascanius, 1772 |
| | *Philine bakeri* | Dall, 1919 |
| Pleurobranchidae | | |
| | *Berthella californica* | (Dall, 1900) |
| Polyceratidae | | |
| | *Polycera* sp. | Cuvier, 1817 |
| Pyramidellidae | | |
| | *Odostomia* spp. | |
| | *Turbonilla* spp. | |
| Retusidae (unid.) | | |
| Tergipedidae | | |
| | *Cuthona* sp. | Alder & Hancock, 1855 |
| | *Cuthona concinna* | (Alder & Hancock, 1843) |
| Umbraculidae | | |
| | *Umbraculum* sp. | |
| **Bivalvia** | | |
| Anomiidae | | |
| | *Pododesmus cepio* | (Gray, 1850) |
| Astartidae | | |
| | *Astarte compacta* | Carpenter, 1864 |
| | *Astarte esquimalti* | (Baird, 1863) |
| Cardiidae | | |
| | *Clinocardium* sp | Keen, 1936 |
| | *Clinocardium ciliatum* | (Fabricius, 1780) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Clinocardium fucanum* | (Dall, 1907) |
| | *Clinocardium nuttallii* | (Conrad, 1837) |
| | *Nemocardium centifilosum* | (Carpenter, 1864) |
| Cardiliidae (unid.) | | |
| Carditidae | | |
| | *Cyclocardia* sp. | Conrad, 1867 |
| | *Cyclocardia ventricosa* | (Gould, 1850) |
| Cuspidariidae | | |
| | *Cardiomya* sp. | A. Adams, 1864 |
| | *Cardiomya pectinata* | (Carpenter, 1864) |
| Glycymerididae | | |
| | *Glycymeris* sp. | Da Costa, 1778 |
| Hiatellidae | | |
| | *Hiatella* sp. | Bosc, 1801 |
| | *Hiatella arctica* | (Linnaeus, 1767) |
| | *Panomya* sp. | Gray, 1857 |
| | *Panomya ampla* | Dall, 1898 |
| | *Panopea abrupta* | (Conrad, 1849) |
| Lasaeidae | | |
| | *Lasaea* sp | Brown, 1827 |
| | *Lasaea subviridis* | Dall, 1899 |
| | *Mysella* sp. | Angas, 1877 |
| | *Neaeromya compressa* | (Dall, 1899) |
| | *Orobitella* sp. | |
| | *Orobitella compressa* | |
| | *Pseudopythina* sp. | P. Fischer, 1884 |
| | *Rochefortia coani* (= *Mysella* sp. A) | Valentich Scott, 1998 |
| | *Rochefortia tumida* (= *Mysella tumida*) | (Carpenter, 1864) |
| Lucinidae | | |
| | *Lucinoma* sp. | Dall, 1901 |
| | *Lucinoma annulata* | (Reeve, 1850) |
| | *Parvilucina tenuisculpta* | (Carpenter, 1864) |
| Lyonsiidae | | |
| | *Agriodesma saxicola* | (Baird, 1863) |
| | *Lyonsia* sp | Turton, 1822 |
| | *Lyonsia bracteata* (= *L. pugetensis*) | (Gould, 1850) |
| | *Lyonsia californica* | Conrad, 1837 |

Appendix B. Continued

| Phylum/Class/Family | Species | |
|---|---|---|
| Mactridae | | |
| | *Spisula falcata* | (Gould, 1850) |
| | *Tresus* sp. | Gray, 1853 |
| | *Tresus capax* | (Gould, 1850) |
| Myidae | | |
| | *Cryptomya californica* | (Conrad, 1837) |
| | *Mya* sp | Linnaeus, 1758 |
| | *Mya arenaria* | Linnaeus, 1758 |
| | *Platyodon* sp | Conrad, 1837 |
| Mytilidae | | |
| | *Crenella decussata* | (Montagu, 1808) |
| | *Megacrenella columbiana* | (Dall, 1879) |
| | *Modiolus* sp. | Lamarck, 1799 |
| | *Modiolus modiolus* | (Linnaeus, 1758) |
| | *Modiolus rectus* | (Conrad, 1837) |
| | *Musculista senhousia* | (Benson, 1842) |
| | *Musculus* sp. | Roding, 1798 |
| | *Musculus discors* | (Linnaeus, 1767) |
| | *Mytilus* sp. | Linnaeus, 1758 |
| | *Mytilus trossulus* | Gould, 1850 |
| Nuculanidae | | |
| | *Nuculana* sp. | Link, 1807 |
| | *Nuculana hamata* | (Carpenter, 1864) |
| | *Nuculana minuta* | (Fabricius, 1776) |
| | *Nuculana penderi* | (Dall & Bartsch, 1910) |
| | *Nuculana taphria* | (Dall, 1896) |
| Nuculidae | | |
| | *Acila castrensis* | (Hinds, 1843) |
| | *Nucula tenuis* | (Montagu, 1808) |
| Pandoridae | | |
| | *Pandora* sp. | Bruguiere, 1797 |
| | *Pandora bilirata* | Conrad, 1855 |
| | *Pandora filosa* | (Carpenter, 1864) |
| | *Pandora glacialis* | (Leach, 1819) |
| | *Pandora wardiana* (= *P. grandis*) | A. Adams, 1859 |
| Pectinidae | | |
| | *Chlamys* sp. | Roding, 1798 |
| | *Chlamys hastata* | (G. B. Sowerby II, 1842) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Chlamys rubida* | (Hinds, 1845) |
| | *Delectopecten* sp. | Stewart, 1930 |
| | *Delectopecten vancouverensis* | (Whiteaves, 1893) |
| Pharidae | | |
| | *Siliqua patula* | (Dixon, 1789) |
| Propeamussidae | | |
| | *Parvamussium alaskensis* | (Dall, 1871) |
| Sareptidae | | |
| | *Yoldia* sp. | Moller, 1842 |
| | *Yoldia hyperborea* | Torell, 1859 |
| | *Yoldia myalis* | (Couthouy, 1838) |
| | *Yoldia seminuda* (= *Y. scissurata*) | Dall, 1871 |
| | *Yoldia thraciaeformis* | (Storer, 1838) |
| Semelidae | | |
| | *Semele rubropicta* | Dall, 1871 |
| Solemyidae | | |
| | *Solemya reidi* | Bernard, 1980 |
| Solenidae | | |
| | *Solen sicarius* | Gould, 1850 |
| Tellinidae | | |
| | *Macoma* sp. | Leach, 1819 |
| | *Macoma acolasta* | Dall, 1921 |
| | *Macoma balthica* | (Linnaeus, 1758) |
| | *Macoma calcarea* | (Gmelin, 1791) |
| | *Macoma carlottensis* | Whiteaves, 1880 |
| | *Macoma elimata* | Dunnill & Coan, 1968 |
| | *Macoma indentata* | Carpenter, 1864 |
| | *Macoma inquinata* | (Deshayes, 1854) |
| | *Macoma lipara* | Dall, 1916 |
| | *Macoma moesta* | (Deshayes, 1855) |
| | *Macoma nasuta* | (Conrad, 1837) |
| | *Macoma obliqua* | (Sowerby, 1817) |
| | *Macoma yoldiformis* | Carpenter, 1864 |
| | *Tellina* sp. | Linnaeus, 1758 |
| | *Tellina carpenteri* | Dall, 1900 |
| | *Tellina modesta* | (Carpenter, 1864) |
| | *Tellina nuculoides* | (Reeve, 1854) |
| | *Tellina* sp. A | SCAMIT, 1995 |

| Phylum/Class/Family | Species | |
|---|---|---|
| Teredinidae | | |
| | *Bankia setacea* | (Tryon, 1863) |
| | *Teredo* sp. | Linnaeus, 1758 |
| Thraciidae | | |
| | *Thracia devexa* | G. O. Sars, 1878 |
| | *Thracia trapezoides* | Conrad, 1849 |
| Thyasiridae | | |
| | *Adontorhina cyclia* | Berry, 1947 |
| | *Axinopsida serricata* | (Carpenter, 1864) |
| | *Thyasira* sp. | Lamarck, 1818 |
| | *Thyasira flexuosa* | (Montagu, 1803) |
| Ungulinidae | | |
| | *Diplodonta* sp. | Bronn, 1831 |
| Veneridae | | |
| | *Compsomyax subdiaphana* | (Carpenter, 1864) |
| | *Humilaria kennerlyi* | (Reeve, 1863) |
| | *Liocyma* sp | Dall, 1870 |
| | *Protothaca* sp. | Dall, 1902 |
| | *Protothaca staminea* | (Conrad, 1837) |
| | *Psephidia lordi* | (Baird, 1863) |
| | *Saxidomus giganteus* | (Deshayes, 1839) |
| | *Transenella tantilla* | (Gould, 1853) |
| **Scaphopoda** | | |
| Gadilidae | | |
| | *Cadulus* sp. | Philippi, 1844 |
| Rhabdidae | | |
| | *Rhabdus* sp. (= *Dentalium* sp.) | Pilbury & Sharp, 1897 |
| | *Rhabdus rectius* (= *Dentalium rectius*) | (Carpenter, 1864) |
| **Cephalopoda** | | |
| Octopodidae | | |
| | *Octopus rubescens* | Berry, 1953 |
| Sepiolidae | | |
| | *Rossia pacifica* | Berry, 1911 |
| **ARTHROPODA** | | |
| **Pycnogonida** | | |
| Ammotheidae | | |
| | *Achelia* sp | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Achelia chelata* | (Hilton, 1939) |
| | *Achelia latifrons* | (Cole, 1904) |
| Nymphonidae | | |
| | *Nymphon pixellae* | Scott, 1913 |
| Phoxichilidiidae | | |
| | *Anoplodactylus* sp. | Wilson, 1878 |
| | *Anoplodactylus erectus* | Cole, 1904 |
| | *Phoxichilidium* sp | |
| | *Phoxichilidium femoratum* | (Rathke, 1799) |
| Pycnogonidae | | |
| | *Pycnogonum* sp. | |
| **Arachnida** | | |
| Halacaridae (unid.) | | |
| **Crustacea** | | |
| **Ostracoda** | | |
| Cylindroleberididae | | |
| | *Bathyleberis* sp | |
| | *Bathyleberis* cf. *hancocki* | |
| | *Diasterope pilosa* | |
| | *Parasterope* sp. | Poulsen, 1965 |
| | *Parasterope barnesi* | Baker, 1978 |
| Philomedidae | | |
| | *Euphilomedes* sp. | Poulsen, 1962 |
| | *Euphilomedes carcharodonta* | (Smith, 1952) |
| | *Euphilomedes producta* | Poulsen, 1962 |
| | *Scleroconcha trituberculatum* | (Lucas, 1931) |
| Rutidermatidae | | |
| | *Rutiderma lomae* | (Juday, 1907) |
| Sarsiellidae | | |
| | *Eusarsiella* sp. | |
| | *Sarsiella* sp. | Norman, 1869 |
| Trachyleberididae | | |
| | *Cythereis* sp. | Jones, 1849 |
| **Cirripedia** | | |
| Balanidae | | |
| | *Balanus* sp. | De Costa, 1778 |
| | *Balanus crenatus* | Bruguière, 1789 |
| | *Balanus hesperius* | Pilsbry, 1916 |

| Phylum/Class/Family | Species | |
|---|---|---|
| **Phyllocarida** | | |
| Nebaliidae | | |
| | *Nebalia* spp. | |
| **Mysidacea** | | |
| Mysidae | | |
| | *Acanthomysis* sp | Czerniavsky, 1882 |
| | *Alienacanthomysis macropsis* | (W. M. Tattersall, 1932) |
| | *Heteromysis odontops* | Walker, 1898 |
| | *Inusitatomysis insolita* | Ii, 1940 |
| | *Meterythrops robusta* | S. I. Smith, 1879 |
| | *Mysidella americana* | Banner, 1948 |
| | *Neomysis* sp | |
| | *Neomysis kadiakensis* | Ortmann, 1908 |
| | *Neomysis mercedis* | Holmes, 1897 |
| | *Pacifacanthomysis nephrophthalma* | (Banner, 1948) |
| | *Pseudomma* sp. | G. O. Sars, 1869 |
| | *Pseudomma berkeleyi* | W. M. Tattersall, 1933 |
| | *Pseudomma truncatum* | Smith, 1879 |
| | *Xenacanthomysis* sp | |
| | *Xenacanthomysis pseudomacropsis* | (W. M. Tattersall, 1933) |
| **Cumacea** | | |
| Diastylidae | | |
| | *Diastylis* sp. | Say, 1818 |
| | *Diastylis hirsuta* | |
| | *Diastylis nucella* | Calman, 1912 |
| | *Diastylis paraspinulosa* | Zimmer, 1926 |
| | *Diastylis pellucida* | Hart, 1930 |
| | *Diastylis santamariensis* | Watling & McCann, 1997 |
| | *Diastylopsis tenuis* | Zimmer, 1936 |
| | *Leptostylis* sp. | G. O. Sars, 1869 |
| | *Leptostylis villosa* | (G. O. Sars, 1869) |
| | *Oxyurostylis pacifica* | Zimmer, 1936 |
| Lampropidae | | |
| | *Hemilamprops* sp. | Sars, 1883 |
| | *Hemilamprops californicus* | Zimmer, 1936 |
| | *Lamprops* sp. | Sars |
| | *Lamprops quadriplicata* | Smith, 1879 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| Leuconiidae | | |
| | *Eudorella* sp. | Norman, 1867 |
| | *Eudorella pacifica* | Hart, 1930 |
| | *Eudorellopsis* sp | Sars, 1883 |
| | *Eudorellopsis integra* | S. I. Smith, 1880 |
| | *Eudorellopsis longirostris* | Given, 1961 |
| | *Leucon* sp. | Krøyer, 1846 |
| | *Leucon subnasica* | Given, 1961 |
| | *Nippoleucon hinumensis* | |
| Nannastacidae | | |
| | *Campylaspis* sp. | Sars, 1865 |
| | *Campylaspis biplicata* | Watling & McCann, 1997 |
| | *Campylaspis canaliculata* | Zimmer, 1936 |
| | *Campylaspis hartae* | Lie, 1969 |
| | *Campylaspis rubicunda* | (Lilljeborg, 1855) |
| | *Campylaspis rubromaculata* | Lie, 1971 |
| | *Campylaspis rufa* | Hart, 1930 |
| | *Cumella californica* (= *Cumella* sp. A) | Watling & McCann, 1997 |
| | *Cumella vulgaris* | Hart, 1930 |
| **Tanaidacea** | | |
| Anarthruridae | | |
| | *Araphura* sp. | Bird & Holdich, 1984 |
| | *Chauliopleona dentata* (= *Leptognathia* sp. E) | Dojiri & Sieg, 1997 |
| | *Leptognathia* sp. | G. O. Sars, 1882 |
| | *Leptognathia brevimanus* | (Lilljeborg, 1864) |
| | *Leptognathia gracilis* | (Krøyer, 1842) |
| | *Leptognathia longiremus* | (Lilljeborg, 1864) |
| | *Scoloura phillipsi* | Sieg & Dojiri, 1991 |
| Leptocheliidae | | |
| | *Leptochelia savignyi* | (Krøyer, 1842) |
| Tanaidae | | |
| | *Tanais* sp. | Latreille, 1831 |
| **Isopoda** | | |
| Aegidae | | |
| | *Aega symmetrica* | Richardson, 1905 |
| | *Rocinela* cf. *americana* | |
| | *Rocinela belliceps* | (Stimpson, 1864) |

| Phylum/Class/Family | Species | |
|---|---|---|
| Anthuridae | | |
| | *Haliophasma geminata* | Menzies & Barnard, 1959 |
| Bopyridae | | |
| | *Argeia pugettensis* | Dana, 1853 |
| Gnathiidae | | |
| | *Gnathia* sp. | Leach, 1814 |
| Idoteidae | | |
| | *Edotea sublittoralis* | Menzies & Barnard, 1959 |
| | *Idotea* sp. | Fabricius, 1799 |
| | *Synidotea* sp | Harger, 1878 |
| | *Synidotea nebulosa* | Benedict, 1897 |
| | *Synidotea nodulosa* | (Krøyer, 1848) |
| Janiridae | | |
| | *Caecianiropsis psammophila* | Menzies & Pettit, 1956 |
| Limnoriidae | | |
| | *Limnoria* sp. | |
| | *Limnoria lignorum* | Rathke, 1799 |
| Munnidae | | |
| | *Munna* sp. | Krøyer, 1839 |
| | *Munna ubiquita* | Menzies, 1952 |
| Munnopsidae | | |
| | *Eurycope* sp. | G. O. Sars, 1864 |
| Paramunnidae | | |
| | *Munnogonium* sp | George & Strömberg, 1968 |
| | *Munnogonium tillerae* | (Menzies & Barnard, 1959) |
| | *Pleurogonium rubicundum* | (G.O. Sars, 1864) |
| Sphaeromatidae | | |
| | *Gnorimosphaeroma oregonensis* | Dana, 1854-55 |
| **Amphipoda: Gammaridea** | | |
| Ampeliscidae | | |
| | *Ampelisca* sp. | Krøyer, 1842 |
| | *Ampelisca agassizi* | (Judd, 1896) |
| | *Ampelisca brevisimulata* | Barnard, 1954 |
| | *Ampelisca careyi* | Dickinson, 1982 |
| | *Ampelisca cristata* | Holmes, 1908 |
| | *Ampelisca hancocki* | Barnard, 1954 |
| | *Ampelisca lobata* | Holmes, 1908 |
| | *Ampelisca pugetica* | Stimpson, 1864 |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Ampelisca* sp. A | |
| | *Ampelisca unsocalae* | Barnard, 1960 |
| | *Byblis millsi* | Dickinson, 1983 |
| | *Haploops tubicola* | Lilljeborg, 1856 |
| Ampithoidae | | |
| | *Peramphithoe* sp. | Bouzelius, 1859 |
| Anisogammaridae | | |
| | *Eogammarus* sp | |
| | *Eogammarus confervicolus* | (Stimpson, 1856) |
| | *Eogammarus oclairi* | Bousfield, 1979 |
| Aoridae | | |
| | *Aoroides* sp | Walker, 1898 |
| | *Aoroides columbiae* | Walker, 1898 |
| | *Aoroides inermis* | Conlan & Bousfield, 1982 |
| | *Aoroides intermedius* | Conlan & Bousfield, 1982 |
| | *Aoroides spinosus* | Conlan & Bousfield, 1982 |
| Argissidae | | |
| | *Argissa hamatipes* | (Norman, 1869) |
| Calliopiidae | | |
| | *Calliopius* sp. | Lilljeborg, 1865 |
| | *Leptamphous* sp. | Sars, 1895 |
| Corophiidae | | |
| | *Corophium* sp. | Latrelle, 1806 |
| | *Corophium acherusicum* | Costa, 1857 |
| | *Corophium baconi* | Shoemaker, 1934 |
| | *Corophium crassicorne* | Bruzelius, 1859 |
| | *Corophium insidiosum* | Crawford, 1937 |
| Eusiridae | | |
| | *Accedomoera vagor* | Barnard, 1969 |
| | *Eusirus* sp | Krøyer, 1845 |
| | *Eusirus cuspidatus* | Krøyer, 1845 |
| | *Oradarea longimana* | (Boeck, 1871) |
| | *Pontogeneia* sp. | Boeck, 1871 |
| | *Pontogeneia inermis* | (Krøyer, 1838) |
| | *Pontogeneia intermedia* | Gurjanova, 1938 |
| | *Pontogeneia rostrata* | Gurjanova, 1938 |
| | *Pontoporeia femorata* | Krøyer, 1842 |
| | *Rhachotropis* sp | Boeck, 1871 |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Rhachotropis clemens* | Barnard, 1967 |
| | *Rhachotropis oculata* | (Hansen, 1888) |
| Gammaridae | | |
| | *Maera danae* | (Stimpson, 1854) |
| | *Maera loveni* | (Bruzelius, 1859) |
| | *Melita* sp | Leach, 1814 |
| | *Melita californica* | Alderman, 1936 |
| | *Melita dentata* | (Krøyer, 1842) |
| | *Melita desdichada* | Barnard, 1962 |
| | *Melita oregonensis* | Barnard, 1954 |
| | *Melita sulca* | (Stout, 1913) |
| Isaeidae | | |
| | *Cheirimedeia* sp. | Barnard, 1962 |
| | *Cheirimedeia zotea* | (Barnard, 1962) |
| | *Gammaropsis thompsoni* | (Walker, 1898) |
| | *Photis* sp. | Krøyer, 1842 |
| | *Photis bifurcata* | Barnard, 1962 |
| | *Photis brevipes* | Shoemaker, 1942 |
| | *Photis lacia* | Barnard, 1962 |
| | *Photis macrotica* | Barnard, 1962 |
| | *Photis oligochaeta* | Conlan, 1983 |
| | *Photis parvidons* | Conlan, 1983 |
| | *Photis* cf. *spasskii* | Gurjanova, 1951 |
| | *Protomedeia* sp. | Krøyer, 1842 |
| | *Protomedeia articulata* | Barnard, 1962 |
| | *Protomedeia grandimana* | Bruggen, 1905 |
| | *Protomedeia prudens* | Barnard, 1966 |
| Ischyroceridae | | |
| | *Ericthonius* sp. | Milne-Edwards, 1830 |
| | *Ericthonius brasiliensis* | (Dana, 1853) |
| | *Ericthonius hunteri* | (Bate, 1862) |
| | *Ericthonius rubricornis* | (Stimpson, 1853) |
| | *Ischyrocerus* sp. | Krøyer, 1842 |
| | *Ischyrocerus anguipes* | Krøyer, 1838 |
| | *Microjassa litotes* | Barnard, 1954 |
| Lysianassidae | | |
| | *Acidostoma* sp. | Lilljeborg, 1865 |
| | *Acidostoma hancocki* | Hurley, 1963 |

Appendix B. Continued

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Allogaussia* sp | Schellenberg, 1926 |
| | *Anonyx* sp | Krøyer, 1838 |
| | *Anonyx lilljeborgi* | Boeck, 1871 |
| | *Aruga holmesi* (= *Lysianassa holmesi*) | (Barnard, 1955) |
| | *Cyphocaris challengeri* | Stebbing, 1888 |
| | *Hippomedon* sp. | Boeck, 1871 |
| | *Hippomedon* cf. *coecus* | (Holmes, 1908) |
| | *Hippomedon columbianus* | Jarrett & Bousfield, 1982 |
| | *Hippomedon subrobustus* | Hurley, 1963 |
| | *Lepidepecreum garthi* | Hurley, 1963 |
| | *Lepidepecreum gurjanovae* | Hurley, 1963 |
| | *Lepidepecreum* sp. A | SCAMIT, 1985 |
| | *Lysianassa* sp | Milne-Edwards, 1830 |
| | *Opisa tridentata* | Hurley, 1963 |
| | *Orchomene decipiens* | (Hurley, 1963) |
| | *Orchomene obtusa* | (Sars, 1895) |
| | *Orchomene pacifica* | (Gurjanova, 1938) |
| | *Orchomene pinguis* | (Boeck, 1861) |
| | *Pachynus barnardi* | Hurley, 1963 |
| | *Prachynella lodo* | Barnard, 1964 |
| | *Schisturella cocula* | Barnard, 1966 |
| Melphidippidae | | |
| | *Melphidippa* sp | Boeck, 1871 |
| | *Melphidippa goesi* | Stebbing, 1899 |
| | *Melphisana bola* | Barnard, 1962 |
| | *Melphisana* sp A | |
| Oedicerotidae | | |
| | *Arrhis* sp. | Boeck, 1861 |
| | *Bathymedon* sp | G. O. Sars, 1895 |
| | *Bathymedon pumilis* | Barnard, 1962 |
| | *Monoculodes* sp. | Stimpson, 1853 |
| | *Monoculodes norvegicus* | (Boeck, 1861) |
| | *Monoculodes zernovi* | Gurjanova, 1938 |
| | *Synchelidium* sp. | G. O. Sars, 1895 |
| | *Synchelidium rectipalmum* | Mills, 1962 |
| | *Synchelidium shoemakeri* | Mills, 1962 |
| | *Westwoodilla* sp. | Bate, 1857 |
| | *Westwoodilla caecula* | (Bate, 1857) |

Appendix B. Continued.

| Phylum/Class/Family | Species | |
|---|---|---|
| Pardaliscidae | | |
| | *Rhynohalicella halona* | (Barnard, 1971) |
| | *Pardalisca cuspidata* | Krøyer, 1842 |
| | *Pardalisca tenuipes* | G. O. Sars, 1895 |
| Phoxocephalidae | | |
| | *Eobrolgus spinosus* | (Holmes, 1905) |
| | *Eyakia robusta* | (Holmes, 1908) |
| | *Foxiphalus* sp. | Barnard, 1979 |
| | *Foxiphalus cognatus* | (Barnard, 1960) |
| | *Foxiphalus obtusidens* | (Alderman, 1936) |
| | *Foxiphalus similis* | (Barnard, 1960) |
| | *Grandifoxus dixonensis* | Jarrett & Bousfield, 1994 |
| | *Harpiniopsis* sp. | Stephensen, 1925 |
| | *Harpiniopsis fulgens* | Barnard, 1960 |
| | *Heterophoxus* sp. | Shoemaker, 1925 |
| | *Heterophoxus affinis* | (Holmes, 1908) |
| | *Heterophoxus conlanae* | Jarrett & Bousfield, 1994 |
| | *Heterophoxus ellisi* | Jarrett & Bousfield, 1994 |
| | *Heterophoxus oculatus* | (Holmes, 1908) |
| | *Metaphoxus frequens* | Barnard, 1960 |
| | *Parametaphoxus quaylei* | Jarrett & Bousfield, 1994 |
| | *Paraphoxus* sp. | G. O. Sars, 1895 |
| | *Paraphoxus gracilis* | Jarrett & Bousfield, 1994 |
| | *Paraphoxus oculatus* | G. O. Sars, 1879 |
| | *Rhepoxynius* sp. | Barnard, 1979 |
| | *Rhepoxynius abronius* | (Barnard, 1960) |
| | *Rhepoxynius barnardi* | Jarrett & Bousfield, 1994 |
| | *Rhepoxynius daboius* | (Barnard, 1960) |
| | *Rhepoxynius pallidus* | (Barnard, 1960) |
| | *Rhepoxynius variatus* | (Barnard, 1960) |
| Pleustidae | | |
| | *Parapleustes* sp. | Buchholz, 1874 |
| | *Parapleustes pugettensis* | (Dana, 1853) |
| | *Pleusymtes* sp. | Barnard, 1969 |
| | *Pleusymtes subglaber* | (Barnard & Given, 1960) |
| | *Thorlaksonius* sp. | |
| | *Thorlaksonius depressus* (= *Pleustes depressa*) | (Alderman, 1936) |

| Phylum/Class/Family | Species | |
|---|---|---|
| Podoceridae | | |
| | *Dulichia* sp | Krøyer, 1845 |
| | *Dulichia rhabdoplastis* | McCloskey, 1970 |
| | *Dyopedos* sp. | Bate, 1857 |
| | *Dyopedos arcticus* | (Murdoch, 1885) |
| | *Dyopedos bispinis* | (Gurjanova, 1930) |
| | *Paradulichia* sp. | Boeck, 1871 |
| | *Paradulichia typica* | Boeck, 1871 |
| | *Podocerus* sp. | Leach, 1814 |
| | *Podocerus cristatus* | (Thomson, 1879) |
| Stenothoidae | | |
| | *Metopa* sp. | Boeck, 1871 |
| | *Metopa proboldes* | |
| | *Metopella* sp. | G. O. Sars, 1895 |
| | *Parametopella* sp | Gurjanova, 1938 |
| | *Probolisca* sp | Gurjanova, 1938 |
| | *Proboloides* sp. | Della Valle, 1893 |
| | *Stenothoe* sp | Dana, 1852 |
| | *Stenula* sp. | Barnard, 1962 |
| Synopiidae | | |
| | *Bruzelia tuberculata* | G. O. Sars, 1883 |
| | *Syrrhoe longifrons* | Shoemaker, 1964 |
| | *Tiron biocellata* | Barnard, 1962 |
| **Amphipoda: Caprellidea** | | |
| Caprellidae | | |
| | *Caprella* sp. | Lamarck, 1801 |
| | *Caprella irregularis* | Mayer, 1890 |
| | *Caprella laeviuscula* | Mayer, 1903 |
| | *Caprella mendax* | Mayer, 1903 |
| Protellidae | | |
| | *Mayerella banksia* | Laubitz, 1970 |
| | *Tritella pilimana* | Mayer, 1890 |
| **Amphipoda: Hyperiidea** | | |
| Hyperiidae | | |
| | *Parathemisto pacifica* | |

| Phylum/Class/Family | Species | |
|---|---|---|
| **Decapoda** | | |
| Axiidae | | |
| | *Acanthaxius spinulicaudus* (= *Axiopsis spinulicauda*) | (Rathbun, 1902) |
| Callianassidae | | |
| | *Neotrypaea* sp. | |
| | *Neotrypaea gigas* | (Dana, 1852) |
| Cancridae | | |
| | *Cancer* sp | |
| | *Cancer branneri* | Rathbun, 1926 |
| | *Cancer gracilis* | Dana, 1852 |
| | *Cancer oregonensis* | (Dana, 1852) |
| | *Cancer productus* | Randall, 1839 |
| Crangonidae | | |
| | *Crangon* sp. | Fabricius, 1798 |
| | *Crangon alaskensis* | Lockington, 1877 |
| | *Crangon dalli* | Rathbun, 1902 |
| | *Crangon franciscorum* | Stimpson, 1856 |
| | *Mesocrangon munitella* | (Walker, 1898) |
| | *Neocrangon communis* (= *Crangon communis*) | (Rathbun, 1899) |
| Grapsidae | | |
| | *Hemigrapsus* sp. | |
| | *Hemigrapsus oregonensis* | (Dana, 1851) |
| Hippolytidae | | |
| | *Eualus* sp. | Thallwitz, 1892 |
| | *Eualus avinus* | (Rathbun, 1899) |
| | *Eualus pusiolus* | (Krøyer, 1841) |
| | *Heptacarpus* sp. | Holmes, 1900 |
| | *Heptacarpus brevirostris* | (Dana, 1852) |
| | *Heptacarpus flexus* | (Rathbun, 1902) |
| | *Heptacarpus stimpsoni* | Holthuis, 1947 |
| | *Spirontocaris* sp. | Bate, 1888 |
| | *Spirontocaris holmesi* | Holthuis, 1947 |
| | *Spirontocaris prionata* | (Stimpson, 1864) |
| | *Spirontocaris snyderi* | Rathbun, 1902 |
| Majidae | | |
| | *Oregonia* sp | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Oregonia gracilis* | Dana, 1851 |
| | *Pugettia* sp. | |
| | *Pugettia producta* | (Randall, 1839) |
| Paguridae | | |
| | *Discorsopagurus schmitti* | (Stevens, 1925) |
| | *Elassochirus* sp. | |
| | *Elassochirus tenuimanus* | (Dana, 1851) |
| | *Pagurus* sp. | |
| | *Pagurus aleuticus* | (Benedict, 1892) |
| | *Pagurus armatus* | (Dana, 1851) |
| | *Pagurus beringanus* | (Benedict, 1892) |
| | *Pagurus capillatus* | (Benedict, 1892) |
| | *Pagurus caurinus* | Hart, 1971 |
| | *Pagurus dalli* | (Benedict, 1892) |
| | *Pagurus ochotensis* | Brandt, 1851 |
| | *Pagurus setosus* | (Benedict, 1892) |
| | *Pagurus stevensae* | Hart, 1971 |
| Pandalidae | | |
| | *Pandalus danae* | Stimpson, 1857 |
| Pasiphaeidae | | |
| | *Parapasiphae* sp. | Smith, 1884 |
| | *Pasiphaea pacifica* | Rathbun, 1902 |
| Pinnotheridae | | |
| | *Fabia* sp. | |
| | *Fabia subquadrata* | Dana, 1851 |
| | *Pinnixa* sp. | |
| | *Pinnixa eburna* | Wells, 1928 |
| | *Pinnixa occidentalis* | Rathbun, 1893 |
| | *Pinnixa schmitti* | Rathbun, 1918 |
| | *Scleroplax granulata* | Rathbun, 1893 |
| Upogebiidae | | |
| | *Upogebia* sp. | |
| Xanthidae | | |
| | *Lophopanopeus bellus* | (Stimpson, 1860) |
| **PHORONIDA** | | |
| Phoronidae | | |
| | *Phoronis* sp. | |

| Phylum/Class/Family | Species | |
|---|---|---|
| | *Phoronopsis* sp. | |
| | *Phoronopsis harmeri* | Pixell, 1912 |
| **BRACHIOPODA** | | |
| **Articulata** | | |
| Cancellothyrididae | | |
| | *Terebratulina* sp | d'Orbigny, 1847 |
| | *Terebratulina unguicula* | (Carpenter, 1865) |
| Laqueidae | | |
| | *Terebratalia* sp | Beecher, 1893 |
| | *Terebratalia transversa* | (Sowerby, 1846) |
| **ENTOPROCTA** | | |
| Barentsiidae | | |
| | *Barentsia* sp. | Hincks, 1880 |
| Loxosomatidae | | |
| | *Loxosoma davenporti* | Nickerson, 1898 |
| Pedicellinidae | | |
| | *Myosoma spinosa* | Robertson, 1900 |
| | *Pedicellina* sp. | M. Sars, 1835 |
| | *Pedicellina cernua* | (Pallas, 1771) |
| **ECTOPROCTA** | | |
| **Stenolaemata** | | |
| Crisiidae | | |
| | *Crisia* sp. | Lamouroux, 1812 |
| Tubuliporidae | | |
| | *Tubulipora* sp. | Lamarck, 1916 |
| **Gymnolaemata** | | |
| Alcyonidiidae | | |
| | *Alcyonidium* sp | Lamouroux, 1812 |
| | *Alcyonidium polyoum* | (Hassall, 1841) |
| | *Alcyonidium* sp. B | |
| Bugulidae | | |
| | *Caulibugula* sp. | |
| | *Caulibugula californica* | (Robertson, 1905) |
| | *Caulibugula ciliata* | (Robertson, 1905) |
| | *Dendrobeania murrayana* | (Johnston, 1847) |

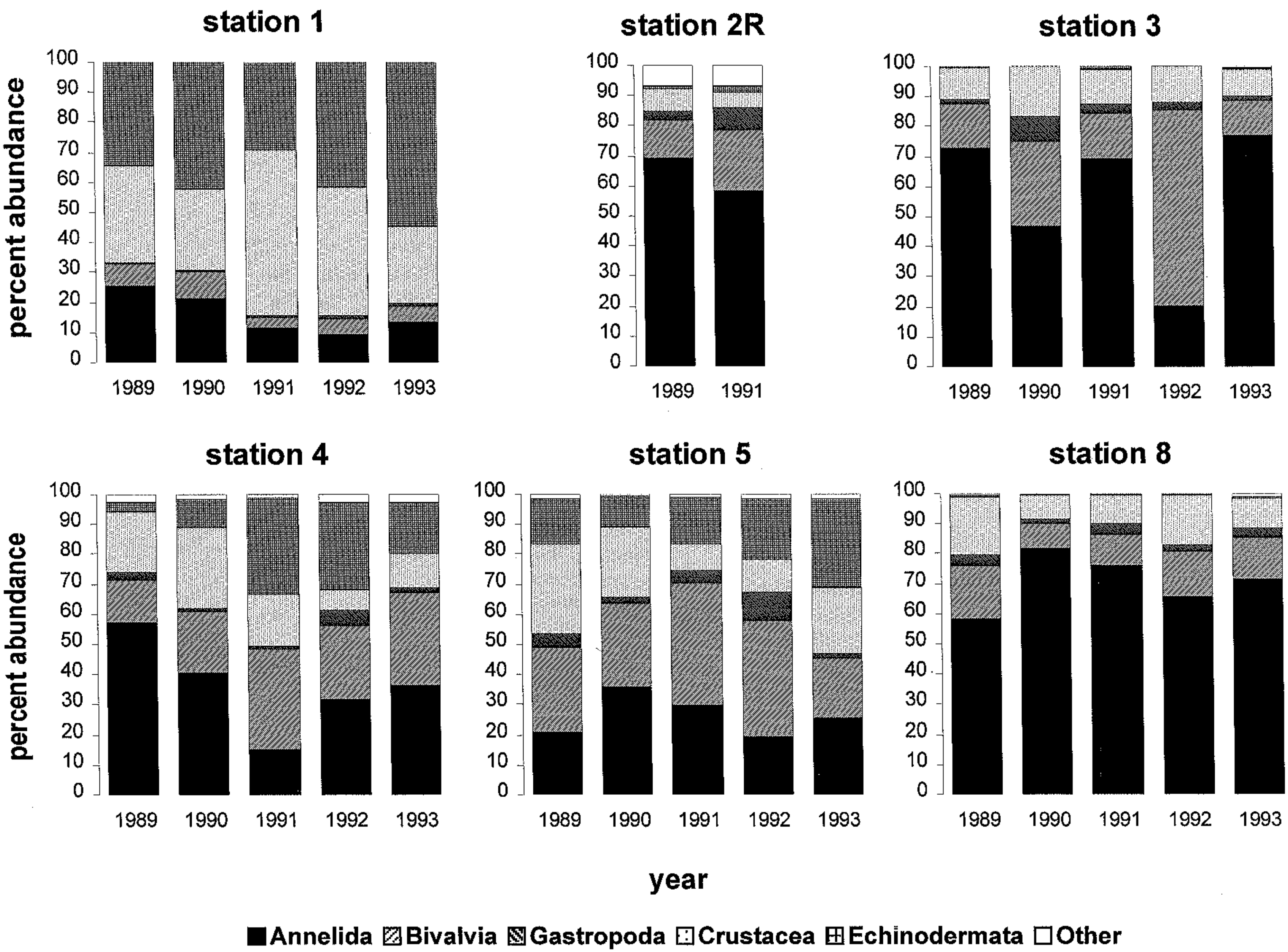
| Phylum/Class/Family | Species | |
|---|---|---|
| Calloporidae | | |
| | *Tegella* sp. | Levinsen, 1909 |
| Candidae | | |
| | *Caberea* sp. | |
| | *Scrupocellaria* sp. | Van Beneden, 1845 |
| | *Tricellaria* sp. | Fleming, 1828 |
| Cellariidae | | |
| | *Cellaria diffusa* | Robertson, 1905 |
| Celleporidae | | |
| | *Celleporina* sp | Gray, 1848 |
| | *Celleporina souleae* (= *C. costazi*) | Morris, 1979 |
| Chaperiidae | | |
| | *Chaperiopsis patula* (= *Chapperia patula*) | (Hincks, 1881) |
| Hippothoidae | | |
| | *Celleporella* sp. | |
| | *Celleporella hyalina* (= *Hippothoa hyalina*) | (Linnaeus, 1767) |
| Smittinidae | | |
| | *Porella* sp. | Gray, 1848 |
| Triticellidae | | |
| | *Triticella* sp. | Dalyell, 1848 |
| | *Triticella pedicellata* | (Alder, 1857) |
| **ECHINODERMATA** | | |
| **Asteroidea** | | |
| Asteriidae | | |
| | *Pisaster* sp. | Mueller & Troschel, 1840 |
| Asteropseidae | | |
| | *Dermasterias imbricata* | (Grube, 1857) |
| Luidiidae | | |
| | *Luidia foliolata* | Grube, 1866 |
| Solasteridae | | |
| | *Crossaster* sp. | |
| | *Crossaster papposus* | (Linnaeus, 1767) |
| | *Solaster* sp | Forbes, 1839 |
| | *Solaster stimpsoni* | Verrill, 1880 |

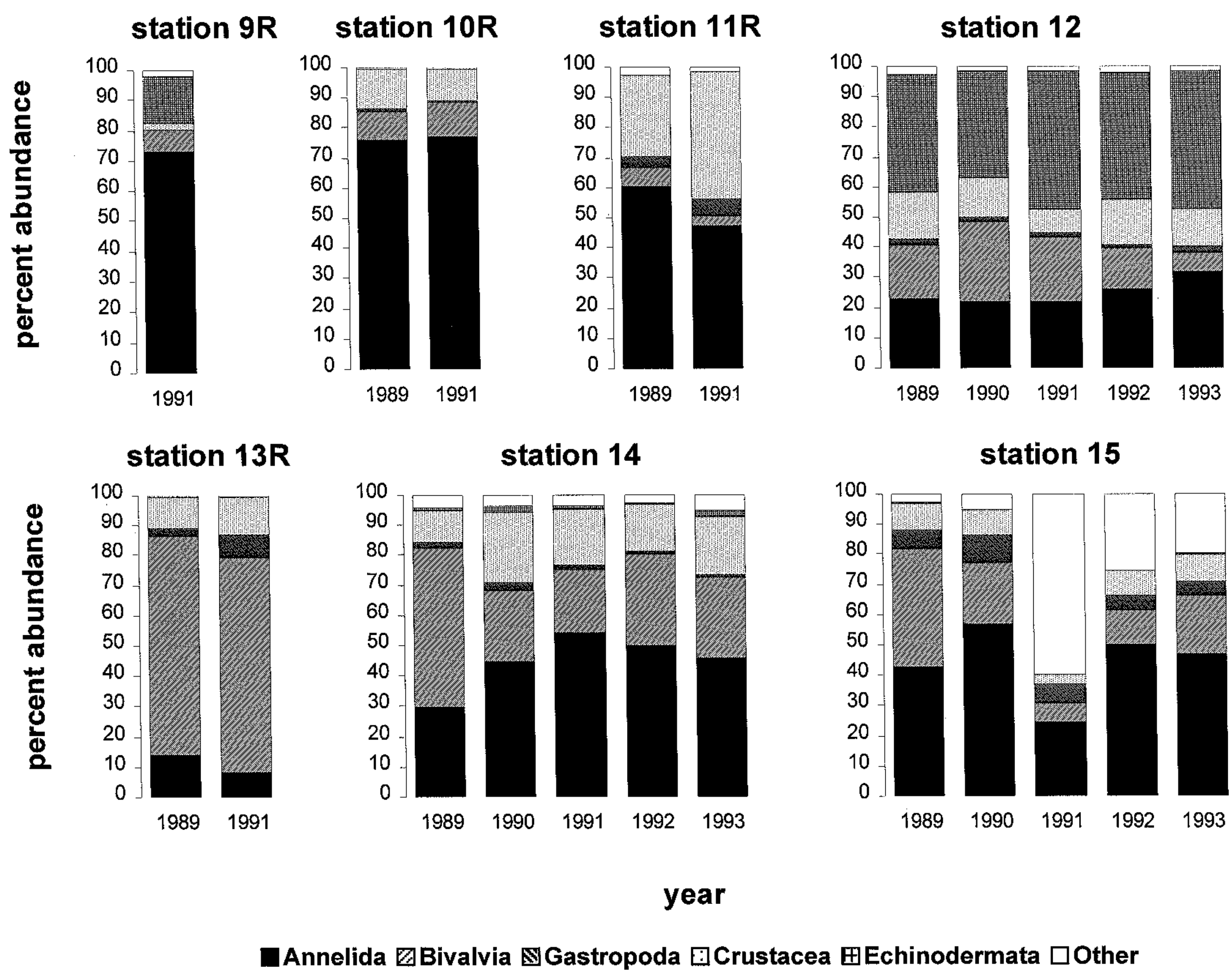
| Phylum/Class/Family | Species | |
|---|---|---|
| **Ophiuroidea** | | |
| Amphiuridae | | |
| | *Amphiodia* sp. | Verrill, 1899 |
| | *Amphiodia periercta* | H. L. Clark, 1911 |
| | *Amphiodia urtica* | (Lyman, 1860) |
| | *Amphioplus* sp. | Verrill, 1899 |
| | *Amphipholis* sp. | Ljungman, 1966 |
| | *Amphipholis pugetana* | (Lyman, 1860) |
| | *Amphipholis squamata* | (delle Chiaje, 1828) |
| | *Amphiura* sp. | Forbes, 1942 |
| | *Amphiura carchara* | H. L. Clark, 1911 |
| Ophiuridae | | |
| | *Ophiura* sp. | Lamarck, 1816 |
| | *Ophiura luetkenii* | (Lyman, 1860) |
| | *Ophiura sarsi* | Lütken, 1855 |
| **Echinoidea** | | |
| Dendrasteridae | | |
| | *Dendraster excentricus* | (Eschscholtz, 1831) |
| Schizasteridae | | |
| | *Brisaster latifrons* | (A. Agassiz, 1898) |
| Strongylocentrotidae | | |
| | *Strongylocentrotus* sp. | Brandt, 1835 |
| | *Strongylocentrotus droebachiensis* | (O. F. Müller, 1776) |
| | *Strongylocentrotus purpuratus* | (Stimpson, 1857) |
| **Holothuroidea** | | |
| Caudinidae | | |
| | *Paracaudina chilensis* | (J. Müller, 1850) |
| Chiridotidae | | |
| | *Chiridota* sp. | Eswchscholtz, 1829 |
| Cucumariidae | | |
| | *Cucumaria* sp. | Blainville, 1834 |
| | *Cucumaria fallax* | Ludwig, 1881 |
| | *Cucumaria miniata* | (Brandt, 1835) |
| | *Cucumaria piperata* | (Stimpson, 1864) |
| | *Pseudocnus* sp. | Panning, 1949 |
| | *Pseudocnus lubricus* (= *Cucumaria lubrica*) | (H. L. Clark, 1901) |

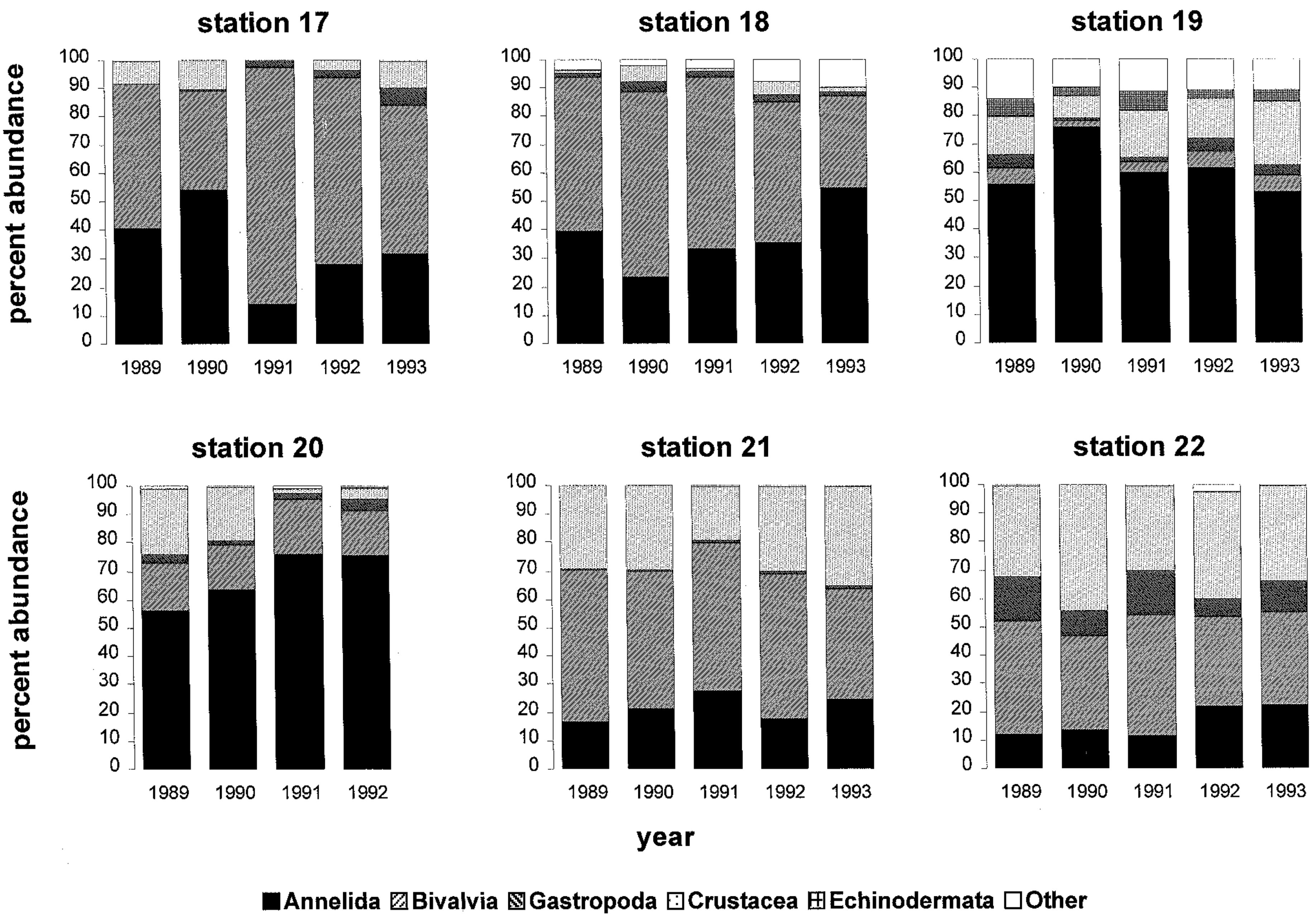
| Phylum/Class/Family | Species | |
|---|---|---|
| Molpadiidae | | |
| | *Molpadia intermedia* | (Ludwig, 1894) |
| Phyllophoridae | | |
| | *Havelockia benti* | (Deichmann, 1937) |
| | *Pentamera* sp | Ayres, 1852 |
| | *Pentamera lissoplaca* | (H. L. Clark, 1924) |
| | *Pentamera populifera* | (Stimpson, 1857) |
| | *Pentamera pseudocalcigera* | Deichmann, 1938 |
| | *Pentamera pseudopopulifera* | Deichmann, 1938 |
| | *Pentamera trachyplaca* | (H. L. Clark, 1924) |
| | *Thyone* sp | Jaegger, 1833 |
| Psolidae | | |
| | *Psolus* sp. | Oken, 1815 |
| | *Psolus chitinoides* | H. L. Clark, 1901 |
| Sclerodactylidae | | |
| | *Eupentacta* sp. | Deichmann, 1938 |
| | *Eupentacta pseudoquinquesemita* | Deichmann, 1938 |
| | *Eupentacta quinquesemita* | (Selenka, 1867) |
| Synaptidae | | |
| | *Leptosynapta* sp. | Verrill, 1867 |
| | *Leptosynapta clarki* | Heding, 1928 |
| | *Leptosynapta transgressor* | Heding, 1928 |
| **HEMICHORDATA** | | |
| **Enteropneusta** (unid.) | | |
| **CHORDATA** | | |
| **Ascidiacea** | | |
| Agnesiidae | | |
| | *Agnesia septentrionalis* | Huntsman, 1912 |
| Ascidiidae | | |
| | *Ascidia* sp. | Linnaeus, 1767 |
| | *Ascidia paratropa* | (Huntsman, 1912) |
| Cionidae | | |
| | *Ciona intestinalis* | (Linnaeus, 1767) |
| Molgulidae | | |
| | *Eugyra arenosa* | Alder & Hancock, 1848 |

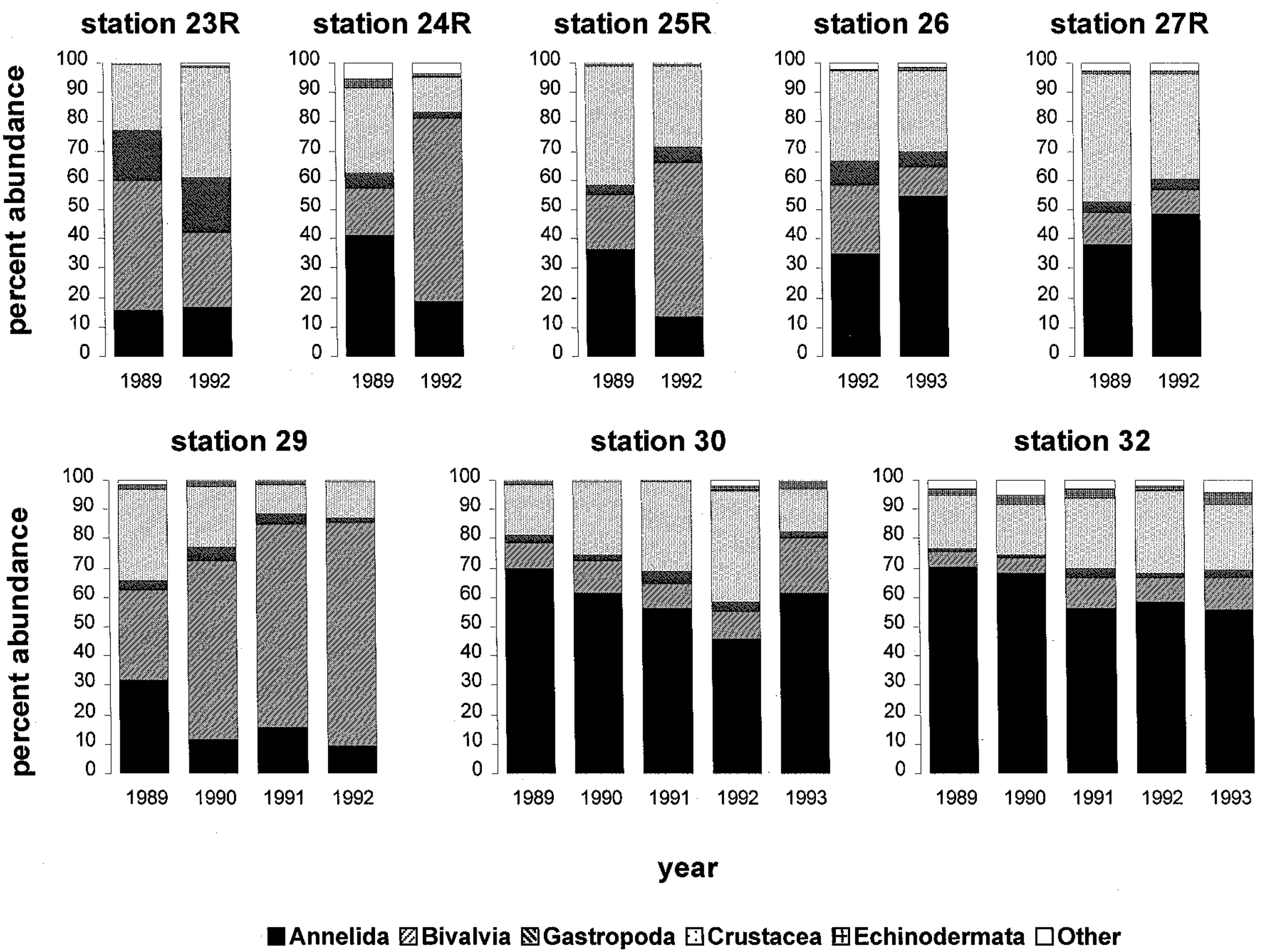
Appendix B. Concluded.

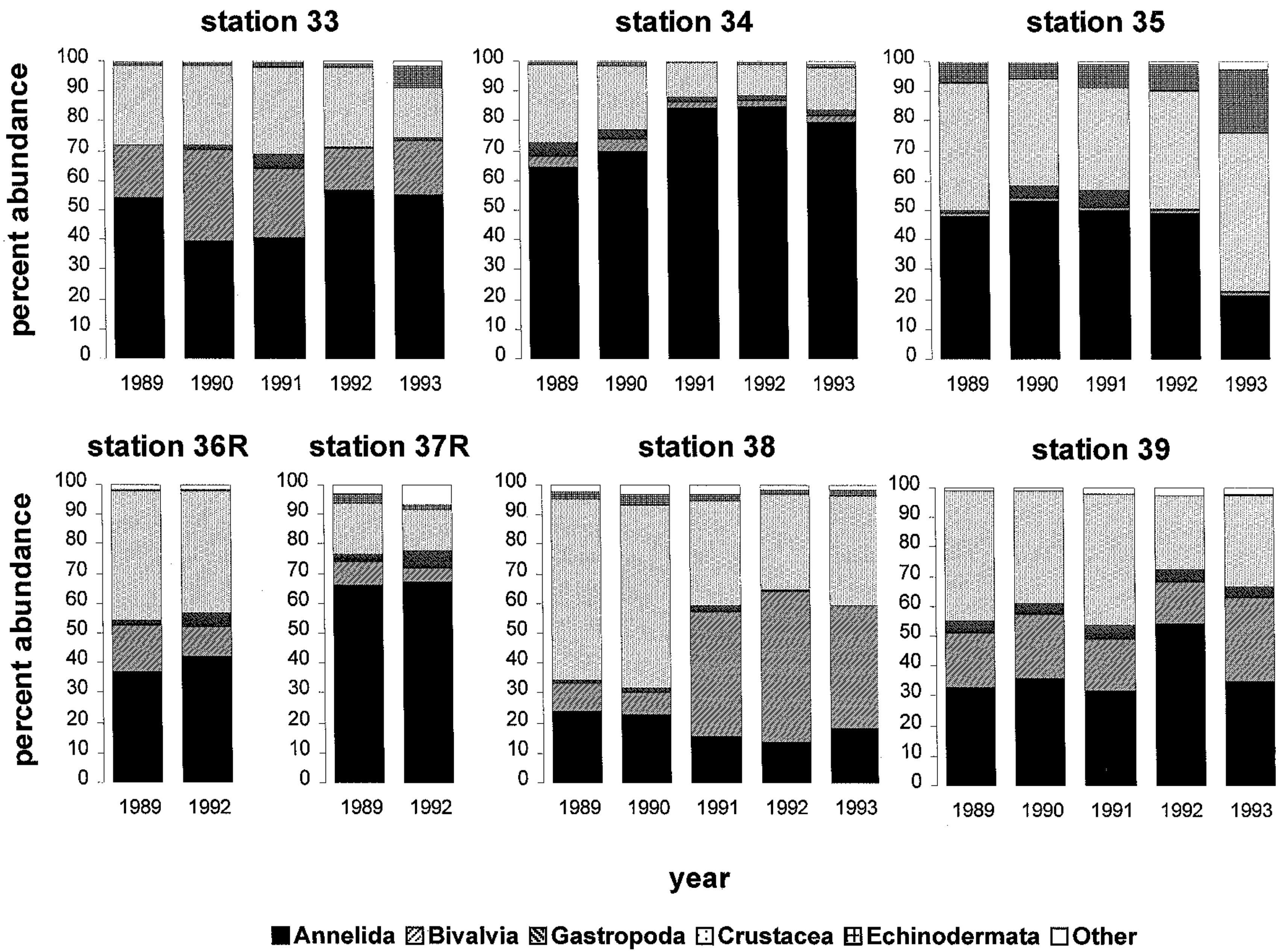
| Phylum/Class/Family | Species | |
|---|---|---|
| Pyuridae | | |
| | *Boltenia* sp. | Savigny, 1816 |
| | *Boltenia villosa* | (Stimpson, 1864) |
| | *Pyura haustor* | (Stimpson, 1864) |
| | *Pyura mirabilis* | (von Drasche, 1884) |
| Rhodosomatidae | | |
| | *Chelyosoma columbianum* | Huntsman, 1912 |
| | *Chelyosoma productum* | Stimpson, 1864 |
| | *Corella willmeriana* | Herdman, 1898 |
| Styelidae | | |
| | *Styela* sp | Fleming, 1822 |
| | *Styela gibbsii* | (Stimpson, 1864) |

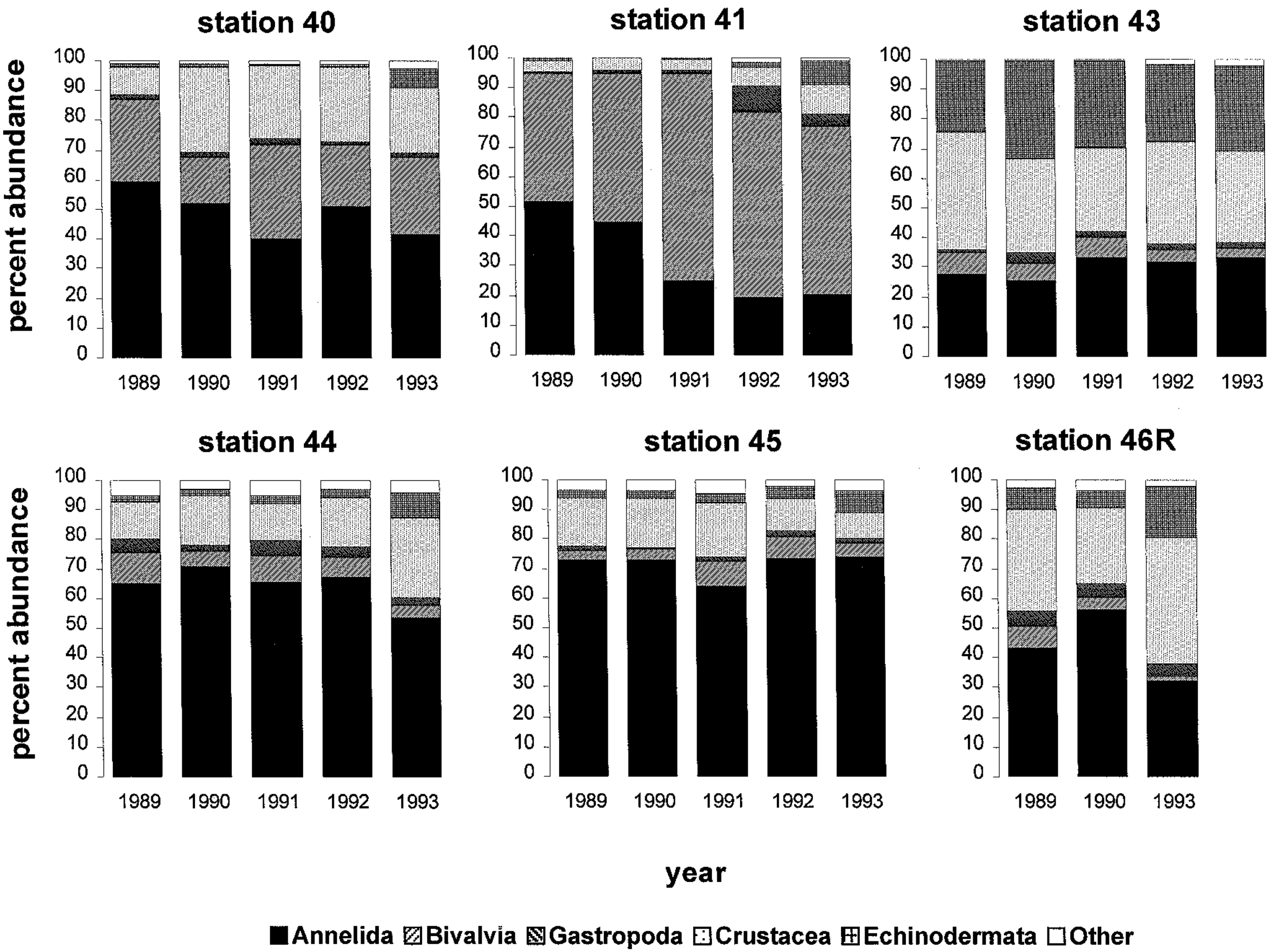

station 1
station 2R
station 3
station 4
station 5
station 8
percent abundance
0
10
20
30
40
50
60
70
80
90
100
1989
1990
1991
1992
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

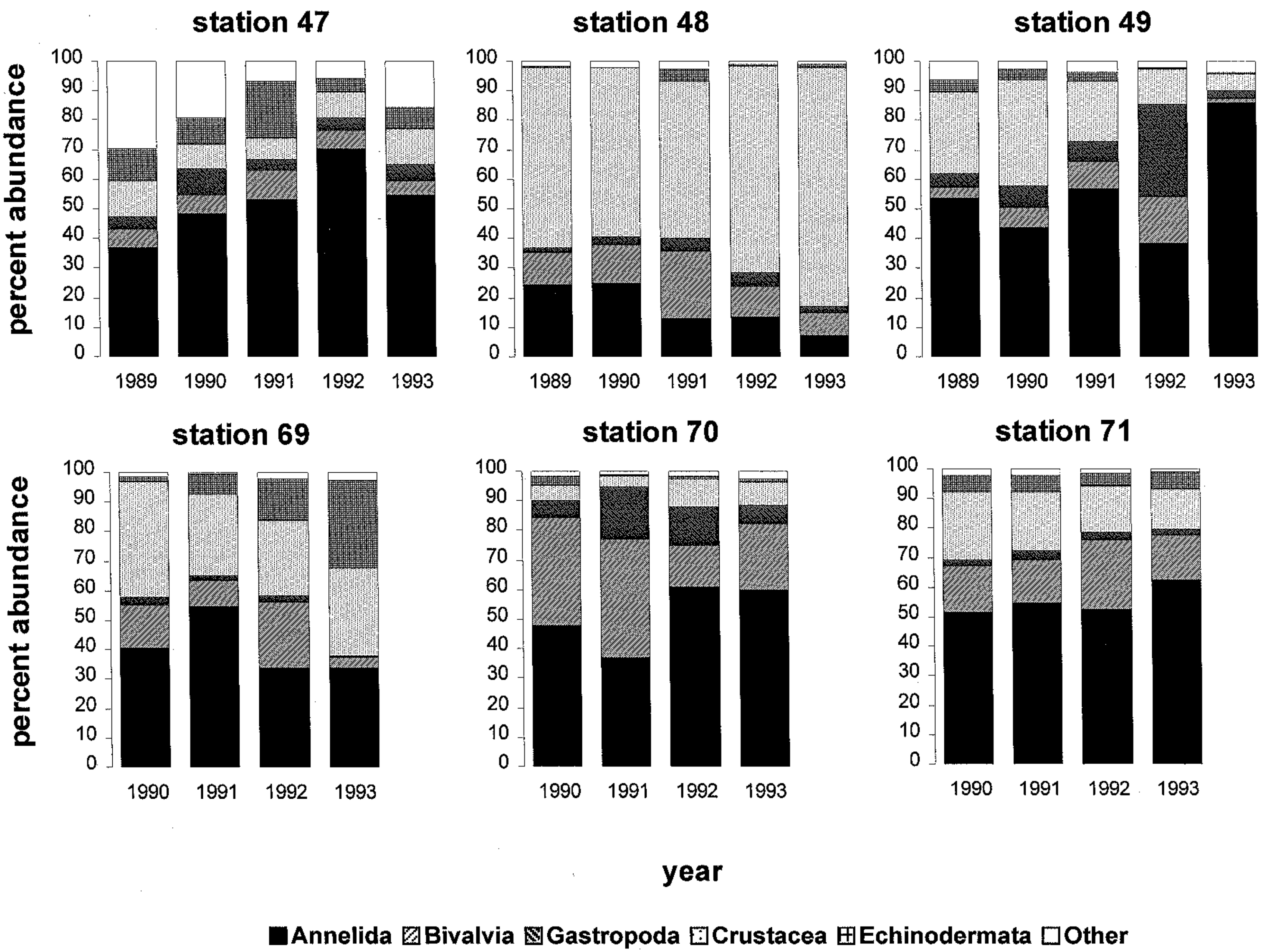

station 9R
station 10R
station 11R
station 12
station 13R
station 14
station 15
percent abundance
year
1989
1990
1991
1992
1993
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

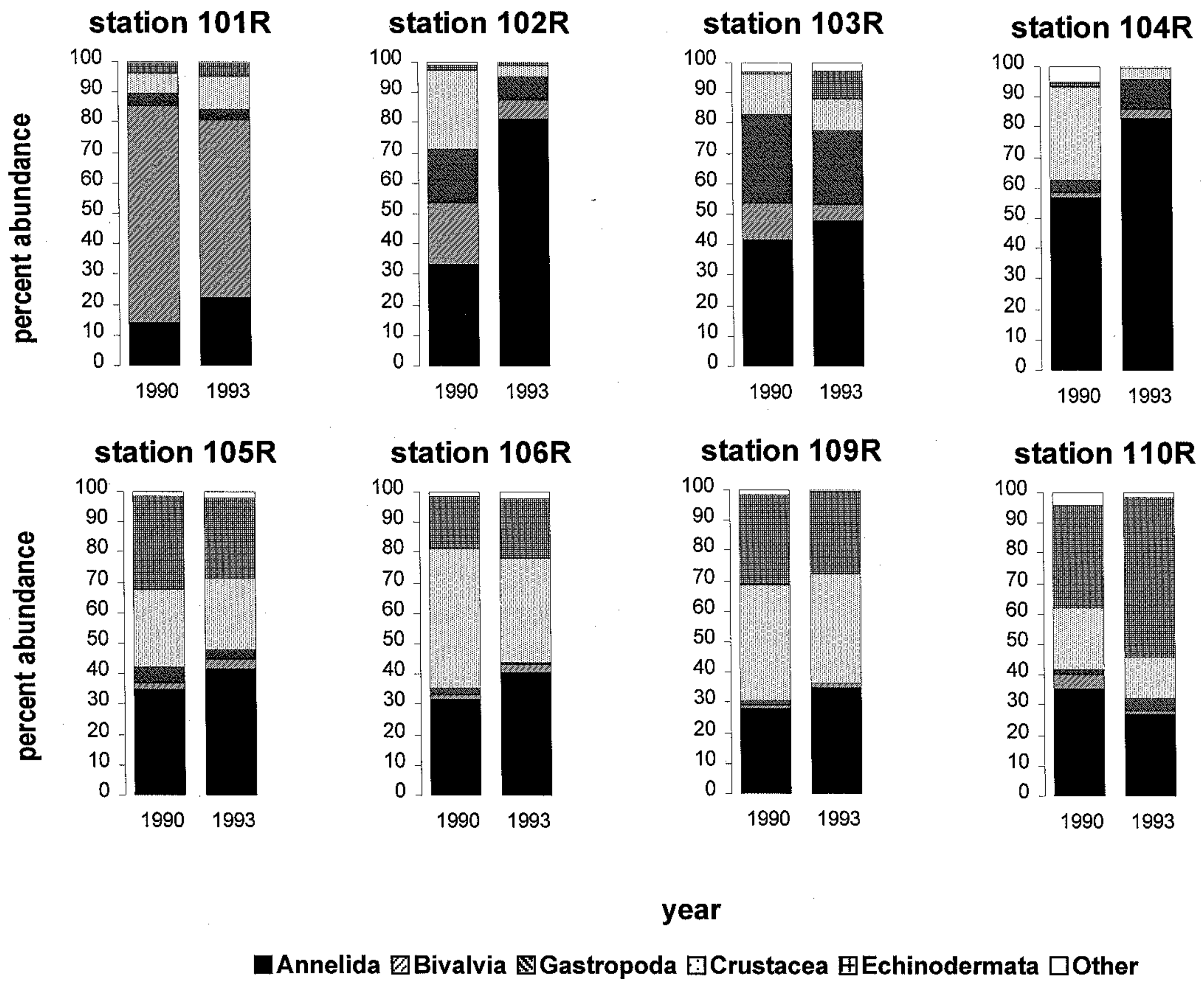

station 17
station 18
station 19
station 20
station 21
station 22
percent abundance
percent abundance
100
90
80
70
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

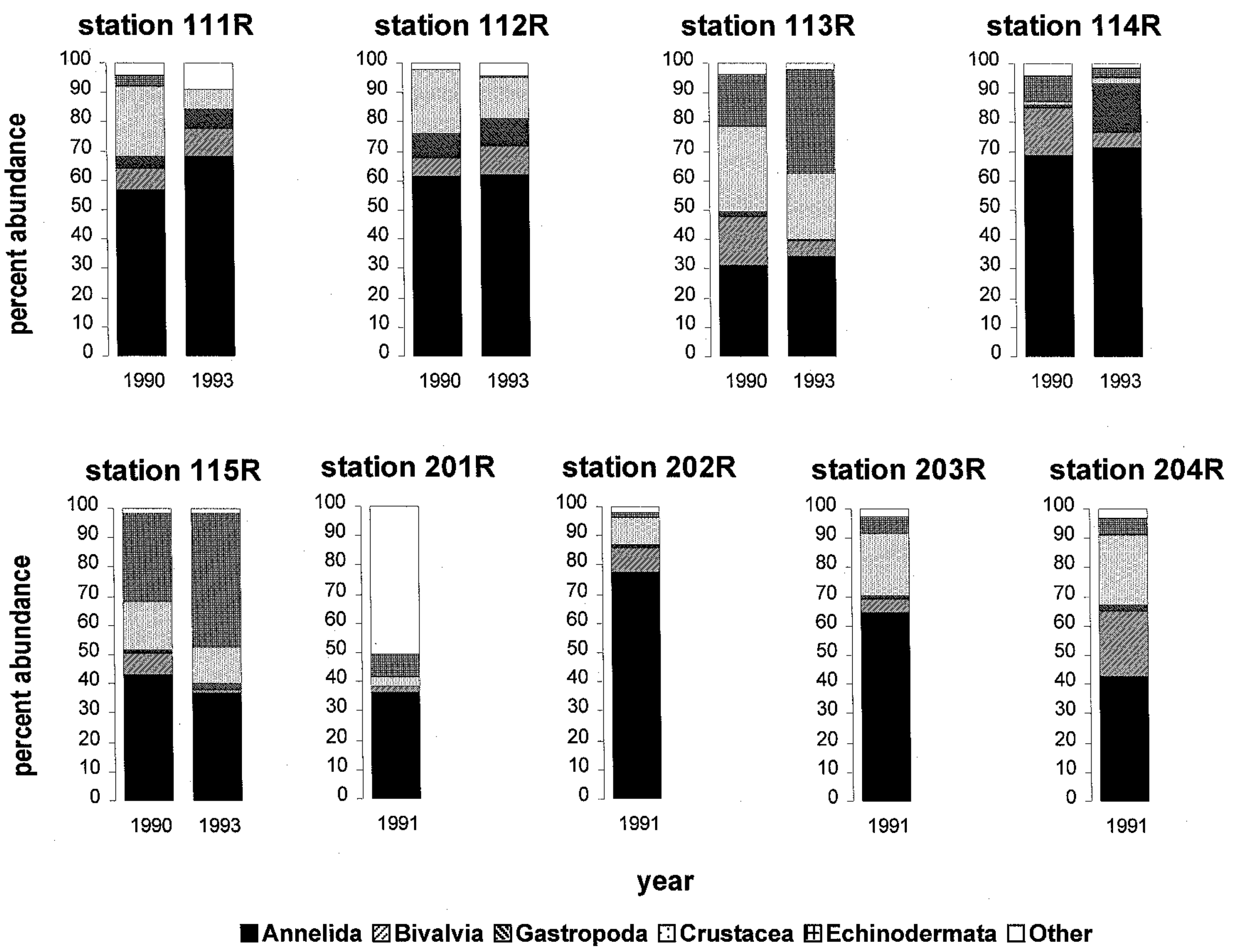

station 23R
station 24R
station 25R
station 26
station 27R
station 29
station 30
station 32
percent abundance
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

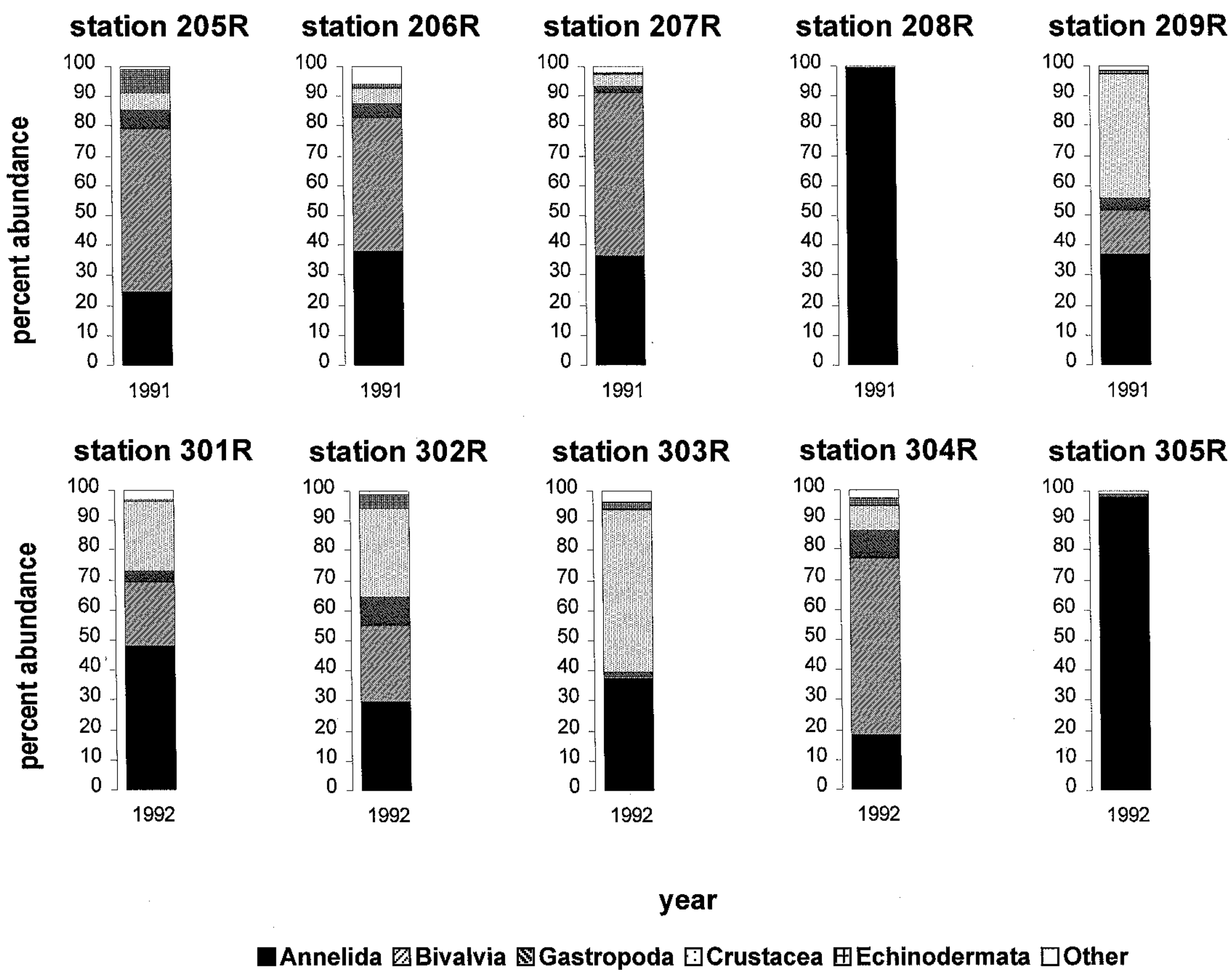

station 33
station 34
station 35
station 36R
station 37R
station 38
station 39
percent abundance
100
90
80
70
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

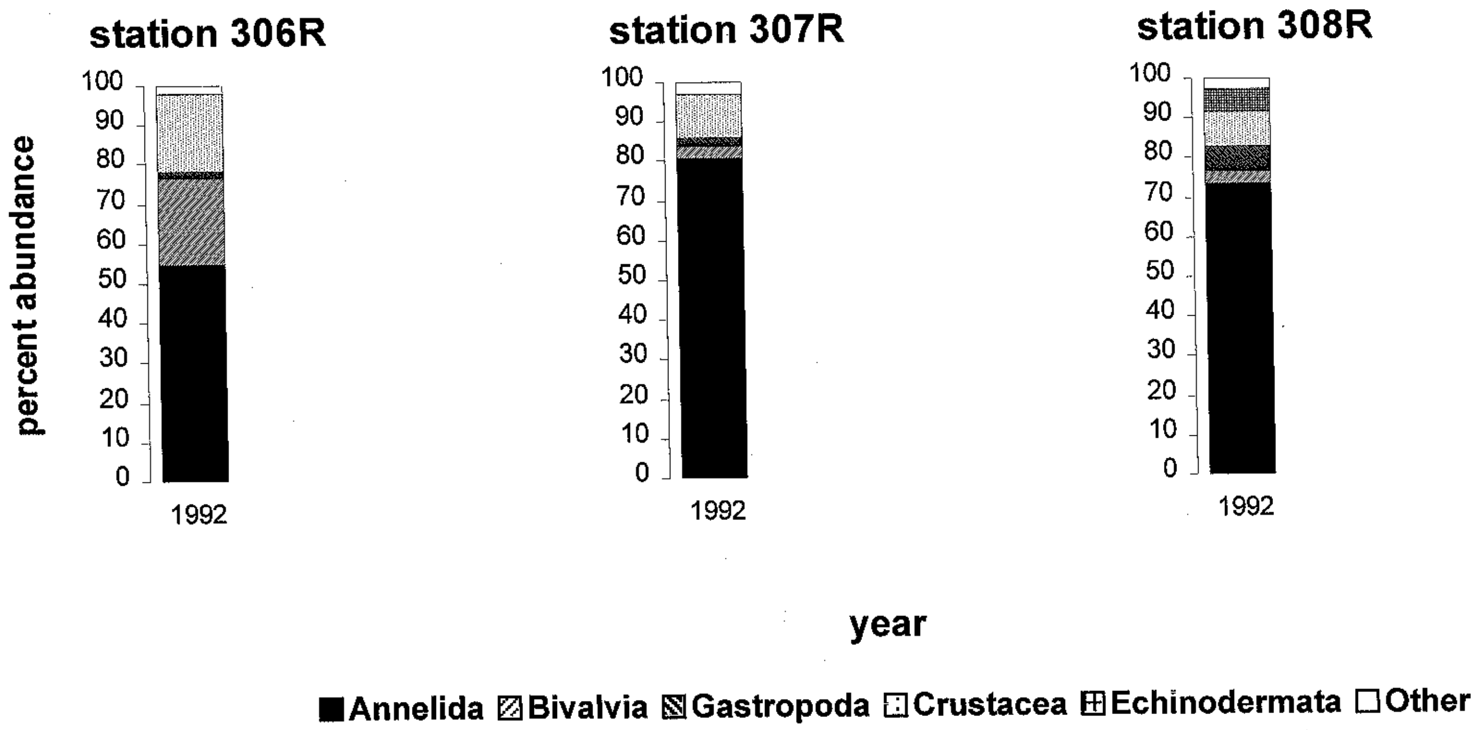

station 40
station 41
station 43
station 44
station 45
station 46R
percent abundance
100
90
80
70
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other


station 47
station 48
station 49
station 69
station 70
station 71
percent abundance
0
10
20
30
40
50
60
70
80
90
100
1989
1990
1991
1992
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other


station 101R
station 102R
station 103R
station 104R
station 105R
station 106R
station 109R
station 110R
percent abundance
0
10
20
30
40
50
60
70
80
90
100
1990
1993
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other


station 111R
station 112R
station 113R
station 114R
station 115R
station 201R
station 202R
station 203R
station 204R
percent abundance
100
90
80
70
60
50
40
30
20
10
0
1990
1993
1991
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other


station 205R
station 206R
station 207R
station 208R
station 209R
station 301R
station 302R
station 303R
station 304R
station 305R
percent abundance
1991
1992
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other


station 306R
station 307R
station 308R
percent abundance
100
90
80
70
60
50
40
30
20
10
0
1992
year
Annelida
Bivalvia
Gastropoda
Crustacea
Echinodermata
Other

# Appendix D

## Species and Station Groups Identified by Classification Analysis

Appendix D. Species and station groups identified by classification analysis of MSMP stations and used in nodal analysis (see figures 13-22).

**Year: 1989**

**Species Groups**

**Group 1**

*Acila castrensis*
*Laonice cirrata*
*Lumbrineris cruzensis*
*Odostomia* sp

**Group 2**

*Alvania compacta*
*Praxillella* sp
*Turbonilla* sp.

**Group 3**

*Ampelisca* sp
*Parvilucina tenuisculpta*
*Axinopsida serricata*
*Glycera nana*
*Mediomastus* sp.
*Glycinde* sp
Nemertina
*Mysella tumida*
*Nephtys signifera*
*Nucula tenuis*
*Lumbrineris luti*
*Paraprionospio pinnata*

**Group 4**

*Aphelochaeta* sp
*Amphiodia urtica/periercta*
*Pholoe minuta*
*Pinnixa occidentalis/schmitti*
*Prionospio (Minuspio) lighti*

**Group 5**

*Polycirrus* sp.
*Polydora socialis/cardalia*
*Compsomyax subdiaphana*
*Nitidella/Mitrella*
*Psephidia lordi*
*Euclymene* sp.

**Group 6**

*Eudorella pacifica*
*Harpiniopsis/Heterophoxus*
*Levinsenia gracilis*
*Terebellides* sp.
*Euphilomedes producta*
*Pectinaria californiensis*

**Group 7**

*Macoma calcarea/elimata*
Cylichnidae
*Yoldia scissurata*
*Nephtys cornuta*
*Spiophanes berkeleyorum*
*Podarkeopsis glabrus*
*Heteromastus* sp
*Macoma carlottensis*

**Group 8**

*Aricidea (Acmira) catherinae/lopezi*
*Lyonsia californica*
*Rutiderma lomae*
Cylindroleberididae
*Eteone* sp

**Group 9**

*Byblis millsi*
*Megacrenella columbiana*
*Diopatra ornata*
*Eumida longicornuta*
*Spiochaetopterus costarum*
*Macoma yoldiformis*
*Platynereis bicanaliculata*
*Chaetozone* sp.
*Cistenides granulata*
*Onuphis iridescens*
*Leitoscoloplos pugettensis*
Sipuncula
*Westwoodilla caecula*
*Euphilomedes carcharodonta*
*Notomastus* sp.
*Prionospio jubata*
*Lumbrineris californiensis*
*Phyllochaetopterus prolifica*
*Magelona longicornis*

**Group 10**

*Amage anops*
*Sthenelais tertiaglabra*
*Thyasira flexuosa*
*Lucinoma annulata*
*Nemocardium centifilosum*
*Pista bansei*
*Nassarius mendicus*

**Group 11**

*Caulleriella* sp
*Dorvillea (D.) pseudorubrovittata*
*Pentamera* sp
*Exogone dwisula*
*Pholoides asperus*
*Neosabellaria cementarium*
*Odontosyllis phosphorea*
*Cirratulus cirratus*
*Mesochaetopterus taylori*

**Group 12**

*Cardiomya* sp.
*Exogone (E.) lourei*
*Musculus* sp.
*Lirobittium attenuatum*
*Hippomedon* cf *coecus*
*Rhepoxynius abronius/variatus*
*Leptochelia savignyi*
*Olivella baetica*

**Group 13**

*Adontorhina cyclia*
*Myriochele heeri*
*Cyclocardia ventricosa*
*Eualus pusiolus*
*Foxiphalus similis/cognatus*
*Polydora brachycephala*
*Ampharete acutifrons*
Phoronida
*Amphipholis* sp
*Pista wui*
Anarthruridae/Leptognathiidae
*Corophium* sp.
*Eyakia robusta*
*Prionospio (Minuspio) multibranchiata*

**Group 14**

*Artacamella hancocki*
*Paraphoxus oculatus*
*Yoldia thraciaeformis*
*Brada sachalina*
*Chaetoderma* sp
*Molpadia intermedia*
*Eudorellopsis longirostris*
*Barantolla americana*
*Melita desdichada*
*Diastylis* sp.
*Malmgreniella* sp.

**Group 15**

*Cossura* sp.
Oligochaeta
*Dentalium* sp.
*Pandora* sp
*Sternaspis scutata*
*Lanassa venusta*
*Nuculana minuta*
*Nereis procera*

**Group 16**

*Boccardia pugettensis*
*Decamastus gracilis*
*Macoma nasuta*

**Group 17**

*Aricidea (Allia) ramosa*
*Lepidasthenia berkeleyae*
*Edwardsia sipunculoides*

**Group 18**

Astartidae
*Scoloplos armiger*
*Spiophanes bombyx*
*Tellina modesta*
*Tellina nuculoides*

**Group 19**

*Protomedeia grandimana*
*Protomedeia penates/prudens*
*Boccardiella hamata*
*Nicomache personata*
*Sigambra tentaculata*
*Echiurus* sp
*Maldane sarsi*

**Group 20**

*Delectopecten vancouverensis*
*Cirrophorus branchiatus*
*Eudorellopsis integra*

**Station Groups**

**Group A**

1 Semiahmoo Bay, Blaine
4 Bellingham Bay
5 Samish Bay
2R Cherry Point
12 Port Townsend Bay

**Group B**

34 Sinclair Inlet
35 Dyes Inlet

**Group C**

18 Oak Harbor
21 Port Gardner
30 Eagle Harbor
41 Commencement Bay
20 Port Susan

**Group D**

8 Port Angeles
10R Dungeness Bay
11R Discovery Bay

**Group E**

14 Hood Canal, Bangor
15 Dabob Bay

**Group F**

32 Magnolia Bluff
37R North Vashon Island
27R West Central Basin
33 Elliott Bay
40 Commencement Bay

**Group G**

43 Carr Inlet
44 East Anderson Island
46R West Nisqually
47 Case Inlet

**Group H**

22 Mukilteo
23R East Central Basin
39 Dash Point
36R Brace Point
25R West Central Basin
13R North Hood Canal

**Group I**

3 Strait of Georgia

**Group J**

48 Outer Budd Inlet
49 Inner Budd Inlet

**Group K**

17 S Hood Canal, Great Bend
29 Shilshole
38 Point Pully
24R East Central Basin
19 Saratoga Passage
45 Devil's Head

**Year: 1990**

**Species Groups**

**Group 1**

*Acila castrensis*
*Aricidea (Acmira) catherinae/lopezi*
*Armandia/Ophelina*
*Cossura* sp.
*Sternaspis scutata*
*Yoldia scissurata*
Oligochaeta
*Heteromastus* sp.

**Group 2**

*Alvania compacta*
*Polycirrus* sp.
*Terebellides* sp
*Turbonilla* sp
*Eteone* sp.

**Group 3**

*Amphiodia urtica/periercta*
*Eudorella pacifica*
*Heterophoxus* sp.
*Levinsenia gracilis*

**Group 4**

*Aphelochaeta* sp
*Glycinde* sp
*Mysella tumida*
*Nephtys signifera*
*Parvilucina tenuisculpta*

**Group 5**

*Lumbrineris luti*
Nemertina
*Paraprionospio pinnata*
*Odostomia* sp.
*Nephtys cornuta*
*Prionospio (Minuspio) lighti*
*Pholoe minuta*
*Pinnixa occidentalis/schmitti*

**Group 6**

*Spiophanes berkeleyorum*
*Lumbrineris cruzensis*

**Group 7**

*Axinopsida serricata*
*Euphilomedes producta*
*Glycera nana*
*Nucula tenuis*

**Group 8**

*Leitoscoloplos pugettensis*
*Prionospio jubata*
*Mediomastus* sp
*Praxillella* sp.

**Group 9**

*Euphilomedes carcharodonta*
*Compsomyax subdiaphana*
*Pectinaria californiensis*
*Psephidia lordi*

**Group 10**

*Ampelisca careyi*
Cylichnidae
*Podarkeopsis glabrus*
*Sigambra tentaculata*
*Nassarius mendicus*
*Nitidella/Mitrella*
*Macoma carlottensis*

**Group 11**

*Aricidea (Allia) ramosa*
*Phyllochaetopterus prolifica*

**Group 12**

*Amage anops*
*Ampharete* sp
*Synchelidium shoemakeri*
*Streblosoma bairdi*
*Macoma calcarea/elimata*
*Onuphis iridescens*

**Group 13**

*Ampelisca hancocki*
*Protomedeia articulata*
Anarthruridae/Leptognathiidae
*Clinocardium* sp
*Photis* sp.

**Group 14**

*Ampelisca lobata*
*Neosabellaria cementarium*
*Corophium* sp
*Exogone dwisula*
*Diopatra ornata*
*Edwardsia sipunculoides*
*Ophiodromus pugettensis*

**Group 15**

*Byblis millsi*
*Megacrenella columbiana*
*Lumbrineris californiensis*
*Notomastus tenuis*
*Lyonsia californica*
*Cistenides granulata*
*Notomastus latericeus*
*Chaetozone* sp.
*Leptochelia savignyi*
*Lanassa venusta*
*Exogone (E.) lourei*

**Group 16**

*Eumida longicornuta*
*Platynereis bicanaliculata*
*Westwoodilla caecula*
*Macoma yoldiformis*
*Laonice cirrata*
*Thysanocardia nigra*
*Polydora socialis/cardalia*
*Spiochaetopterus costarum*
*Magelona longicornis*

**Group 17**

*Mesochaetopterus taylori*
*Pholoides asperus*

**Group 18**

*Amphipholis squamata*
*Odontosyllis phosphorea*
*Pherusa plumosa*
*Cirratulus cirratus*
*Pachycerianthus fimbriatus*
*Artacama coniferi*
*Nereis procera*
*Pilargis maculata*
*Chaetoderma* sp.
*Dorvillea (D.) pseudorubrovittata*

**Group 19**

*Apistobranchus ornatus*
*Boccardia pugettensis*
*Prionospio (Minuspio) multibranchiata*
*Clymenura gracilis*
*Syllis (Ehlersia) heterochaeta/hyperioni*
*Rhepoxynius abronius*
*Thyasira flexuosa*

**Group 20**

*Decamastus gracilis*
*Delectopecten vancouverensis*
Phoronida
*Myriochele* sp.
*Nephtys discors*

**Group 21**

*Protothaca staminea*
*Rhepoxynius variatus*
*Tellina modesta*
*Maldane sarsi*

**Group 22**

*Barantolla americana*
*Pista wui*
*Scalibregma inflatum*
*Natica clausa*
*Polydora brachycephala*

**Group 23**

*Bathymedon pumilis*
*Eudorellopsis integra*
*Paraphoxus oculatus*
*Harpiniopsis fulgens*
*Molpadia intermedia*
*Protomedeia penates/prudens*
*Lirobittium attenuatum*
*Dorvillea (Schistomeringos) annulata*

**Group 24**

*Eyakia robusta*
*Sarsiella* sp

**Group 25**

*Protomedeia grandimana*
Scaphopoda

**Group 26**

*Foxiphalus obtusidens*
*Magelona sacculata*
*Olivella baetica*
*Macoma nasuta*

**Station Groups**

**Group A**

1 Semiahmoo Bay, Blaine
12 Port Townsend Bay
4 Bellingham Bay
5 Samish Bay

**Group B**

14 Hood Canal, Bangor
30 Eagle Harbor
71 Fidalgo Bay
8 Port Angeles

**Group C**

34 Sinclair Inlet
35 Dyes Inlet

**Group D**

20 Port Susan

**Group E**
113R Willochet Bay
33 Elliott Bay
43 Carr Inlet
32 Magnolia Bluff
44 East Anderson Island
47 Case Inlet
46R West Nisqually

**Group F**
21 Port Gardner
40 Commencement Bay
41 Commencement Bay
69 Port Madison

**Group G**
103R Mid Totten Inlet
15 Dabob Bay
22 Mukilteo

**Group H**
101R North Oakland Bay
70 Oakland Bay, Shelton
102R Inner Totten Inlet
104R Inner Eld Inlet
49 Inner Budd Inlet
18 Oak Harbor

**Group I**
105R Outer Eld Inlet
48 Outer Budd Inlet
106R Mid Budd Inlet
109R Henderson Inlet
111R Mid Case Inlet
115R Outer Filucy Bay
45 Devil's Head
110R Inner Case Inlet

**Group J**
114R Henderson Bay

**Group K**
17 S Hood Canal, Great Bend
19 Saratoga Passage
29 Shilshole
38 Point Pully

**Group L**
112R Nisqually Delta
39 Dash Point

**Group M**
3 Strait of Georgia

**Year: 1991**
**Species Groups**

**Group 1**
*Acila castrensis*
*Lumbrineris cruzensis*
*Polydora socialis/cardalia*

**Group 2**
*Alvania compacta*
*Nitidella/Mitrella*
*Amphiodia urtica/periercta*
*Odostomia* sp

**Group 3**
*Aphelochaeta* sp
Nemertina
*Praxillella* sp
*Mediomastus* sp
*Glycera nana*
*Lumbrineris luti*
*Parvilucina tenuisculpta*
*Glycinde* sp
*Mysella tumida*
*Pholoe minuta*
*Pinnixa occidentalis/schmitti*

**Group 4**
*Eudorella pacifica*
*Heterophoxus* sp
*Prionospio (Minuspio) lighti*
*Paraprionospio pinnata*
*Terebellides* sp

**Group 5**
*Axinopsida serricata*
*Euphilomedes producta*
*Macoma carlottensis*
*Nucula tenuis*
*Leitoscoloplos pugettensis*
*Prionospio jubata*
*Spiophanes berkeleyorum*

**Group 6**
*Psephidia lordi*
*Compsomyax subdiaphana*
*Macoma elimata*
*Euclymene zonalis*

**Group 7**
*Ampelisca careyi*
*Yoldia scissurata*
Cylichnidae
*Aricidea (Acmira) catherinae/lopezi*
*Cossura* sp
*Laonice cirrata*
*Levinsenia gracilis*

**Group 8**
*Chaetozone* sp
*Megacrenella columbiana*
*Lucinoma annulata*
*Nephtys signifera*
*Turbonilla* sp
Sipuncula
*Westwoodilla caecula*
*Diopatra ornata*
*Magelona longicornis*
*Eumida longicornuta*
*Spiochaetopterus costarum*
*Pectinaria californiensis*
*Eteone* sp
*Polycirrus* sp
*Nephtys cornuta*
*Podarkeopsis glabrus*

**Group 9**
*Euphilomedes carcharodonta*
*Barantolla americana*
*Lanassa* sp
*Melita desdichada*
*Leptochelia savignyi*
*Notomastus tenuis*
*Platynereis bicanaliculata*
*Tellina modesta*
*Pista wui*

**Group 10**
*Adontorhina cyclia*
Anarthruridae/Leptognathiidae
*Rhodine bitorquata*
Oligochaeta
*Onuphis iridescens*
*Ampharete acutifrons*
*Diastylis* sp.
*Goniada brunnea*
*Drilonereis falcata minor*
*Maldane sarsi*
*Melinna* sp
*Pista bansei*
*Pista brevibranchiata*
**Group 11**
*Artacama coniferi*
*Pilargis maculata*
*Chaetoderma* sp
*Heteromastus filobranchus*
**Group 12**
*Decamastus gracilis*
*Exogone (E.) lourei*
*Myriochele heeri*
*Phyllochaetopterus prolifica*
**Group 13**
*Amage anops*
*Macoma yoldiformis*
*Ophiodromus pugettensis*
*Aricidea (Allia) ramosa*
*Cirratulus cirratus*
*Corophium* sp
*Mesochaetopterus taylori*
*Cistenides granulata*
*Edwardsia sipunculoides*
*Exogone dwisula*
*Pholoides asperus*
*Lumbrineris californiensis*
*Syllis (Ehlersia) heterochaeta/hyperioni*
**Group 14**
Cylindroleberididae
*Synchelidium* sp.
*Macoma nasuta*
*Nassarius mendicus*
**Group 15**
*Amphipholis squamata*
*Macoma calcarea*
Phoronida

**Group 16**
*Dentalium* sp
*Nuculana minuta*
*Pandora* sp
*Myriochele oculata*
*Sternaspis scutata*
*Ophelina acuminata*
*Protothaca staminea*
**Group 17**
*Lirobittium attenuatum*
*Rhepoxynius abronius*
*Rhepoxynius variatus*
**Group 18**
*Ampelisca pugetica*
*Asabellides lineata*
*Foxiphalus similis/cognatus*
*Cyclocardia ventricosa*
*Boccardia* sp.
*Euchone incolor*
*Rhepoxynius* cf *barnardi*
**Group 19**
*Ampelisca unsocalae*
*Stylatula elongata*
*Pentamera pseudocalcigera*
**Group 20**
Astartidae
*Hemipodus borealis*
*Polygordius* sp.
*Hesionura coineaui*
*Heteropodarke heteromorpha*
*Tellina nuculoides*
*Natica clausa*
*Owenia fusiformis*
*Spiophanes bombyx*
**Group 21**
*Cucumaria piperata*
*Dorvillea (D.) pseudorubrovittata*
*Nebalia* sp.
*Olivella baetica*
*Streblosoma bairdi*
**Group 22**
*Eyakia robusta*
*Scalibregma inflatum*
*Protomedeia grandimana*

**Group 23**
*Brada sachalina*
*Bylgides macrolepidus*
*Nephtys discors*
*Parvamussium alaskensis*
*Eudorellopsis integra*
*Molpadia intermedia*
*Paraphoxus oculatus*
*Protomedeia prudens*
*Gattyana treadwelli*
**Group 24**
*Leptosynapta transgressor*
*Ophiura sarsi*
*Sigambra tentaculata*
**Station Groups**
**Group A**
1 Semiahmoo Bay, Blaine
204R East Sound
**Group B**
48 Outer Budd Inlet
49 Inner Budd Inlet
70 Oakland Bay, Shelton
**Group C**
17 S Hood Canal, Great Bend
19 Saratoga Passage
29 Shilshole
38 Point Pully
**Group D**
30 Eagle Harbor
32 Magnolia Bluff
44 East Anderson Island
33 Elliott Bay
40 Commencement Bay
69 Port Madison
47 Case Inlet
43 Carr Inlet
**Group E**
10R Dungeness Bay
11R Discovery Bay
**Group F**
13R North Hood Canal
15 Dabob Bay
22 Mukilteo
39 Dash Point
**Group G**
12 Port Townsend Bay
4 Bellingham Bay
5 Samish Bay

**Group H**

205R NW Blakely Island
8 Port Angeles
206R Friday Harbor
207R West Beach
2R Cherry Point
71 Fidalgo Bay

**Group I**

14 Hood Canal, Bangor
45 Devil's Head
201R Roberts Bank
202R Point Roberts

**Group J**

18 Oak Harbor
20 Port Susan
209R Skagit Bay
21 Port Gardner
41 Commencement Bay

**Group K**

203R Bellingham Bay
34 Sinclair Inlet
35 Dyes Inlet

**Group L**

3 Strait of Georgia

**Group M**

9R East of Green Point

**Group N**

208R Sequim Bay

**Year: 1992**

**Species Groups**

**Group 1**

*Acila castrensis*

**Group 2**

*Alvania compacta*
*Nitidella/Mitrella*

**Group 3**

*Aphelochaeta* sp.
*Paraprionospio pinnata*
*Odostomia* sp.
*Pholoe minuta*
*Pinnixa occidentalis/schmitti*
*Lumbrineris luti*

**Group 4**

*Axinopsida serricata*
*Glycinde* sp
Nemertina
*Prionospio (Minuspio) lighti*
*Mysella tumida*
*Parvilucina tenuisculpta*
*Prionospio jubata*
*Mediomastus* sp
*Nephtys signifera*
*Polycirrus* sp
*Phyllodoce* sp.
*Westwoodilla caecula*
*Polydora socialis/cardalia*

**Group 5**

*Glycera nana*
*Spiophanes berkeleyorum*

**Group 6**

*Amphiodia urtica/periercta*
*Eudorella pacifica*
*Heterophoxus* sp

**Group 7**

*Podarkeopsis glabrus*
*Levinsenia gracilis*
*Terebellides* sp
*Nucula tenuis*
*Praxillella* sp.

**Group 8**

Cylichnidae
*Macoma carlottensis*
*Euphilomedes producta*
*Pectinaria californiensis*

**Group 9**

*Euclymene* sp
*Leitoscoloplos pugettensis*
*Lanassa* sp
*Macoma calcarea/elimata*
*Nemocardium centifilosum*

**Group 10**

*Euphilomedes carcharodonta*
*Psephidia lordi*

**Group 11**

*Cossura* sp.
*Heteromastus filobranchus*
*Macoma nasuta*
*Nephtys cornuta*

**Group 12**

*Amage anops*
*Rhodine bitorquata*

**Group 13**

*Anobothrus gracilis*
*Megacrenella columbiana*
*Byblis millsi*
*Lumbrineris californiensis*
*Cistenides granulata*
*Leptochelia savignyi*
*Diopatra ornata*
*Eumida longicornuta*
*Spiochaetopterus costarum*

**Group 14**

*Onuphis iridescens*
Phoronida

**Group 15**

*Barantolla americana*
*Chaetozone* sp
*Notomastus tenuis*
*Syllis (Typosyllis) harti*
*Thysanocardia nigra*
*Laonice cirrata*
*Magelona longicornis*

**Group 16**

*Caulleriella* sp.
*Syllis (Ehlersia) heterochaeta/hyperioni*
*Edwardsia sipunculoides*
*Eulalia (Eulalia) bilineata*
*Mesochaetopterus taylori*

**Group 17**

Cylindroleberididae
*Hippomedon* cf *coecus*
*Platynereis bicanaliculata*
*Tellina modesta*
*Rhepoxynius abronius*

**Group 18**

*Exogone dwisula*
*Phyllochaetopterus prolifica*
*Pholoides asperus*

**Group 19**

*Nassarius mendicus*

**Group 20**

*Ampelisca hancocki*
*Ophelina acuminata*
*Aricidea (Acmira) catherinae/lopezi*
*Myriochele oculata*
*Nuculana minuta*
Anarthruridae/Leptognathiidae
*Cardiomya* sp.
*Asabellides lineata*
*Exogone (E.) lourei*
*Eudorellopsis longirostris*

**Group 21**

*Ampharete acutifrons*
*Malmgreniella* sp.
*Pista bansei*
*Pista wui*
*Chaetoderma* sp
*Diastylis* sp.
*Solen sicarius*
*Melita desdichada*

**Group 22**

*Brada sachalina*
*Yoldia thraciaeformis*
*Yoldia hyperborea*
*Photis brevipes*

**Group 23**

*Neotrypaea* sp.
*Scalibregma inflatum*
*Rictaxis punctocaelatus*
*Polinices pallidus*

**Group 24**

*Aricidea (Allia) ramosa*
*Lumbrineris cruzensis*
*Nereis procera*
*Polydora* sp. 1

**Group 25**

*Ampelisca careyi*
Scaphopoda
*Pachycerianthus fimbriatus*
*Sternaspis scutata*

**Group 26**

*Cirratulus cirratus*
*Dorvillea (D.) pseudorubrovittata*
*Eulima/Balcis*
*Olivella baetica*
*Corophium crassicorne*
*Monoculodes* sp.

**Group 27**

*Orchomene pacifica*
*Spiophanes bombyx*

**Group 28**

*Lirobittium attenuatum*

**Group 29**

*Adontorhina cyclia*
*Onuphis elegans*
*Thyasira flexuosa*
*Myriochele heeri*
*Polydora* sp. A

**Group 30**

*Crangon alaskensis*
*Protothaca staminea*
*Trochochaeta multisetosa*
*Eudorellopsis integra*
*Micropodarke dubia*
*Streblosoma bairdi*

**Group 31**

*Cucumaria piperata*
*Eyakia robusta*
*Decamastus gracilis*
*Delectopecten vancouverensis*

**Group 32**

*Maldane sarsi*

**Group 33**

*Macroclymene* sp.
*Photis lacia*
*Rhepoxynius* cf *barnardi*
*Rhepoxynius variatus*

**Group 34**

*Boccardiella hamata*
*Protomedeia articulata*

**Group 35**

*Sigambra tentaculata*
*Petaloproctus tenuis*

**Group 36**

*Bathymedon pumilis*
*Brisaster latifrons*
*Maera loveni*
*Harpiniopsis fulgens*
*Molpadia intermedia*
*Paraphoxus oculatus*

**Group 37**

*Protomedeia prudens*
*Astarte esquimalti*
*Crenella decussata*
*Protomedeia grandimana*
*Lamprops quadriplicata*

**Station Groups**

**Group A**

1 Semiahmoo Bay, Blaine
4 Bellingham Bay
5 Samish Bay
12 Port Townsend Bay

**Group B**

45 Devil's Head

**Group C**

8 Port Angeles
71 Fidalgo Bay
302R Oak Bay
30 Eagle Harbor
308R Liberty Bay

**Group D**

34 Sinclair Inlet
35 Dyes Inlet
303R Quartermaster Harbor

**Group E**

14 Hood Canal, Bangor
26 Central Basin

**Group F**

18 Oak Harbor
20 Port Susan

**Group G**

21 Port Gardner
22 Mukilteo
41 Commencement Bay

**Group H**

15 Dabob Bay

**Group I**

32 Magnolia Bluff
27R West Central Basin
37R North Vashon Island
44 East Anderson Island
47 Case Inlet
33 Elliott Bay
40 Commencement Bay
69 Port Madison
43 Carr Inlet
306R Seahurst

**Group J**

39 Dash Point
36R Brace Point
23R East Central Basin
25R West Central Basin
301R Cherry Point

**Group K**

48 Outer Budd Inlet
49 Inner Budd Inlet
70 Oakland Bay, Shelton

**Group L**
3 Strait of Georgia
**Group M**
305R Hood Canal, Lynch Cove
307R Holmes Harbor
**Group N**
304R Quartermaster Harbor

**Group O**
17 S Hood Canal, Great Bend
19 Saratoga Passage
29 Shilshole
24R East Central Basin
38 Point Pully

**Year: 1993**
**Species Groups**
**Group 1**
*Acila castrensis*
*Protomedeia* sp
**Group 2**
*Alvania compacta*
*Lumbrineris californiensis/cruzensis*
**Group 3**
*Amphiodia urtica/periercta*
*Pholoe minuta*
*Paraprionospio pinnata*
*Pinnixa occidentalis/schmitti*
*Prionospio (Minuspio) lighti*
*Eudorella pacifica*
*Harpiniopsis/Heterophoxus*
**Group 4**
*Aphelochaeta* sp
Lineidae
*Tubulanus* sp
*Nitidella/Mitrella*
*Lumbrineris luti*
*Macoma* sp
*Nephtys signifera*
*Mysella tumida*
*Parvilucina tenuisculpta*
*Glycera nana*
*Mediomastus* sp
*Leitoscoloplos pugettensis*
*Prionospio jubata*
*Spiochaetopterus costarum*
**Group 5**
*Glycinde picta*
*Nephtys cornuta*
*Odostomia* sp
*Podarkeopsis glabrus*
**Group 6**
Cylichnidae

**Group 7**
*Axinopsida serricata*
*Euphilomedes producta*
*Pectinaria californiensis*
*Nucula tenuis*
*Cossura* sp
*Levinsenia gracilis*
**Group 8**
*Aricidea (Acmira) catherinae/lopezi*
*Compsomyax subdiaphana*
*Psephidia lordi*
*Polydora socialis*
*Terebellides californica*
*Spiophanes berkeleyorum*
**Group 9**
*Euphilomedes carcharodonta*
*Eyakia/Paraphoxus/Rhepoxynius*
**Group 10**
*Amage anops*
*Byblis millsi*
*Mesochaetopterus taylori*
**Group 11**
*Chaetozone* sp
*Glycinde armigera*
*Westwoodilla caecula*
Euclymeninae
*Turbonilla* sp
*Lyonsia californica*
*Polycirrus* sp
*Megacrenella columbiana*
*Notomastus tenuis*
*Syllis (Ehlersia) heterochaeta/hyperioni*
**Group 12**
*Leptochelia savignyi*
Phoronida
**Group 13**
Aoridae/Corophiidae
*Diopatra ornata*
*Eumida longicornuta*
*Edwardsia sipunculoides*
*Platynereis bicanaliculata*
*Magelona longicornis*
*Phyllochaetopterus prolifica*

**Group 14**
*Ampelisca hancocki*
*Neotrypaea* sp
*Chaetoderma* sp
*Laonice cirrata*
*Pilargis maculata*
**Group 15**
*Aricidea (Allia) ramosa*
*Lepidasthenia berkeleyae*
*Praxillella gracilis*
*Terebellides reishi*
*Praxillella pacifica*
**Group 16**
*Heteromastus filobranchus*
*Onuphis iridescens*
*Yoldia scissurata*
**Group 17**
*Ampelisca careyi*
*Nassarius mendicus*
*Sigambra tentaculata*
**Group 18**
Ceriantharia
*Yoldia hyperborea*
Oligochaeta
*Sternaspis scutata*
**Group 19**
*Ampelisca lobata*
*Caulleriella* sp A
*Kurtzia arteaga*
*Pholoides asperus*
*Cistenides granulata*
*Pista bansei*
*Eulalia (Eulalia) bilineata*
**Group 20**
*Ampharete acutifrons*
*Syllis (Typosyllis) harti*
*Pista wui*
*Barantolla americana*
*Lanassa* sp
*Dorvillea (D.) pseudorubrovittata*
*Exogone (E.) lourei*

**Group 21**
Cylindroleberididae
*Synchelidium* sp.
*Rictaxis punctocaelatus*
*Notomastus latericeus*
*Olivella baetica*

**Group 22**
*Diastylis* sp
*Melita desdichada*
*Orchomene* sp
*Pagurus* sp
*Photis* sp.
*Tellina* sp.

**Group 23**
*Lirobittium attenuatum*

**Group 24**
*Apistobranchus ornatus*
*Myriochele heeri*
*Cardiomya* sp
*Nuculana minuta*
*Decamastus gracilis*
*Delectopecten vancouverensis*
*Myriochele oculata*

**Group 25**
*Prionospio (Minuspio) multibranchiata*

**Group 26**
*Cyclocardia ventricosa*
*Ophelina acuminata*
*Euchone incolor*
*Maldane sarsi*

**Group 27**
*Brada sachalina*
*Nephtys punctata*
*Molpadia intermedia*
*Eudorellopsis integra*

**Group 28**
*Polydora cardalia*

**Group 29**
*Ampharete labrops*
Sarsiellidae
*Protothaca staminea*

**Group 30**
*Cucumaria piperata*
*Magelona sacculata*

**Station Groups**

**Group A**
1 Semiahmoo Bay, Blaine
34 Sinclair Inlet
35 Dyes Inlet
4 Bellingham Bay
5 Samish Bay
12 Port Townsend Bay
45 Devil's Head
115R Outer Filucy Bay

**Group B**
8 Port Angeles
71 Fidalgo Bay
20 Port Susan

**Group C**
14 Hood Canal, Bangor
26 Central Basin
18 Oak Harbor
30 Eagle Harbor
40 Commencement Bay
69 Port Madison
41 Commencement Bay
32 Magnolia Bluff
33 Elliott Bay
43 Carr Inlet
44 East Anderson Island
47 Case Inlet
113R Willochet Bay
46R West Nisqually

**Group D**
15 Dabob Bay
22 Mukilteo
21 Port Gardner

**Group E**
39 Dash Point
103R Mid Totten Inlet
112R Nisqually Delta

**Group F**
3 Strait of Georgia

**Group G**
48 Outer Budd Inlet
105R Outer Eld Inlet
106R Mid Budd Inlet
109R Henderson Inlet
110R Inner Case Inlet
111R Mid Case Inlet
114R Henderson Bay

**Group H**
49 Inner Budd Inlet
104R Inner Eld Inlet
102R Inner Totten Inlet
70 Oakland Bay, Shelton
101R North Oakland Bay

**Group I**
17 S Hood Canal, Great Bend
19 Saratoga Passage
29 Shilshole
38 Point Pully