Benthic infauna and sediment characteristics offshore from the Columbia River, August 1994

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Northwest Fisheries Science Center

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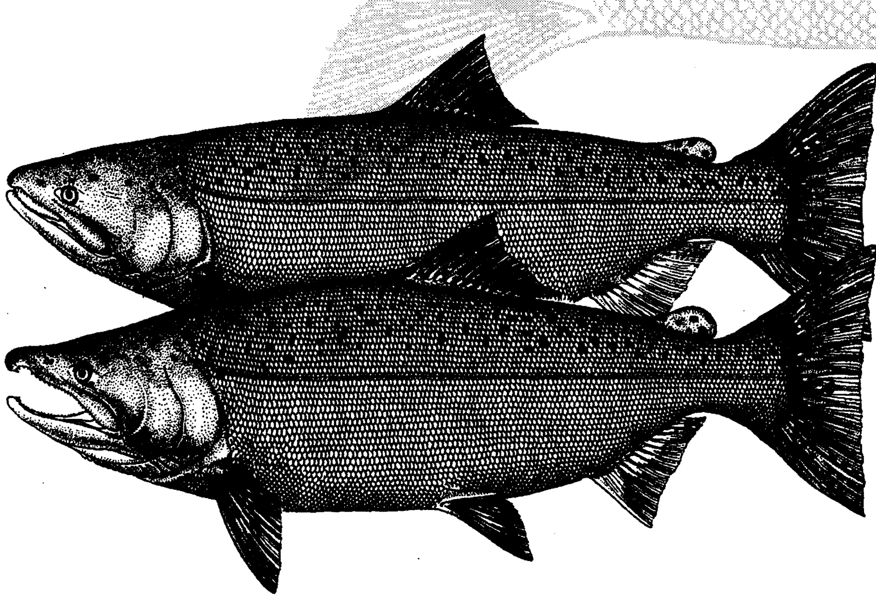

BENTHIC INFAUNA AND SEDIMENT CHARACTERISTICS

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and
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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers (COE), Portland District, is responsible for maintaining the navigational channel in the lower Columbia River estuary. This maintenance involves the annual removal of 3 to 9 million cubic yards of material, which is placed in one of four designated Ocean Dredged-Material Disposal Sites (ODMDS-A,B,E and F). Because material disposed of at ODMDS B had not dispersed as expected, creating a mound within 14.6 m (48 ft MLLW) of the ocean surface, temporary spatial expansions of Sites A, B, and F were initiated by the COE, Portland District, in 1992 while seeking a long-term solution for ocean disposal of dredged-material.

To minimize negative biological effects, new ODMDSs should be located in areas with no unique biological characteristics or critical habitat and relatively low standing crops of benthic and epibenthic invertebrates and fishes. The primary goal of the present study, which was conducted in August 1994, was to assess benthic invertebrate communities at 29 stations and sediment characteristics at 30 stations north and south of the Columbia River entrance. The same stations were sampled in July 1993 (Emmett and Hinton 1995).

Stations were located in an area approximately 16 km north, 17 km south, and 16 km west of the Columbia River mouth in depths ranging from 12.8 to 67.1 m. Benthic invertebrate and sediment samples were collected using a 0.1 m^2 modified Gray-O'Hara box corer.

During the August 1994 survey, 337 different benthic invertebrate taxa were identified. The number of taxa per station ranged from 55 to 158 and averaged 105. Densities of organisms per station ranged from 2,299 to 48,293 organisms/m^2 and averaged 13,242 organisms/m^2. Polychaetes were the most abundant taxa, averaging 7,362/m^2 and molluscs were the least abundant, averaging 917/m^2. The three most abundant taxa within each major

taxonomic group found throughout the study area included the polychaetes *Owenia fusiformis*, *Prionospio lighti*, and *Spiochaetopterus costarum*; the molluscs *Siliqua* spp., *Axinopsida serricata*, and *Olivella pycna*; and the crustaceans *Diastylopsis* spp., *Diastylopsis tenuis*, and *Leucon* spp.. Diversity (H) ranged from 1.81 to 4.91, and was considered high (>3.50) at 21 of the 29 stations. Equitability (E) ranged from 0.28 to 0.75 with most values between 0.50 and 0.70. Seven benthic invertebrate cluster groups (groups of stations with similar benthic invertebrate species and numbers) were identified, and five stations had no group affiliation. The largest cluster group was comprised of seven stations and was dominated by juvenile sanddollars (*Dendraster excentricus*), the polychaeta *Magelona sacculata* and nemertea. Other taxa that were dominant in the remaining cluster groups include the polychaetes *Owenia fusiformis*, *Pionospio lighti* and *Chaetozone setosa*; the cumaceans *Diastylopsis tenuis* and *D. dawsoni*. For the 27 stations occupied in both 1993 and 1994 there were no significant differences between years for the number of benthic invertebrate taxa and densities. Average median grain size was 0.15 mm, average percent silt/clay was 13.2%, and average percent volatile solids was 1.1% for all 30 stations. Sediments from 22 of the 30 stations were classified as fine sand (median grain size 0.125-0.250 mm).

Benthic invertebrate densities and composition can vary widely off the mouth of the Columbia River, as exemplified by the number of cluster groups that occurred in the 1994 survey. This area is subjected to a variety of influences: river flow, upwelling, downwelling, seasonal winds and currents, all of which can affect species diversity and densities. These influences may create many micro-habitats that could be in various stages of development.

Results from the 1994 and other recent surveys suggest that the nearshore, shallow-water (<40 m) areas, which typically have lower benthic invertebrate densities, should be investigated further as ocean dredged-material disposal sites.

CONTENTS

INTRODUCTION

The U.S. Army Corps of Engineers (COE), Portland District, is authorized to maintain navigational channels in the Columbia River and its estuary. Four Ocean Dredged-Material Disposal Sites (ODMDSs) off the mouth of the Columbia River have been designated by the Environmental Protection Agency to receive dredged material (Fig. 1). These sites are identified as ODMDSs A, B, E, and F and are used for disposal of materials dredged primarily from shoals at the mouth of the Columbia River, but may also receive dredged material from other areas in the lower estuary. Average annual dredged material quantities from the mouth of the Columbia River range from 3 to 9 million cubic yards, with most of the material disposed at Sites A and B. Site F was used for disposal of fine grained material dredged during the 1989 Tongue Point Monitoring Program (Siipola et al. 1993). A total of 2.29 and 1.5 million cubic yards of dredged-material from the mouth of the Columbia River were placed ad ODMDS F in 1993 and 1994 respectively. In 1992, ODMDS A, B and F were expanded for emergency dredged-material disposal because material disposed at the primary ocean disposal site (ODMDS B) had not dispersed as expected, but accumulated into a mound, that came within 14.6 m (48 ft) of the surface. The temporary (5-year) spatial expansions of Sites A, B, and F were initiated by the COE, Portland District, while searching for a long-term solution for dredged-material disposal.

A widespread benthic invertebrate survey offshore from the Columbia River was conducted during the mid 1970s under the COE's Dredged Materials Research Program (Richardson et al. 1977). A relatively recent site-specific survey of ODMDS F was conducted by the COE, Portland District, and the National Marine Fisheries Service (NMFS) from 1989 to 1992 (Siipola et al. 1993, Hinton and Emmett 1994). The 1993 survey was conducted offshore from the mouth of the Columbia River with stations north and south of the river entrance (Emmett and Hinton 1995).

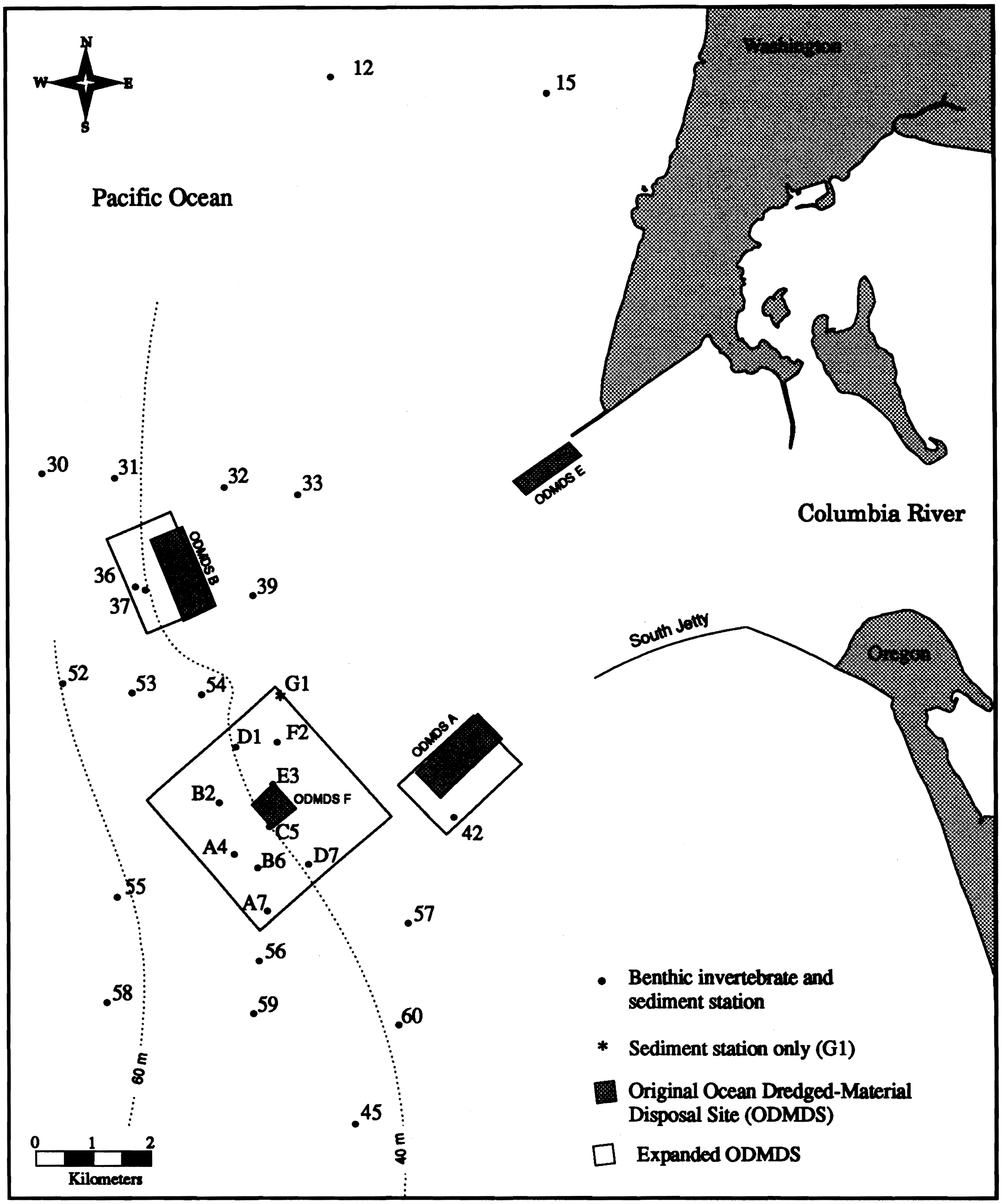

Figure 1. Location of benthic invertebrate and sediment sampling stations offshore from the Columbia River, August 1994.

To minimize their negative biological effects, new ODMDSs should be located in areas with no critical or unique biological characteristics and relatively low standing crops of benthic and epibenthic invertebrates and fishes. The primary goal of the present study was to assess benthic invertebrate communities at 29 stations and sediment characteristics at 30 stations in an area offshore from the Columbia River in August 1994. The same stations were occupied in July 1993 (Emmett and Hinton 1995). Eight of the benthic invertebrate stations were previously sampled during an intensive benthic survey at ODMDS F (Siipola et al. 1993).

METHODS

Sampling

Benthic Invertebrates

The sampling stations were located offshore from the Columbia River, extending about 16 km north, 17 km south, and 16 km west of the river mouth (Fig. 1). Twenty-nine stations were sampled for both benthic invertebrates and sediments; one additional station (G1) was sampled for sediment only. Station depths ranged from 12.8 to 67.1 m (Appendix Table 1). The Global Positioning System (GPS) was used to identify station geographic coordinates and to locate previously sampled stations.

A 0.1-m^2 modified Gray-O'Hara box corer (Pequegnat et al. 1981) was used to collect bottom samples (Appendix Fig. 1). Five benthic invertebrate samples were taken at each station. Benthic invertebrate samples were preserved in 18.9-liter buckets with a buffered 4% formaldehyde solution containing rose bengal (a protein stain). Within 2 weeks, the samples were individually sieved through a 0.5-mm mesh screen and the residue containing the macroinvertebrates was preserved in a 70% ethanol solution. Benthic organisms were sorted from the preserved samples, identified to the lowest practical taxonomic level (usually species), and counted. All specimens were placed in vials containing 70% ethanol and stored at the NMFS Point Adams Biological Field Station, Hammond, Oregon.

Sediments

Sediment samples for physical analyses were collected at all 30 stations. These samples were collected from the box corer using a stainless steel spoon, placed in labeled plastic bags, and refrigerated until delivery to the COE North Pacific Division Materials Testing Laboratory at Troutdale, Oregon.

Data Analyses

Benthic Invertebrates

At each station where benthic invertebrates were collected, the total number of organisms was determined and the number of organisms/m^2 was calculated. Each sample collected at a station was treated as a replicate, allowing calculation of a mean number of organisms/m^2 and standard deviation for each species and for each station. Two community structure indices were also calculated for each station. The first was diversity (H), which was determined using the Shannon-Wiener function (Krebs 1978):

$$H = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where $p_i = n_i/N$ (n_i is the number of individuals of the *i*th taxon in the sample, and N is the total number of individuals in the sample) and s = number of taxa. The second community structure index was equitability (E), which measures proportional abundances among the various taxa in a sample (Krebs 1978):

$$E = H/\log_2 s$$

where H = Shannon-Wiener function and s = number of taxa. E has a possible range of 0.00

to 1.00, with 1.00 indicating that all taxa in the sample are numerically equal.

Cluster analysis, using the Bray-Curtis dissimilarity index with a group-averaging fusion strategy (Clifford and Stephenson 1975), was used to identify stations that had similar species and densities. A dissimilarity value of ≤ 0.5 was considered a significant difference between groups. The mean number of individuals/m^2 for each species per station was used in the analysis. Species that had densities of less than 50 individuals/m^2 were excluded from the analysis to reduce the effect of uncommon species.

Sediments

Physical analyses of sediments included determinations of grain size and volatile solids. Median grain size and percent silt/clay were calculated for each sample.

RESULTS

Benthic Invertebrates

During the August 1994 benthic invertebrate survey, 348 different taxa were identified (Appendix Table 2). However, 11 taxa were not considered benthic organisms and were eliminated from the analysis. The number of benthic invertebrate taxa per station averaged 105 and ranged from 55 (Station 39) to 158 (Station 55) (Table 1, Appendix Table 3). Overall station densities averaged 13,242 invertebrates/m^2, and ranged from 2,299 organisms/m^2 (Station 42) to 48,293 organisms/m^2 (Station 54). Most station densities were < 25,000 organisms/m^2.

Polychaetes were the most abundant taxa, averaging 7,362/m^2, and molluscs were least abundant, averaging 917/m^2 (Table 2). The three most abundant taxa within each major taxonomic group found throughout the study area included the polychaetes *Owenia fusiformis*, *Prionospio lighti*, and *Spiochaetopterus costarum*; the molluscs *Siliqua* spp., *Axinopsida*

Table 1. Summary of benthic invertebrate collections by stations offshore from the Columbia River, August 1994.

Station	Date	Number of taxa	Number/m²	Standard deviation	H[a]	E[b]
A4	10Aug	104	5,562	765	4.53	0.68
A7	10Aug	112	5,483	867	4.84	0.71
B2	9Aug	136	13,798	7,462	4.39	0.62
B6	10Aug	95	6,010	2,311	3.96	0.60
C5	9Aug	90	3,205	766	4.53	0.70
D1	9Aug	129	17,439	4,176	3.59	0.51
D7	10Aug	115	6,752	3,643	4.12	0.60
E3	9Aug	96	11,458	6,287	3.10	0.47
F2	9Aug	101	24,514	7,112	3.00	0.45
12	8Aug	81	7,857	3,227	2.01	0.32
15	8Aug	73	10,395	11,204	2.13	0.34
30	8Aug	136	19,588	2,093	3.88	0.55
31	8Aug	94	27,168	7,564	1.86	0.28
32	8Aug	69	6,416	2,726	3.61	0.59
33	8Aug	72	2,748	509	4.45	0.72
36	9Aug	125	23,396	4,449	4.10	0.59
37	8Aug	92	4,120	1,856	4.09	0.63
39	8Aug	55	47,034	24,103	1.81	0.31
42	9Aug	73	2,299	521	3.68	0.59
45	10Aug	110	5,198	1,025	4.42	0.65
52	9Aug	138	14,065	4,416	4.37	0.62
53	9Aug	128	29,937	8,621	3.01	0.43
54	9Aug	85	48,293	39,436	2.09	0.33
55	10Aug	158	8,940	820	4.65	0.64
56	10Aug	122	7,142	1,967	4.91	0.71
57	10Aug	96	3,860	1,625	4.12	0.63
58	10Aug	148	10,587	981	4.58	0.64
59	10Aug	111	6,642	1,636	4.68	0.69
60	10Aug	108	4,131	406	4.69	0.69
Mean		105	13,242		3.77	0.56
SD		21	9,159		0.80	0.11

[a]Diversity (Shannon-Weiner function)
[b]Equitability

Table 2. Dominant benthic invertebrates found at 29 stations (all combined) offshore from the Columbia River, August 1994.

Taxon	Mean number/m^2
Polychaeta	
Owenia fusiformis	3,480
Prionopsio lighti	726
Spiochaetopterus costarum	470
Magelona sacculata	460
Chaetozone setosa	324
Mediomastus californiensis	313
Spiophanes berkeleyorum	171
Pectinaria californiensis	153
Pholoe minuta	113
Mediomastus spp.	108
Nephtys caecoides	105
Miscellaneous (161 taxa/catagories)	942
Total	7,362
Crustacea	
Diastylopsis spp.	2,146
Diastylopsis tenuis	451
Leucon spp.	209
Euphilomedes carcharodonta	171
Orchomene pinquis	119
Diastylopsis dawsoni	107
Rhepoxynius spp.	100
Caprellidea	45
Cylindroleberididae	39
Miscellaneous (102 taxa/catagories)	356
Total	3,743
Mollusca	
Siliqua spp.	278
Axinopsida serricata	105
Olivella pycna	100
Mytilidae	95
Macoma spp.	62
Nitidella gouldi	50
Olivella spp.	46
Tellina spp.	27
Acila castrensis	23
Olivella baetica	22
Mysella tumida	19
Miscellaneous (37 taxa/catagories)	91
Total	917
Miscellaneous	
Dendraster excentricus	835
Nemertea	261
Echiurida	22
Amphiodia urtica	20
Miscellaneous (13 taxa/catagories)	27
Total	1,164
Total	13,186

serricata, and *Olivella pycna*; and the crustaceans *Diastylopsis* spp., *Diastylopsis tenuis*, and *Leucon* spp..

Diversity (H) ranged from 1.81 to 4.91, and was considered high (>3.50) at 21 of the 29 stations (Table 1, Appendix Table 3). Equitability (E) ranged from 0.28 to 0.72 with values at 18 stations ranging between 0.50 and 0.70. The two stations with the highest densities (stations 39 and 54) also had low H values due to the lower number of taxa and the dominance of one or more of those taxa (i.e., low E values). Stations with highest H and E values typically had a higher than average number of taxa, but no numerically dominant taxa.

Seven benthic invertebrate cluster groups (groups of stations with similar benthic invertebrate species and densities) were identified, but five stations had no group affiliation (Figs. 2 and 3). Stations designated by letters A through F should not be confused with Cluster Groups A through E. Cluster Group A contained the most stations (7). Located south of ODMDS F, Group A was dominated by juvenile sanddollar (*Dendraster excentricus*) and had an average benthic invertebrate density of 5,563 organisms/m^2. The next largest cluster groups, C and D, were each comprised of four stations. Group C had an average benthic invertebrate density of 7,842 organisms/m^2 and was dominated by two polychaetes, *S. costarum* and *P. lighti*. Group D had an average density of 24,638 organisms/m^2 and was dominated by the polychaete *O. fusiformis* and the sanddollar *D. excentricus*. Groups E and G differed from other cluster groups as they were dominated by polychaetes and cumaceans. Average density for Group G was the highest for any cluster group (47,663 organisms/m^2) and this group had cumaceans *Diastylopsis* spp. as the dominant taxa, followed by *O. fusiformis*.

Benthic invertebrate densities followed a general geographical distribution offshore from the mouth of the Columbia River. Stations located in shallow water (approximately

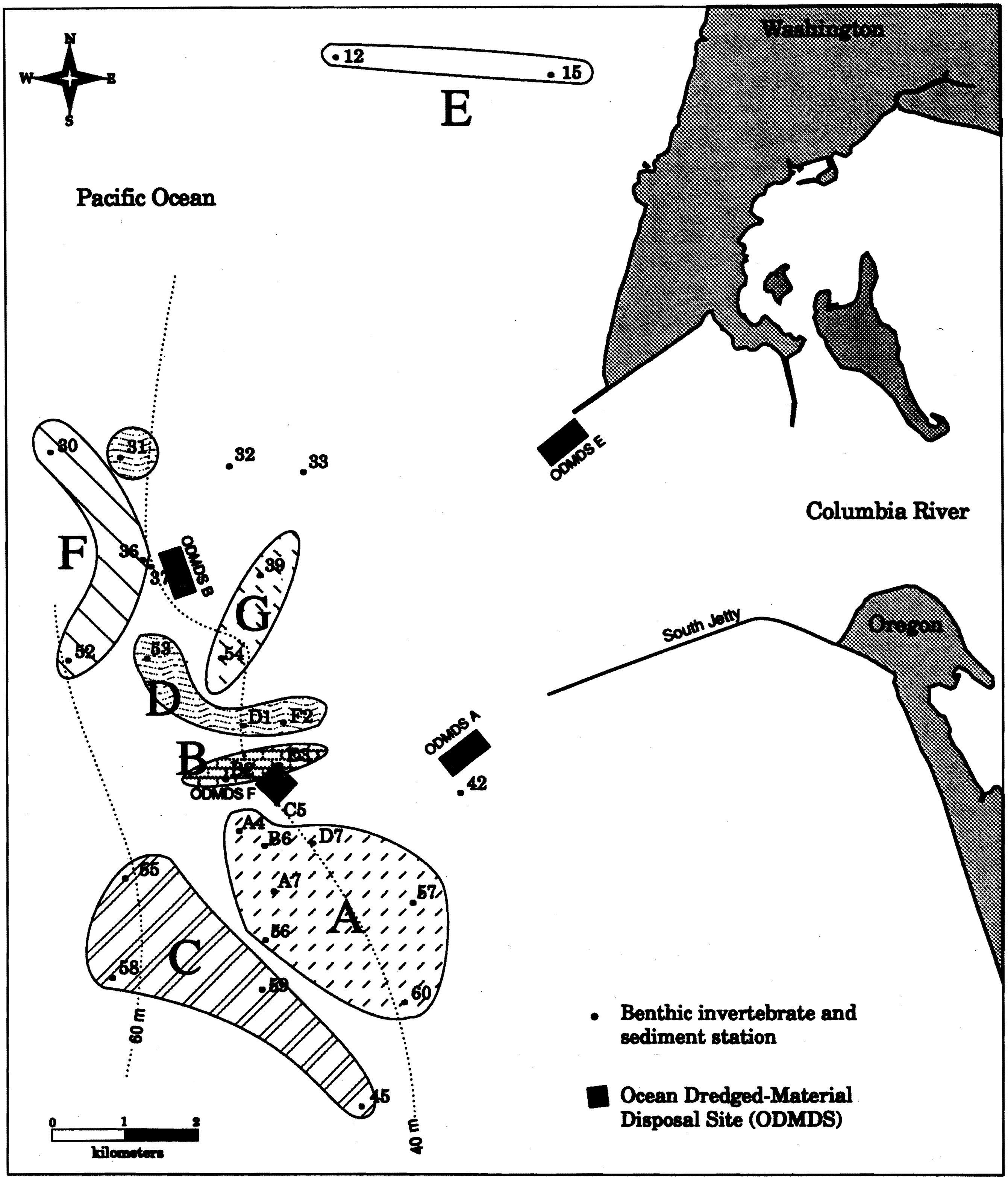

Figure 2. Location of benthic invertebrate cluster groups (A-G) offshore from the Columbia River, August 1994. Five stations did not cluster.

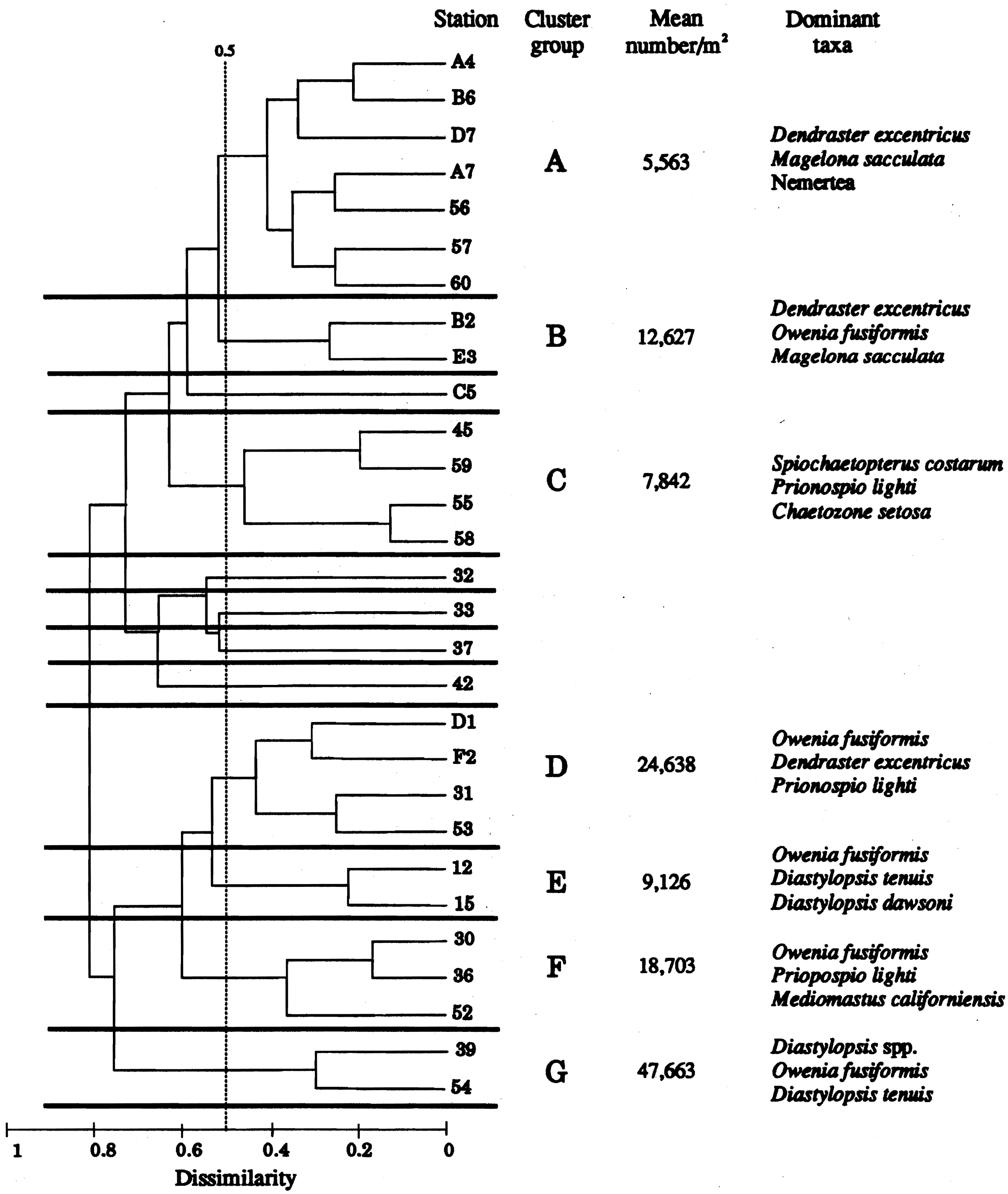

Figure 3. Dendrogram results from cluster analysis of benthic invertebrate densities at 29 stations off the mouth of the Columbia River, August 1994.

40 m depth) north and south of the Columbia River entrance generally had lower benthic invertebrate densities than stations located in the entrance channel or in deeper water farther offshore (Fig. 4).

Sediments

Average median grain size was 0.15 mm, average percent silt/clay was 13.2%, and average percent volatile solids were 1.1% for all 30 stations (Table 3). Sediments from 22 of 30 stations were classified as fine sand (median grain size 0.125-0.250 mm). The highest silt/clay value was measured at Station 30, which is about 60 m deep and located just north from the mouth of the Columbia River. Stations with highest percent silt/clay were generally in water deeper than 40 m and were located slightly north from the Columbia River mouth (Fig. 5). Percent volatile solids were generally low, ranging from 0.1 to 5.2%, with most values < 1.0%. Generally stations that had the highest percent silt/clay values also had the highest percent volatile solids values.

Annual Fluctuations

Twenty-seven stations sampled for benthic invertebrates offshore from the mouth of the Columbia River in 1993 were reoccupied in 1994 (Emmett and Hinton 1995). The number of benthic invertebrate taxa and densities were not significantly different between years (ANOVA; $P > 0.05$); however, H and E were significantly different (ANOVA; $P < 0.05$). Although this finding may be real, these significant differences were likely influenced by improvements in identifications for several polychaetes and crustaceans.

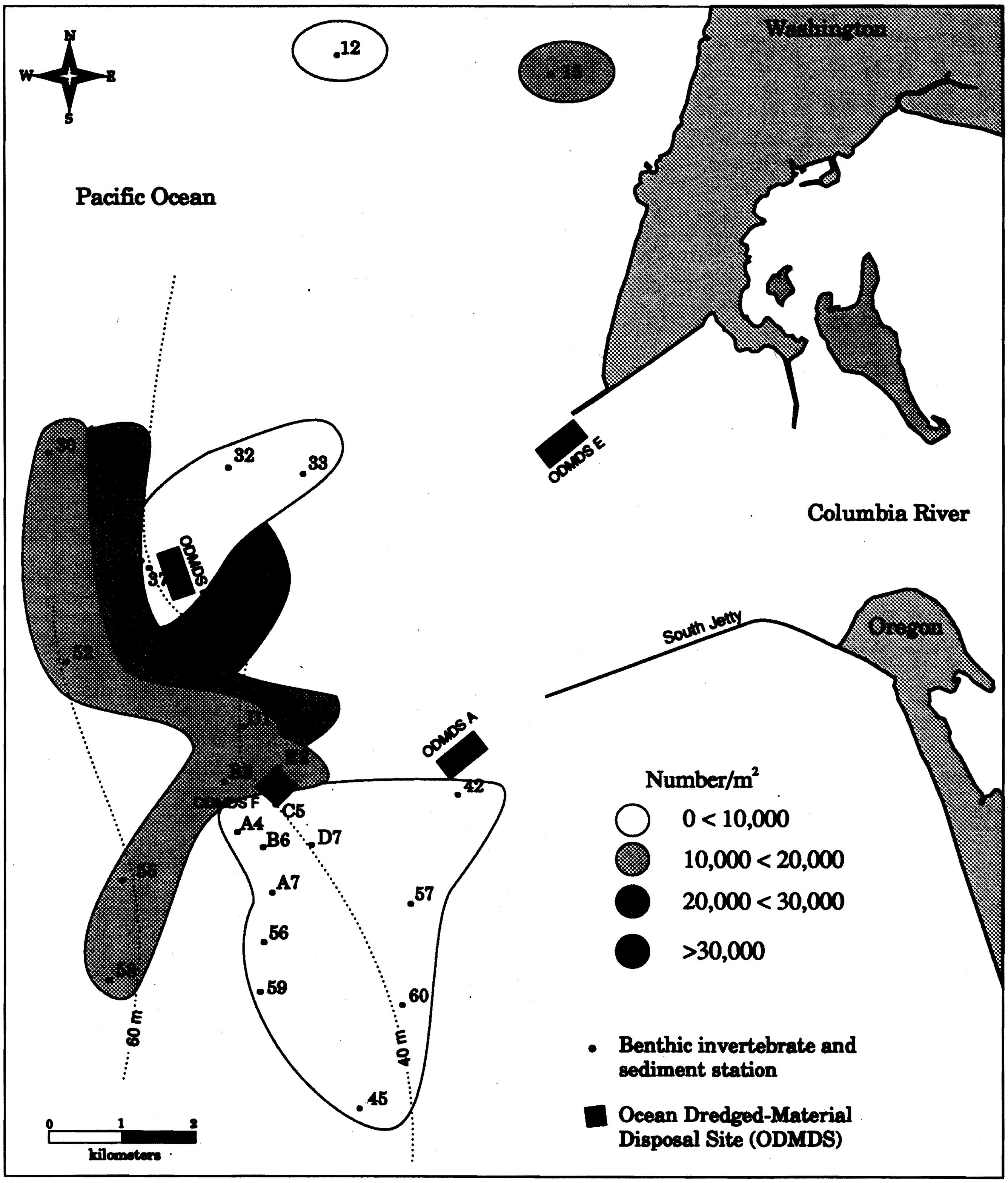

Figure 4. Benthic invertebrate densities at 29 stations offshore from the Columbia River, August 1994.

Table 3. Sediment characteristics at 30 stations offshore from the Columbia River, August 1994.

Station	Median grain size (mm)	Percent silt/clay	Percent volatile solids
A4	0.21	2.4	0.8
A7	0.16	2.0	0.5
B2	0.16	5.4	1.0
B6	0.19	3.4	0.5
C5	0.19	2.0	0.6
D1	0.16	15.6	2.0
D7	0.21	0.8	0.5
E3	0.17	5.9	0.6
F2	0.36	0.5	0.3
G1	0.15	13.0	1.2
12	0.10	9.1	0.6
15	0.11	6.5	0.7
30	0.04	62.5	5.2
31	0.07	41.4	2.7
32	0.11	12.0	0.7
33	0.15	5.9	0.9
36	0.13	23.9	1.8
37	0.17	2.2	0.8
39	0.06	50.9	1.6
42	0.21	1.6	0.7
45	0.16	2.0	0.7
52	0.15	15.5	0.4
53	0.14	23.6	2.2
54	0.05	57.7	3.1
55	0.16	8.3	1.2
56	0.16	6.6	0.1
57	0.14	3.6	0.3
58	0.16	7.4	1.3
59	0.16	3.8	0.6
60	0.15	1.6	0.6
Mean	0.15	13.2	1.1

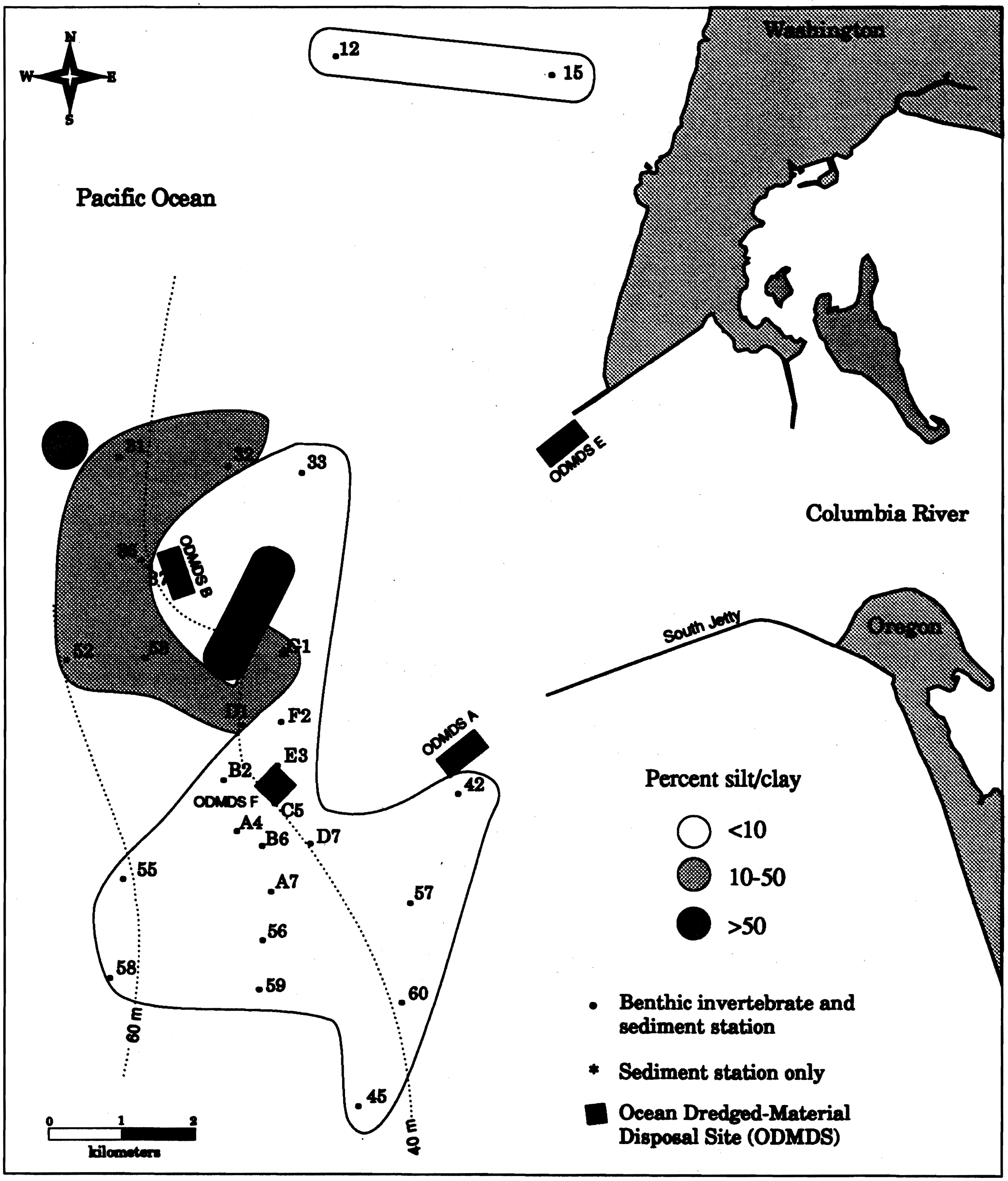

Figure 5. Percent silt/clay at 30 stations offshore from the Columbia River, August 1994.

In surveys conducted in 1992 and 1993, benthic invertebrate densities tended to be lowest near the mouth of the Columbia River and to increase with distance from the mouth (Hinton and Emmett 1994, Emmett and Hinton 1995). In 1993, the lowest densities occurred directly off the mouth of the Columbia River and increased in a westerly direction. However, in 1994, benthic invertebrate densities were highest directly off the mouth of the Columbia River and generally decreased in a westerly direction (Fig. 4). The lower invertebrate densities in shallow water (<40 m) north and south of the Columbia River entrance resembled densities found in in the 1993 survey.

Eight stations at or adjacent to ODMDS F that were sampled in 1994 were previously sampled from 1989 to 1993. The number of benthic invertebrate taxa per station at and adjacent to ODMDS F increased significantly (ANOVA, $P < 0.01$) from 1989 to 1994 (Table 4). Benthic invertebrate densities at these eight stations also differed significantly from 1989 to 1994 (ANOVA; $P < 0.01$), increasing by an order of magnitude from 1989 to 1992 (Table 5). Invertebrate densities in 1993 were also high, but were lower than densities in 1992. In 1994, mean invertebrate density for the eight previously sampled stations was the highest of all 6 years (11,094 organisms/m^2). Diversity (H) and equitability (E) at and adjacent to ODMDS F also varied significantly from 1989 to 1994 (Tables 6 and 7) (ANOVA; $P < 0.01$), with lowest mean values for both indices occurring in 1992 and 1994.

Table 4. Numbers of benthic invertebrate taxa at eight stations at and adjacent to ODMDS F offshore from the Columbia River, June-July 1989-1993 and August 1994.

Station	1989	1990	1991	1992	1993	1994
A4	71	73	99	110	112	104
B2	68	93	105	121	115	136
B6	68	72	107	108	111	95
C5	67	109	106	110	80	90
D1	80	86	89	107	103	129
D7	59	71	100	92	118	115
E3	58	88	108	111	89	96
F2	71	73	92	93	92	101
Mean	68	83	101	107	103	108
SD	7	13	7	10	14	17

Table 5. Densities (mean number/m^2) of benthic invertebrates at eight stations at and adjacent to ODMDS F, offshore from the Columbia River, June-July 1989-1993 and August 1994. Station densities were calculated by averaging replicates from each station.

Station	1989	1990	1991	1992	1993	1994
A4	1,223	2,238	3,599	13,759	9,278	5,562
B2	1,294	3,262	4,362	14,027	8,807	13,798
B6	871	2,574	3,872	11,479	5,783	6,010
C5	1,142	2,978	3,833	7,821	1,542	3,205
D1	1,517	3,587	4,001	14,819	6,124	17,439
D7	788	2,584	3,660	6,646	12,381	6,752
E3	992	2,793	6,823	9,820	5,156	11,456
F2	1,046	1,588	5,760	9,422	3,101	24,514
Mean	1,109	2,701	4,489	10,974	6,522	11,094
SD	237	617	1,172	3,036	3,510	7,224

Table 6. Diversities (H) of benthic invertebrates at eight stations at and adjacent to ODMDS F offshore from the Columbia River, June-July 1989-1993 and August 1994.

Station	1989	1990	1991	1992	1993	1994
A4	4.88	4.75	5.13	3.81	3.79	4.53
B2	4.97	4.90	4.95	3.50	4.80	4.39
B6	5.08	4.28	5.27	3.98	4.79	3.96
C5	4.92	5.20	5.17	4.17	4.97	4.53
D1	4.89	4.84	4.60	3.66	4.72	3.59
D7	5.02	4.19	4.70	3.96	3.53	4.12
E3	4.71	4.33	4.95	4.04	3.38	3.10
F2	4.94	4.71	4.03	3.46	4.42	3.00
Mean	4.93	4.65	4.85	3.82	4.30	3.90
SD	0.11	0.35	0.40	0.26	0.64	0.61

Table 7. Equitabilities (E) of benthic invertebrates at eight stations at and adjacent to ODMDS F offshore from the Columbia River, June-July 1989-1993 and August 1994.

Station	1989	1990	1991	1992	1993	1994
A4	0.79	0.77	0.77	0.56	0.56	0.68
B2	0.82	0.75	0.74	0.51	0.70	0.62
B6	0.83	0.69	0.78	0.59	0.71	0.60
C5	0.81	0.77	0.77	0.61	0.79	0.70
D1	0.77	0.75	0.71	0.54	0.71	0.51
D7	0.85	0.68	0.71	0.61	0.51	0.60
E3	0.80	0.67	0.73	0.59	0.52	0.47
F2	0.80	0.76	0.62	0.53	0.68	0.45
Mean	0.81	0.73	0.73	0.57	0.65	0.58
SD	0.02	0.04	0.05	0.04	0.10	0.09

DISCUSSION

The benthic invertebrate community offshore from the Columbia River is subjected to a variety of influences: river flow, upwelling, downwelling, seasonal winds, and currents. All of these influences affect species diversity and densities. As a result, benthic invertebrate taxa and densities varied widely throughout the study area. This was clearly illustrated by cluster analysis, in which 24 benthic invertebrate sampling stations formed 7 different cluster groups, and 5 stations remained independant.

The relatively large number of cluster groups and stations that did not cluster in such a small area indicates that a complex benthic invertebrate community exists off the mouth of the Columbia River. Harsh environmental conditions in shallow-water habitats can depress benthic invertebrate densities (Oliver et al. 1980, Probert 1984, Emerson 1989). However, for our survey, stations in shallow water had both the highest and lowest benthic invertebrate densities, and some stations indicated a decrease in density with increasing depth. This anomaly is probably the result of two phenomena: first, the widely fluctuating environmental conditions (e.g., currents and wave surges and shifting sediments) which create many different micro-habitats that are colonized by various opportunistic organisms; and second, the condition of those habitats, which can be in various stages of development. For example, the very mobile cumaceans (*Diastylopsis* spp.) can quickly take advantage of a recently disturbed area, whereas tube-dwelling polychaetes would need more time to colonize the same area after a disturbance.

As in previous benthic invertebrate surveys off the mouth of the Columbia River, polychaetes were numerically dominant at most stations (Siipola et al. 1993, Hinton and Emmett 1994, Emmett and Hinton 1995). Most stations during these previous studies were dominated by the polychaetes *Owenia fusiformis* and *Spiochaetopterus costarum*. The abundance of *Spiochaetopterus costarum* was consistent with the results from the Tongue Point Monitoring Program, where it was the dominant organism in 1992, but this polychaete was virtually non-existent in 1989-1991 (Siipola et al. 1993). *Prionospio lighti* was the most abundant polychaete in 1993, and the second most dominant polychaete off the mouth of the Columbia River in 1994. This species has been found consistently in other benthic surveys off Oregon or Washington, but was not highly abundant (Lie and Kisker 1970, Richardson et al. 1977, Emmett et al. 1987, Miller et al. 1988, Emmett and Hinton 1992, Siipola et al. 1993, Hinton and Emmett 1994).

Benthic invertebrate abundance at individual stations is probably related to specific physical and biological habitat parameters such as sediment grain size, percent silt/clay, percent volatile solids, frequency of sediment disturbance, and predation; whereas overall population abundances within a large area reflect broad environmental factors, such as upwelling and primary production. Primary production phenomenon has been identified as a major determinant for benthic invertebrate populations in the Bering and Chukchi Seas (Grebmeier et al. 1989), and upwelling is known to directly influence primary and secondary productivity in nearshore coastal environments (Wulff and Field 1983, Lopez-Jamar et al. 1992). Over the past 6 years, average densities at the eight sampling stations at and adjacent to ODMDS F rose continuously from 1989 to 1992, declined in 1993 and increased dramatically in 1994 (Fig. 6). Considering spring upwelling and its effects on primary productivity along with the observed changes in annual benthic invertebrate density suggests there may be some correlation. Benthic invertebrate populations are probably responding directly to nutrient levels and the resultant primary production in the water column. This is not surprising, since many of the benthic invertebrate species collected in 1993 and 1994 are

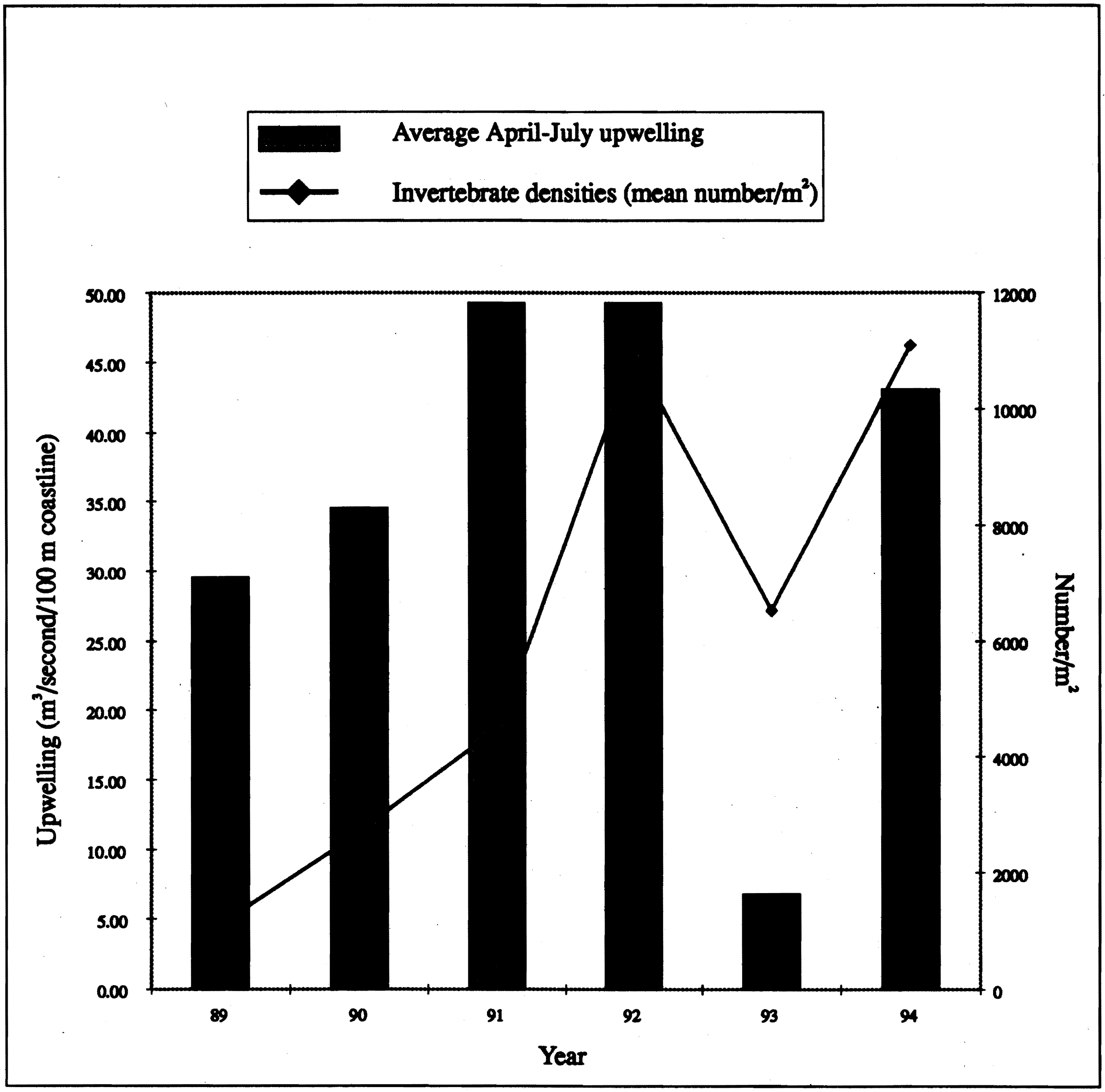

Figure 6. Plot of average upwelling during April through July and benthic invertebrate densities at eight stations at and adjacent to ODMDS F, offshore from the Columbia River, 1989-1994. Upwelling values are for 45°N latitude and 125°W longitude, and were obtained from the Pacific Fisheries Environmental Group, Monterey, CA.

suspension and surface deposit feeders (Fauchald and Jumars 1979), dependent on organic detritus and phytoplankton settling on or near the bottom. In addition, benthic invertebrate biomass has been directly related to pelagic productivity in the Bering and Chukchi Seas (Grebmeir et al. 1988).

The distribution of sediment types observed offshore from the Columbia River during this survey was similar to sediment distributions described in previous studies of the area (Kulm et al. 1975, Sternberg et al. 1977, Kachel and Smith 1989). As expected, sediment grain size decreased in a northwesterly direction from the mouth of the Columbia River.

Annual sediment characteristics near the mouth of the Columbia River often vary extensively. For example, percent fines for one station were 1.2, 19.6, 0.8, 1.1, and 13.0%, from 1990 to 1994 (Siipola et al. 1993). Since these variations were independent of any dredged-material disposal event, apparently the deposition and movement of fine-grained materials vary annually.

Benthic invertebrate populations often cycle on various time scales (Gray and Christie 1983). Only by studying invertebrate species and populations over a wide area and long time periods can the effects of dredging be separated from annual population fluctuations. Areas that were selected to receive dredged material in 1994 at the expanded disposal site of ODMDS F were in the vicinity of eight of our long-term sampling stations. Yet, it is difficult to determine what kind of impact, if any, the dredged-material disposal had on benthic invertebrate communities. Six of the eight stations nearest these disposal areas had an increase in mean benthic invertebrate densities from 1993 to 1994. However, the same trend was seen throughout the whole study area during this time period, which may indicate that dredged-material disposal had only a minimal effect on benthic invertebrate densities.

CONCLUSIONS

Benthic invertebrate densities and community structure at 29 stations off the mouth of the Columbia River varied widely in 1994. This variability was most notable at shallow-water stations, where invertebrate densities were both highest and lowest for this survey. In 1993, benthic invertebrate densities generally increased with distance from the mouth of the Columbia River and were loosely associated with increasing depth. However, during this survey, benthic invertebrate densities seem to decrease with distance from the mouth of the river. Comparisons between similar stations sampled in 1993 and 1994 showed that while densities and number of taxa were not significantly different, diversity (H) and Equitability (E) were. At eight stations sampled at and adjacent to ODMDS F, annual benthic invertebrate densities and numbers of taxa per station increased significantly from 1989 to 1994, except in 1993, when it decreased. One factor that may be influencing this fluctuation is spring upwelling, which is known to effect primary productivity.

Recent offshore benthic invertebrate surveys suggest nearshore shallow-water (<40 m) areas should be investigated further for use as ocean dredged-material disposal sites. Benthic invertebrate densities were lowest at most shallow-water stations south of the Columbia River mouth durings 1989-92 and north and south of the mouth during 1992-94. Deepwater deposition of dredged material off the mouth of the Columbia River has resulted in large mounds that are relatively stable and can therefore become hazards to navigation and fishing activities. Shallow-water areas seem to warrant further investigation for new (or potential) dredged-material disposal sites for two reasons: they have relatively low benthic invertebrate densities, and the material deposited could potentially be redistributed by sediment-transporting events (waves, currents and annual circulation patterns).

This report does not constitute NMFS's formal comments under the Fish and Wildlife Coordination Act or the National Environmental Policy Act.

ACKNOWLEDGMENTS

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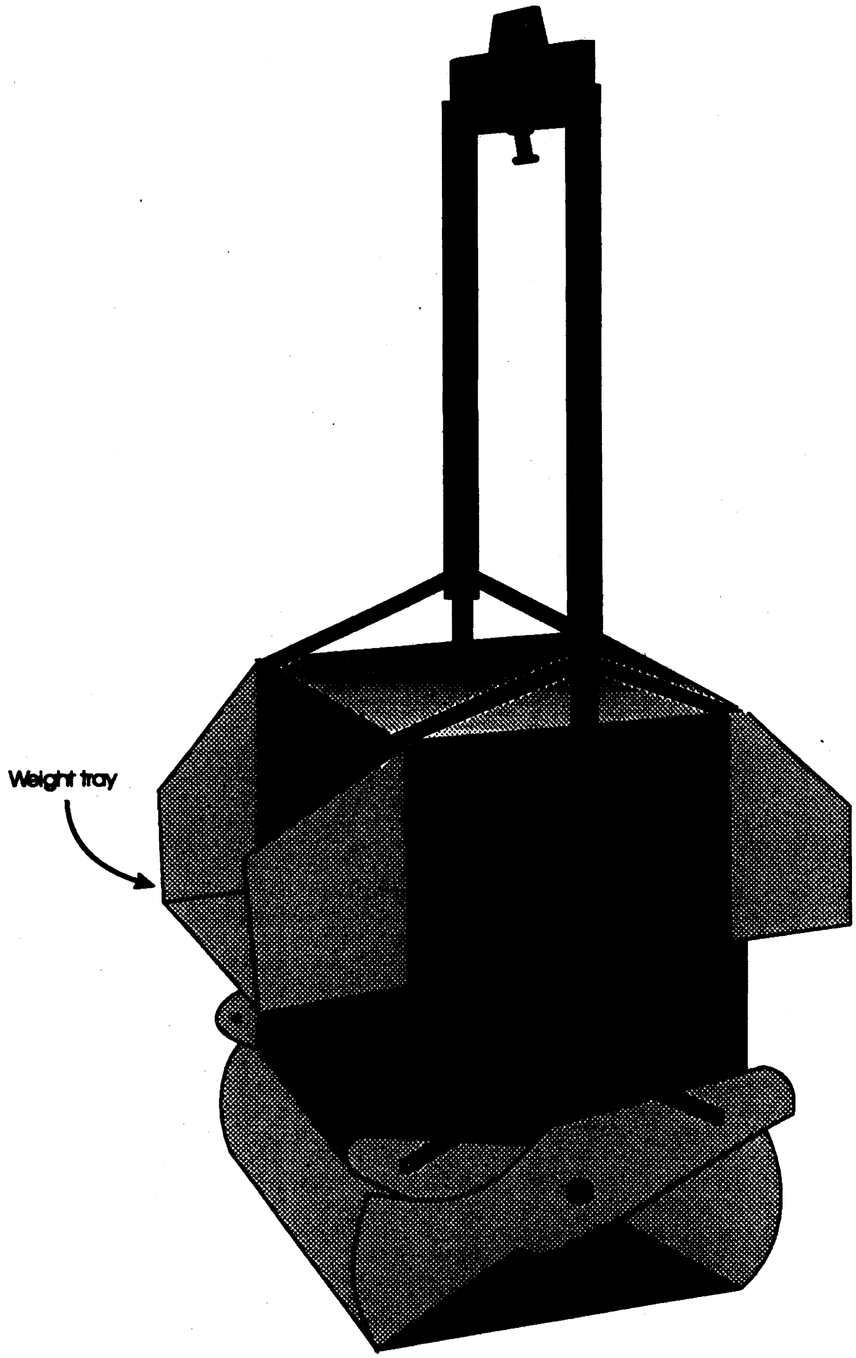
APPENDIX FIGURE



Appendix Figure 1. The 0.1-m^2 box corer (Gray-O'Hara modification of a standard box corer) used for benthic invertebrate sampling offshore from the Columbia River, August 1994. For deeper penetration, 113-kg (250-lb) weights were placed in each tray located on opposite sides of the sampler.

APPENDIX TABLES

Appendix Table 1. Geographic location, date of sampling, and water depth of benthic invertebrate and sediment stations sampled offshore from the Columbia River, August 1994.

Station	Date	Depth m (ft)	Latitude	Longitude
A4	10 Aug	45.7 (150)	46° 11.50'N	124° 9.50'W
A7	10 Aug	45.7 (150)	10.99	8.96
B2	9 Aug	45.1 (148)	11.99	9.73
B6	10 Aug	42.7 (140)	11.39	9.10
C5	9 Aug	40.5 (133)	11.80	8.99
D1	9 Aug	41.5 (136)	12.53	9.52
D7	10 Aug	38.1 (125)	11.47	8.45
E3	9 Aug	36.3 (119)	12.19	9.00
F2	9 Aug	35.1 (115)	12.61	8.99
G1	8 Aug	29.0 (95)	12.03	8.99
12	8 Aug	24.7 (81)	18.98	8.98
15	8 Aug	12.8 (42)	18.98	6.00
30	8 Aug	53.3 (175)	15.00	12.50
31	8 Aug	45.1 (148)	15.00	11.50
32	8 Aug	23.2 (76)	15.02	10.03
33	9 Aug	14.6 (48)	15.00	9.00
36	8 Aug	53.9 (177)	14.01	11.10
37	8 Aug	37.8 (124)	13.98	10.99
39	9 Aug	23.2 (76)	14.00	9.46
42	10 Aug	25.0 (82)	12.03	6.47
45	9 Aug	50.3 (165)	9.02	7.47
52	9 Aug	57.9 (190)	11.01	12.01
53	9 Aug	50.0 (164)	12.99	11.01
54	10 Aug	42.1 (138)	13.00	11.00
55	10 Aug	66.1 (217)	11.00	10.96
56	10 Aug	49.1 (161)	10.50	8.98
57	10 Aug	34.1 (112)	11.00	7.01
58	10 Aug	67.1 (220)	10.00	11.03
59	10 Aug	53.3 (175)	10.00	8.98
60	10 Aug	40.2 (132)	10.00	6.99

Appendix Table 2. Epibenthic and benthic invertebrate taxa collected by box corer offshore from the Columbia River, August 1994.

Taxon	Identified
Cnidaria	
Anthozoa	x
Platyhelminthes	x
Turbellaria	x
Nemertea	x
Annelida	
Polychaeta	
Polynoidae	x
Gattyana spp.	x
Halosydna brevisetosa	x
Lepidonotus squamatus	x
Lepidasthenia berkeleyae	x
Tenonia priops	x
Malmgreniella spp.	x
Malmgeniella macginitiei	x
Pholoididae	
Pholoides aspera	x
Sigalionidae	x
Pholoe minuta	x
Sthenelais spp.	x
Sthenelais berkeleyi	x
Sthenelais tertiaglabra	x
Sigalion spp.	x
Thalenessa spinosa	x
Chrysopetalidae	
Paleanotus bellis	x
Phyllodocidae	x
Eteone californica	x
Eteone fauchaldi	x
Eteone longa	x
Eteone pacifica	x
Eteone spilotus	x
Eteone spp.	x
Eumida sanguinea	x
Eulalia viridis	x
Eulalia bilineata	x
Eumida spp.	x
Eumida longicornuta	x
Paranaitides (Phyllodoce) *polynoides*	x
Phyllodoce groenlandica	x
Phyllodoce hartmanae	x
Phyllodoce williamsi	x
Phyllodoce longipes	x
Phyllodoce multipapillata	x
Phyllodoce spp.	x
Hesionidae	x
Heteropodarke heteromorpha	x
Microphthalmus sczelkowii	x
Microphthalmus nr. *hamosus*	x
Microphthalmus cf. *aberrans*	x
Micropodarke dubia	x
Podarkeopsis glabrus	x

Appendix Table 2. Continued.

Taxon	Identified
Pilargidae	
Pilargus maculata	x
Parandalia fauveli	x
Syllidae	x
Autolytus (=Proceraea)	x
Proceraea cornutus	x
Streptosyllis spp.	x
Streptosyllis latipalpa	x
Nereidae	x
Nereis procera	x
Nereis zonata	x
Platyneries bicanaliculata	x
Nephtyidae	x
Nephtys spp.	x
Nephtys assignis	x
Nephtys caeca	x
Nephtys cornuta cornuta	x
Nephtys ferruginea	x
Nephtys longosetosa	x
Nephtys californiensis	x
Nephtys caecoides	x
Sphaerodoridae	
Sphaerodoropsis minuta	x
Glyceridae	
Glycera spp.	x
Glycera americana	x
Glycera convoluta	x
Glycera nana	x
Goniadidae	x
Glycinde spp.	x
Glycinde armigera	x
Glycinde picta	x
Goniada maculata	x
Goniada brunnea	x
Onuphidae	x
Onuphis spp.	x
Onuphis iridescens	x
Onuphis elegans	x
Lumbrineridae	x
Eranno bicirrata	x
Lumbrineris limnicola	x
Lumbrineris luti	x
Orbiniidae	x
Scoloplos spp.	x
Scoloplos armiger	x
Scoloplos acmeceps	x
Leitoscoloplos pugettensis	x
Orbinia (Phylo) *felix*	x
Paraonidae	x
Aricidea spp.	x
Aricidae lopezi	x
Aricidea (Acesta) *catherinae*	x
Paraonella platybranchia	x
Spionidae	x
Laonice cirrata	x
Polydora spp.	x
Polydora caulleryi	x
Polydora brachycephala	x
Prionospio spp.	x

Taxon	Identified
Prionospio lighti	x
Prionospio pinnata	x
Prionospio steenstrupi	x
Prionospio multibranchiata	x
Spio cirrifera	x
Boccardia polybranchia	x
Boccardia pugettensis	x
Spiophanes spp.	x
Spiophanes berkeleyorum	x
Spiophanes bombyx	x
Paraprionospio pinnata	x
Scolelepis squamata	x
Scolelepis foliosa	x
Magelona	
Magelona spp.	x
Magelona berkeleyi	x
Magelona longicornis	x
Magelona sacculata	x
Trochochaetidae	
Trochochaeta multisetosa	x
Chaetopteridae	
Mesochaetopterus taylori	x
Spiochaetopterus costarum	x
Cirratulidae	x
Cirratulus cirratus	x
Aphelochaeta spp.	x
Aphelochaeta multifilis	x
Chaetozone spp.	x
Chaetozone setosa	x
Cossuridae	
Cossura spp.	x
Cossura pygodectylata	x
Flabelligeridae	
Pherusa spp.	x
Pherusa plumosa	x
Scalibregmidae	
Asclerocheilus beringianus	x
Opheliidae	x
Ophelina spp.	x
Ophelina acuminata	x
Armandia brevis	x
Ophelia spp.	x
Ophelia limacina	x
Travisia spp.	x
Travisia brevis	x
Travisia gigas	x
Capitellidae	x
Barantolla americana	x
Capitella capitata complex	x
Decamastus gracilis	x
Heteromastus spp.	x
Heteromastus filiformis	x
Heteromastus filobranchus	x
Notomastus lineatus	x
Notomastus tenuis	x
Mediomastus spp.	x
Mediomastus californiensis	x

Taxon	Identified
Arenicolidae	x
Arenicola marina	x
Aberinicolidae	
Abarenicola spp.	x
Maldanidae	x
Asychis disparidentata	x
Euclymene spp.	x
Euclymene zonalis	x
Oweniidae	
Galathowenia oculata	x
Owenia fusiformis	x
Pectinariidae	
Pectinaria spp.	x
Pectinaria granulata	x
Pectinaria californiensis	x
Ampharetidae	x
Ampharete spp.	x
Ampharete acutifrons	x
Lysippe mexicana	x
Melinna elisabethae	x
Terebellidae	
Pista spp.	x
Pista estevanica	x
Polycirrus californius	x
Sabellidae	x
Chone dunneri	x
Euchone incolor	x
Oligochaeta	x
Hirudinea	x
Mollusca	
Gastropoda	x
Turbinidae	
Spiromoellaria quadrae	x
Epitoniidae	
Epitonium indianorum	x
Calyptraeidae	
Crepipatella lingulata	x
Columbellidae	
Amphissa columbiana	x
Naticidae	
Nitidella gouldi	x
Nassariidae	
Nassarius spp.	x
Nassarius mendicus	x
Nassarius fossatus	x
Olividae	
Olivella spp.	x
Olivella baetica	x
Olivella pycna	x
Turridae	x
Kurtziella plumbea	x
Oenopota spp.	x
Pyramidellidae	
Odostomia spp.	x
Turbonilla spp.	x

Taxon	Identified
Cephalaspidea	x
Cylichnidae	
Acteocina culcitella	x
Cylichna attonsa	x
Aglajidae	
Melanochlamys diomedea	x
Gastropteridae	
Gastropteron pacificum	x
Pelecypoda	x
Nuculidae	
Acila castrensis	x
Nucula tenuis	x
Yoldia scissurata	x
Mytilidae	x
Mytilus edulis	x
Pectenidae	x
Lucinidae	
Parvilucina tenuisculpta	x
Thyasiridae	
Axinopsida serricata	x
Kellidae	
Pseudopythina rugifera	x
Montacutidae	
Mysella tumida	x
Solenidae	
Siliqua spp.	x
Siliqua sloati	x
Tellinidae	
Macoma spp.	x
Macoma calcarea	x
Macoma carlottensis	x
Macoma nasuta	x
Tellina spp.	x
Tellina modesta	x
Tellina nuculoides	x
Veneridae	
Compsomyax subdiaphana	x
Hiatellidae	
Mya spp.	x
Hiatella arctica	x
Pandoridae	
Pandora filosa	x
Lyonsiidae	
Lyonsia californica	x
Scaphopoda	x
Arthropoda	
Pycnogonida	x
Ostracoda	
Cylindroleberididae	x
Diasterope pilosa	x
Philomedidae	
Euphilomedes carcharodonta	x

Taxon	Identified
Copepoda	
Calanoida	x
Calanidae	
Calanus spp.	x
Harpacticoida	x
Cirripedia	x
Leptostraca	
Nebaliidae	
Nebalia pugettensis	x
Mysidacea	
Mysidae	
Acanthomysis columbiae	x
Archaeomysis grebnitzkii	x
Exocanthomysis davisi	x
Neomysis spp.	x
Neomysis kadiakensis	x
Neomysis rayii	x
Cumacea	
Lampropidae	x
Hemilamprops spp.	x
Hemilamprops californica	x
Leuconidae	
Leucon spp.	x
Eudorellopsis spp.	x
Eudorellopsis longirostris	x
Colurostylidae	
Colurostylis spp.	x
Colurostylis occidentalis	x
Diastylidae	x
Diastylis spp.	x
Diastylis alaskensis	x
Diastylopsis spp.	x
Diastylopsis dawsoni	x
Diastylopsis tenuis	x
Tanaidacea	
Paratanaidae	
Leptochelia savignyi	x
Isopoda	
Sphaeromatidae	
Ancinus granulatus	x
Tecticeps spp.	x
Tecticeps convexus	x
Idoteidae	
Edotea sublittoralis	x
Idotea fewkesi	x
Synidotea spp.	x
Synidotea angulata	x
Asellota	x
Munnidae	x

Taxon	Identified
Amphipoda	
Ampeliscidae	
Ampelisca spp.	x
Ampelisca macrocephala	x
Ampithoidae	x
Ampithoe spp.	x
Agrissidae	
Argissa hamatipes	x
Atylidae	
Atylus tridens	x
Corophidae	
Corophium spp.	x
Corophium salmonis	x
Corphium brevis	x
Gammaridae	
Megaluropus spp.	x
Anisogammaridae	x
Anisogammarus pugettensis	x
Eogammarus confervicolus	x
Haustoridae	
Eohaustorius spp.	x
Eohaustorius estuarius	x
Eohaustorius sencillus	x
Hyalidae	
Allorchestes agustus	x
Isaeidae	x
Gammaropsis spp.	x
Photis spp.	x
Photis macinerneyi	x
Photis parvidons	x
Protomedeia spp.	x
Protomedeia articulata	x
Ischyroceridae	x
Ischyrocerus spp.	x
Lysianassidae	x
Anonyx spp.	x
Lepidepecreum gurjanovae	x
Opisa tridentata	x
Orchomene spp.	x
Orchomene pacifica	x
Orchomene pinquis	x
Pachynus c.f. barnardi	x
Psammonyx longimerus	x
Oedicerotidae	
Monoculodes spp.	x
Monoculodes spinipes	x
Synchelidium shoemakeri	x
Westwoodilla caecula	x
Pardaliscidae	
Pardalisca spp.	x
Phoxocephalidae	
Foxiphalus major	x
Mandibulophoxus mayi	x
Rhepoxynius spp.	x
Rhepoxynius abronius	x
Rhepoxynius daboius	x
Rhepoxynius fatigans	x
Rhepoxynius tridentatus	x

Taxon	Identified
Rhepoxynius vigitegus	x
Rhepoxynius boreovariatus	x
Pleustidae	x
Parapleustes spp.	x
Pleusymtes spp.	x
Pleusmytes subglaber	x
Podoceridae	
Dyopedos spp.	x
Dyopedos arcticus	x
Stenothoidae	x
Hyperiidae	
Hyperoche spp.	x
Caprellidea	x
Caprellidae	x
Metacaprella spp.	x
Metacaprella kennerlyi	x
Caprella spp.	x
Decapoda	
Crangonidae	
Crangon alaskansis	x
Lissocrangon stylirostris	x
Callianassidae	
Callianassa californiensis	x
Paguridae	x
Pagurus spp.	x
Pagurus armatus	x
Brachyura	
Cancridae	
Cancer magister	x
Pinnotheridae	
Pinnixa spp.	x
Pinnixa eburna	x
Sipuncula	
Sipunculidae	x
Echiurida	x
Phoronida	x
Echinodermata	
Ophiuroidea	x
Ophiura spp.	x
Amphiuridae	
Amphiodia spp.	x
Amphiodia urtica	x
Echinoidea	
Dendraster excentricus	x
Holothuroidea	x
Caudinidae	
Paracaudina chilensis	x
Chaetognatha	
Sagittidae	
Sagitta spp.	x
TOTAL	348

Appendix Table 3. Summaries of benthic invertebrate collections by station offshore from the Columbia River, August 1994. (Because of its length, this Appendix Table was not included in this report but can be obtained by contacting the authors at Hammond Biological Field Station, P.O. Box 155, Hammond, OR 97121.)