Benthic and Epibenthic Invertebrates, Fishes, and Sediments
At and Adjacent to a Proposed New Site for Area D, an In-Water Dredged-Material Disposal Site in the Lower Columbia River, 1991

FINAL REPORT

by
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Susan A. Hinton,
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March 1993

COASTAL ZONE AND ESTUARINE STUDIES

BENTHIC AND EPIBENTHIC INVERTEBRATES, FISHES, AND SEDIMENTS AT AND ADJACENT TO A PROPOSED NEW SITE FOR AREA D, AN IN-WATER DREDGED-MATERIAL DISPOSAL SITE IN THE LOWER COLUMBIA RIVER, 1991

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INTRODUCTION

The U.S. Army Corps of Engineers (COE), Portland District, is responsible for maintaining navigation channels in the Columbia River estuary. This responsibility requires annual dredging and disposal of millions of cubic yards of bottom sediments. One in-water disposal site in the lower estuary, commonly referred to as Area D, no longer provides safe operating depths for large dredges, so the COE has proposed relocating the disposal site immediately downstream from the present Area D (Fig. 1).

In February 1991, the COE contracted the National Marine Fisheries Service (NMFS) to conduct two biological surveys: one in March and one in June 1991. These surveys were conducted at the proposed site for Area D and two adjacent areas to provide baseline information concerning species composition and abundance of benthic invertebrates, Dungeness crabs (*Cancer magister*), shrimps, and fishes. Subsequently, the COE funded two additional surveys, which were completed in September and December 1991.

Study areas adjacent to the proposed Area D included a reference area of similar depth (Stations 8-11) and a deeper-water area (Stations 12-14) (Fig. 1). Sampling stations in the reference area were established to serve as reference sites for stations in the proposed Area D (Stations 1-6). The deeper-water area is downstream and northwest of the proposed Area D. This deeper-water area may be less biologically productive than the proposed Area D, and therefore could be a possible alternative disposal site.

Preliminary results from the March, June, and September 1991 surveys were presented in previous progress reports. This report presents final results for all four surveys.

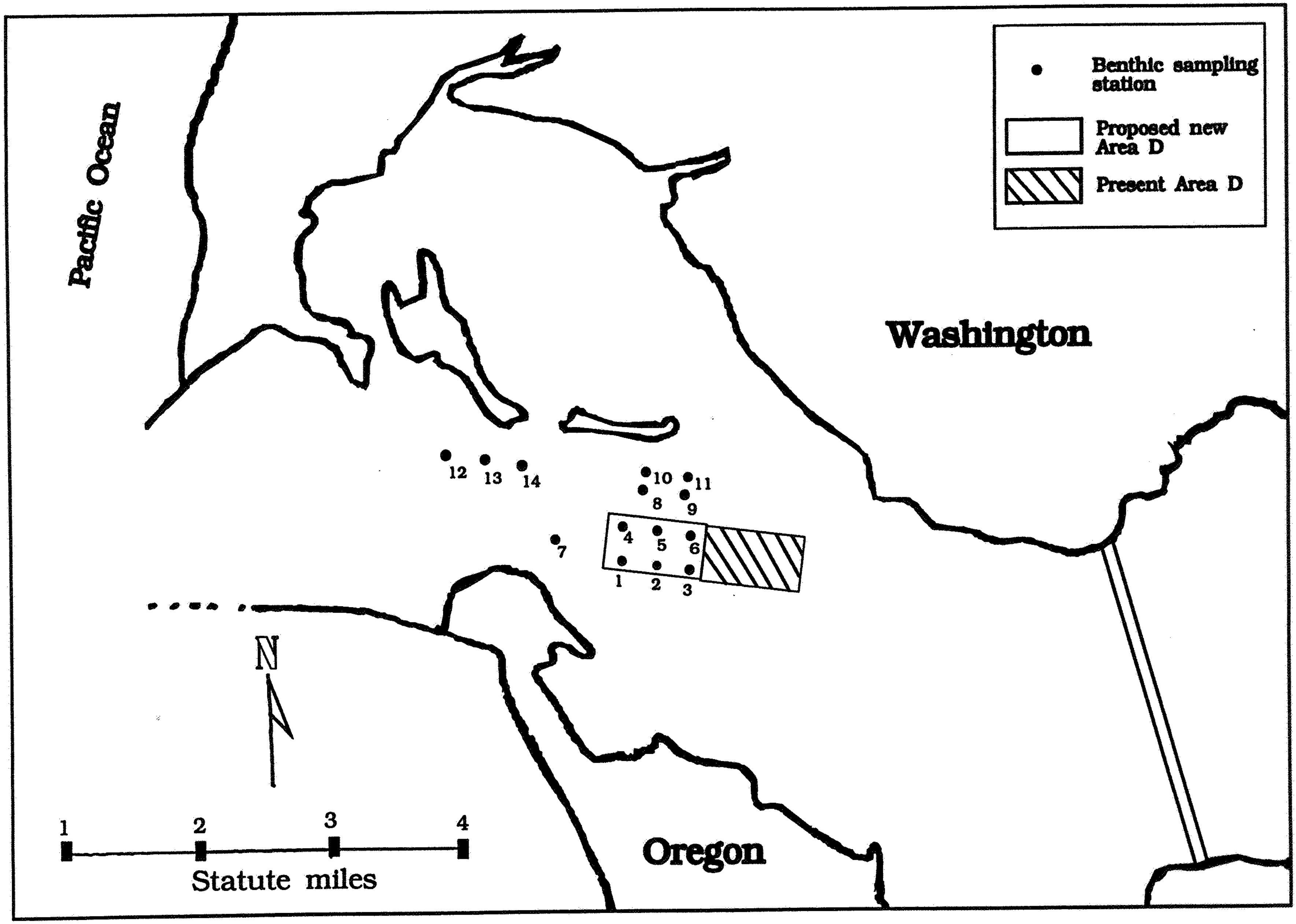

Figure 1.--Locations of benthic invertebrate and sediment stations at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

METHODS

Sampling

Benthic Invertebrates and Sediments

Benthic samples were collected at 14 stations during March, June, September, and December 1991 (Fig. 1; Appendix Table 1). Three sampling stations were located along each of two east-west transects within the proposed Area D. Four stations located north of the proposed Area D were established to serve as future reference stations for the six stations in the proposed Area D. These reference stations were established along two east-west transects in depths similar to the proposed Area D, and as far away from the new area as practical. It is unlikely that dredged material deposited in the proposed Area D will impact these reference stations due to river and tidal flow. Also, one station (Station 7) was located immediately downstream from the proposed Area D. Although not within the proposed area, this station could be impacted by sediments carried out of the proposed Area D by river currents. A similar station upstream from the proposed Area D was not established because it would have been located in the present Area D. Finally, three deeper-water benthic stations were established along a transect downstream and northwest of the proposed Area D.

Six benthic samples were collected at each station with a 0.1-m^2 Van Veen grab sampler (Word 1976). Five samples were used to determine species composition, abundance, and community structure of benthic invertebrates; one sample was used by the COE to determine sediment structure. Each benthic invertebrate sample was preserved in a buffered formaldehyde solution ($\geq$ 4%) containing rose bengal, an organic stain. In the laboratory, samples were washed with water through a 0.5-mm screen. All benthic invertebrates were sorted from each sample, identified to the lowest practical taxon, counted, and stored in 70% ethanol. The sixth benthic sample was placed in a labeled plastic bag and refrigerated for later analysis of grain size, percent silt/clay, and percent volatile solids by the COE North Pacific Division Materials Laboratory, Troutdale, Oregon.

Fishes, Dungeness Crabs, and Shrimps

Five trawling efforts were completed during each survey (Fig. 2; Appendix Table 1). One trawl was done along each of two sampling transects at the proposed Area D, and one trawl done along each of two reference station transects. In addition, one trawl was done in the deeper-water area downstream and northwest of the proposed Area D.

Trawling was done with an 8-m (headrope length) semiballoon shrimp trawl. The trawl has 38-mm (stretched measure) mesh size in the body, and a 10-mm mesh liner inserted in the cod end. Trawling efforts were conducted for 5 minutes during a flood or early ebb tide. The distance traveled during trawling was determined using a radar range-finder.

Fishes, Dungeness crabs, and shrimps collected with the trawl were measured and weighed. Total lengths were measured on fishes and carapace widths were measured on Dungeness crabs; shrimps were measured from the tip of the rostrum to the tip of the telson. When a large number (i.e., more than 50 individuals) of a species was collected in a trawling effort, 50 individuals were measured and weighed; the remainder was counted.

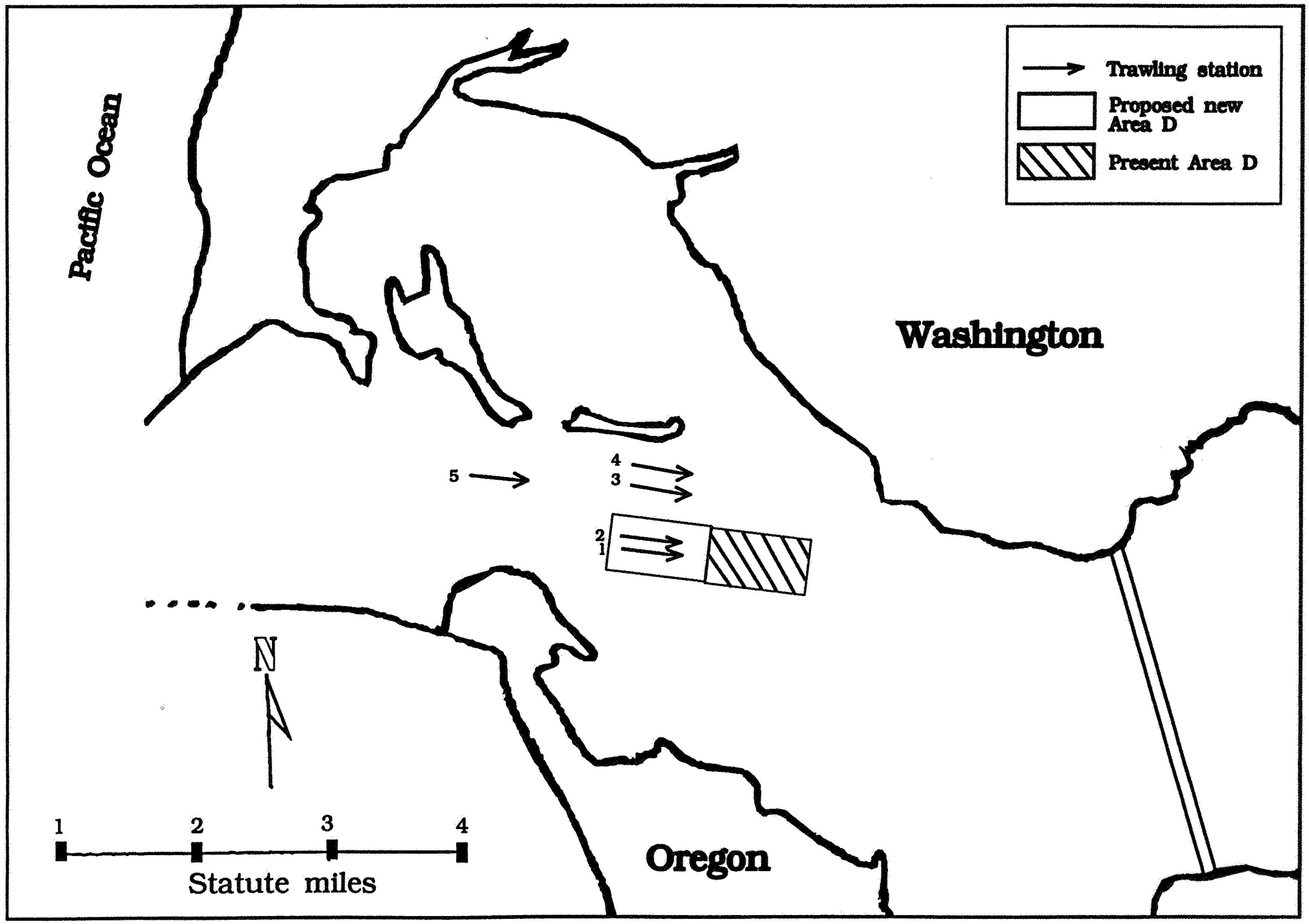

Figure 2.--Locations of trawling stations at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Data Analyses

Benthic Invertebrates

Benthic invertebrate data were analyzed by station to determine species composition, densities (by total and species), and community structure (diversity and equitability). The Shannon-Wiener function (H) was used to determine diversity (Krebs 1978).

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

where $p_i = X_a/n$ (X_a = the number of individuals of a particular species in the sample, and n = the total number of all individuals in the sample) and s = number of species. Equitability (E) was the second community structure index determined. E measures the proportional abundances among the various species in a sample (Krebs 1978) and ranges from 0.00 to 1.00, with 1.00 indicating all species in the sample are numerically equal.

$$E = H/\log_2 s$$

where H = Shannon-Wiener function and s = number of species. H and E were calculated for each sampling station.

Benthic invertebrate densities were compared among areas and surveys using two-way analysis of variance (ANOVA) (Ryan et al. 1985). The data were transformed ($\log_{10}$) prior to running ANOVA. Means of the five samples from each sampling station provided the basic data entries for the statistical tests. When results from ANOVA were significant ($P < 0.05$), Fisher's protected least significant difference (FPLSD) (Petersen 1985) was used to identify significant differences between individual areas or surveys. H and E were also compared by area and season using the above statistical tests, except the data were not transformed.

Fishes, Dungeness Crabs, and Shrimps

We estimated fish, Dungeness crab, and shrimp densities (expressed as number/hectare [ha]) in each area using the distance traveled, estimated fishing width of the trawl (5 m), and catch data. Fish, Dungeness crab, and shrimp data were analyzed to determine species composition, densities (by total and species), and length-frequency distributions. Only the most abundant species were included in the length-frequency histograms. No statistical comparisons were attempted because of the limited sampling efforts in each area.

Sediments

Median grain size (mm), percent silt/clay, and percent volatile solids were calculated for each station. Two-way ANOVA was used to compare median grain size between areas and surveys. When results from ANOVA were significant ($P < 0.05$), FPLSD was used to identify significant differences between individual areas or surveys. Percent silt/clay and percent volatile solids were not compared using ANOVA because of several high outlying values.

RESULTS

Benthic Invertebrates

The number of taxa identified in samples collected in the proposed Area D and adjacent downstream, reference, and deeper-water areas varied among surveys (Appendix Table 2; includes all organisms collected). Similar numbers of taxa were identified in samples collected in March and June, 92 and 95, respectively. Fewer taxa were collected in September and December, 63 and 78, respectively.

In the proposed Area D, benthic invertebrate densities averaged 1,634 organisms/m^2 in March; 3,481 organisms/m^2 in June; 1,035 organisms/m^2 in September; and 1,942 organisms/m^2 in December (Tables 1-4). Densities in the reference area averaged 7,010 organisms/m^2 in March; 4,181 organisms/m^2 in June; 5,828 organisms/m^2 in September; and 5,323 organisms/m^2 in December. In the deeper-water area, densities averaged 506 organisms/m^2 in March; 1,027 organisms/m^2 in June; 232 organisms/m^2 in September; and 517 organisms/m^2 in December. Densities at Station 7, which is immediately downstream from the proposed Area D, averaged 558 organisms/m^2 in March; 1,354 organisms/m^2 in June; 442 organisms/m^2 in September; and 784 organisms/m^2 in December.

Benthic invertebrate densities in the proposed Area D (Stations 1-6) were significantly higher than densities in the deeper-water area (Stations 12-14) and significantly lower than densities in the reference area (Stations 8-11) (ANOVA, FPLSD; $P < 0.05$). There were no significant differences in benthic invertebrate densities between surveys, with one exception--June densities were significantly higher than September densities ($P < 0.05$). No statistical comparisons of the area immediately downstream from the proposed Area D were made because there was only one station (Station 7) in this area.

Benthic invertebrate diversity (H) was significantly higher in the proposed Area D and the deeper-water area than in the reference area (ANOVA, FPLSD; $P < 0.05$); however, there was no significant difference in H between the proposed Area D and the deeper-water area ($P > 0.05$). The significantly lower H in the reference area resulted from relatively lower numbers of taxa and low equitability (i.e., unequal proportional abundances among taxa) (Tables 1-4). Diversity was significantly higher in December

Table 1.--Summary of benthic invertebrate collections at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, March 1991.

Station	Number of taxa	Mean number per m^2	Standard deviation	Diversity (H)	Equitablility (E)
		PROPOSED DISPOSAL AREA			
1	17	1,111	269	2.32	0.57
2	23	1,713	485	2.62	0.58
3	24	1,792	997	2.67	0.58
4	15	776	276	2.69	0.69
5	26	2,874	575	2.42	0.52
6	21	1,540	290	3.02	0.69
Mean	21	1,634	719	2.62	0.60
		DOWNSTREAM FROM PROPOSED DISPOSAL AREA			
7	17	558	204	1.90	0.46
		REFERENCE AREA			
8	14	14,162	18,308	0.41	0.11
9	10	9,143	2,106	0.69	0.21
10	12	3,838	4,817	1.06	0.30
11	9	896	646	0.93	0.29
Mean	11	7,010	5,864	0.77	0.23
		DEEPER-WATER AREA			
12	19	456	287	2.72	0.64
13	16	237	186	3.09	0.77
14	12	826	237	2.15	0.60
Mean	16	506	298	2.65	0.67

Table 2.--Summary of benthic invertebrate collections at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, June 1991.

Station	Number of taxa	Mean number per m^2	Standard deviation	Diversity (H)	Equitability (E)
		PROPOSED DISPOSAL AREA			
1	17	4,915	3,305	1.55	0.38
2	33	3,183	1,392	2.40	0.47
3	28	1,650	544	3.17	0.66
4	22	2,363	1,164	1.87	0.42
5	31	8,026	1,978	1.35	0.27
6	21	749	544	2.95	0.67
Mean	25	3,481	2,641	2.22	0.48
		DOWNSTREAM FROM PROPOSED DISPOSAL AREA			
7	20	1,354	347	2.14	0.50
		REFERENCE AREA			
8	19	2,951	1,277	2.03	0.48
9	18	6,223	6,120	1.36	0.33
10	10	4,823	2,726	1.18	0.35
11	9	2,729	2,381	1.24	0.39
Mean	14	4,181	1,654	1.45	0.39
		DEEPER-WATER AREA			
12	25	966	229	2.96	0.64
13	17	1,242	624	2.67	0.65
14	20	874	614	2.52	0.58
Mean	21	1,027	192	2.72	0.62

Table 3.--Summary of benthic invertebrate collections at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, September 1991.

Station	Number of taxa	Mean number per m^2	Standard deviation	Diversity (H)	Equitability (E)
		PROPOSED DISPOSAL AREA			
1	17	839	238	2.56	0.63
2	24	1,507	608	2.79	0.61
3	24	1,284	585	2.27	0.50
4	13	296	246	3.17	0.86
5	21	1,884	256	2.87	0.65
6	14	399	195	2.66	0.70
Mean	19	1,035	632	2.72	0.66
		DOWNSTREAM FROM PROPOSED DISPOSAL AREA			
7	13	442	159	2.74	0.74
		REFERENCE AREA			
8	12	15,566	5,786	0.50	0.14
9	12	4,587	3,000	1.23	0.34
10	13	1,636	574	1.36	0.37
11	12	1,524	837	1.27	0.35
Mean	12	5,828	6,645	1.09	0.30
		DEEPER-WATER AREA			
12	15	180	87	2.48	0.64
13	10	149	39	2.21	0.66
14	15	368	176	2.39	0.61
Mean	13	232	118	2.36	0.64

Table 4.--Summary of benthic invertebrate collections at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, December 1991.

Station	Number of taxa	Mean number per m^2	Standard deviation	Diversity (H)	Equitability (E)
PROPOSED DISPOSAL AREA					
1	29	1,089	472	3.20	0.66
2	23	3,930	1,764	2.15	0.48
3	35	1,281	586	3.63	0.71
4	30	2,248	448	3.11	0.63
5	37	1,702	482	3.45	0.66
6	17	1,404	552	2.30	0.56
Mean	28	1,942	1,054	2.97	0.62
DOWNSTREAM FROM PROPOSED DISPOSAL AREA					
7	16	784	283	2.61	0.65
REFERENCE AREA					
8	17	14,197	14,194	0.61	0.15
9	22	2,436	529	2.67	0.60
10	13	1,518	518	2.09	0.56
11	13	3,141	1,502	1.47	0.40
Mean	16	5,323	5,953	1.71	0.43
DEEPER-WATER AREA					
12	21	425	231	3.27	0.74
13	21	612	247	3.09	0.70
14	28	515	193	3.74	0.78
Mean	23	517	94	3.37	0.74

than in March, June, and September ($P < 0.05$). Higher numbers of taxa and higher values for E in December caused the significant differences between the surveys.

Overall, taxa collected in the deeper-water area were numerically more equally distributed than taxa in the two other areas (Tables 1-4). E values were significantly higher in the proposed Area D and deeper-water area than in the reference area (ANOVA, FPLSD; $P < 0.05$); however, there was no significant difference in E between the proposed Area D and the deeper-water area ($P > 0.05$). There were no significant differences in E between surveys ($P > 0.05$).

In the proposed Area D, dominant taxa included turbellarians; nemerteans; polychaetes, particularly Eteone longa, Magelona sacculata, Polydora brachycephala, and Scolelepis squamata; the mysid Archaeomysis grebnitzkii; and amphipods, particularly Eohaustorius washingtonianus and Grandifoxus grandis (Table 5; Appendix Table 3). In the reference area, dominant taxa included turbellarians; nemerteans; polychaetes, particularly Eteone longa and Polygordius spp.; and the mysid Archaeomysis grebnitzkii. Dominant taxa in the deeper-water area included turbellarians; nemerteans; polychaetes, particularly Eteone longa and Polygordius spp.; and the mysid Archaeomysis grebnitzkii. In the area immediately downstream from the proposed Area D, dominant taxa included nemerteans; polychaetes, particularly Spionidae, Eteone longa, Magelona sacculata, and Scolelepis squamata; and the mysid Archaeomysis grebnitzkii.

Fishes, Dungeness Crabs, and Shrimps

The number of taxa collected in trawls was similar for the March, June, and December surveys, ranging from 24 to 29. Only 18 taxa were collected in September (Appendix Tables 4 and 5). Fishes were generally more abundant in the proposed Area D (Trawls 1 and 2) than in the reference (Trawls 3 and 4) and deeper-water areas (Trawl 5)

Table 5.--Densities (mean number/m^2) of dominant benthic invertebrates collected at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Taxon	Mar	Jun	Sep	Dec
PROPOSED DISPOSAL AREA				
Turbellaria	2	500	34	322
Nemertea	112	706	96	303
Polychaeta				
Eteone longa	73	52	95	312
Magelona sacculata	162	1,462	146	133
Polydora brachycephala	0	59	6	174
Scolelepis squamata	2	4	326	164
Mysidacea				
Archaeomysis grebnitzkii	416	84	68	43
Amphipoda				
Eohaustorius washingtonianus	385	0	7	66
Grandifoxus grandis	70	206	68	146
DOWNSTREAM FROM PROPOSED DISPOSAL AREA				
Nemertea	134	835	59	134
Polychaeta				
Spionidae	2	85	0	0
Eteone longa	53	156	52	322
Magelona sacculata	2	57	6	83
Scolelepis squamata	0	7	103	18
Mysidacea				
Archaeomysis grebnitzkii	316	4	132	75
REFERENCE AREA				
Turbellaria	588	1,659	252	663
Nemertea	2,911	2,193	927	610
Polychaeta				
Eteone longa	54	6	18	258
Polygordius spp.	3,358	0	4,430	3,522
Mysidacea				
Archaeomysis grebnitzkii	62	141	143	116
DEEPER-WATER AREA				
Turbellaria	18	94	6	28
Nemertea	140	246	40	51
Polychaeta				
Eteone longa	64	278	12	105
Polygordius spp.	133	12	4	36
Mysidacea				
Archaeomysis grebnitzkii	41	139	119	110

(Fig. 2; Table 6). Juvenile or adult Dungeness crabs were generally not abundant in any of the areas during the four surveys. Dungeness crab densities in the proposed Area D averaged 168/ha in June; however, 91% of these crabs were megalops (larvae) and probably were not permanent residents. The largest number of juvenile or adult Dungeness crabs was collected in December in the deeper-water area.

The most abundant organisms collected by trawling in the proposed Area D included Pacific tomcod (*Microgadus proximus*) and California bay shrimp (*Crangon franciscorum*) in March; unidentified juvenile smelt, Pacific tomcod, Dungeness crab megalops, and California bay shrimp in June; whitebait smelt (*Allosmerus elongatus*), Pacific tomcod, and English sole (*Pleuronectes vetulus*) in September; and longfin smelt (*Spirinchus thaleichthys*), Pacific tomcod, California bay shrimp, and smooth bay shrimp (*Lissocrangon stylirostris*) in December (Table 7). In the reference area, longfin smelt and California bay shrimp were the most abundant organisms in March; unidentified juvenile smelt, Pacific tomcod, and California bay shrimp in June; longfin smelt and Pacific tomcod in September; and Pacific tomcod, California bay shrimp, and smooth bay shrimp in December. The most abundant trawled organisms in the deeper-water area were eulachon (*Thaleichthys pacificus*) and California bay shrimp in March; unidentified juvenile smelt and California bay shrimp in June; Pacific tomcod and smooth bay shrimp in September; and longfin smelt, Pacific tomcod, Dungeness crab, California bay shrimp, and smooth bay shrimp in December. No sturgeon (*Acipenser* spp.) were collected during any of the surveys.

In general, H (by area) was low to moderate, ranging from 1.24 in March in the proposed Area D to 2.82 in December in the proposed Area D (Table 6; Appendix Table 5). Overall, E values (by area) were moderate, ranging from 0.30 in March in the proposed Area D to 0.70 in December in the deeper-water area (Table 6; Appendix Table 5).

Table 6.--Summary of bottom trawling at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991. Dungeness crab megalops are included in the totals for crabs; only Dungeness crabs were captured. Each value for the proposed disposal and reference areas is an average from two trawling efforts; only one trawling effort was made at the deeper-water area.

Month	Number of taxa	Fishes per ha	Crabs per ha	Shrimps per ha	Total organisms per ha	H[a]	E[b]
			PROPOSED DISPOSAL AREA				
Mar	18	321	24	1,628	1,973	1.24	0.30
Jun	12	1,652	168	969	2,789	1.95	0.55
Sep	14	884	6	97	989[c]	2.24	0.59
Dec	20	1,707	78	932	2,717	2.82	0.65
			REFERENCE AREA				
Mar	11	444	8	496	948	1.72	0.50
Jun	18	359	7	112	478	2.60	0.62
Sep	10	666	4	76	746	2.16	0.65
Dec	15	553	16	686	1,255	2.45	0.63
			DEEPER-WATER AREA				
Mar	12	235	14	1,193	1,442	1.28	0.36
Jun	15	367	64	1,438	1,869	1.47	0.38
Sep	12	475	9	609	1,093	2.33	0.65
Dec	14	1,460	252	1,381	3,093	2.67	0.70

[a] Diversity.
[b] Equitability.
[c] Includes a small giant octopus (Octopus dofleini).

Table 7.--Dominant taxa (by area) collected by bottom trawling at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991; all values are numbers/ha (deeper-water area) or mean numbers/ha (proposed disposal area and reference area).

Taxon	Mar	Jun	Sep	Dec
PROPOSED DISPOSAL AREA				
Whitebait smelt	0	56	310	0
Longfin smelt	4	40	2	459
Unidentified juvenile smelt	0	1,160	4	63
Pacific tomcod	152	338	398	852
English sole	2	2	98	31
Dungeness crab (includes megalops)	24	168	6	78
California bay shrimp	1,598	969	65	402
Smooth bay shrimp	30	0	32	522
REFERENCE AREA				
Longfin smelt	348	4	273	88
Unidentified juvenile smelt	2	140	35	15
Pacific tomcod	10	140	214	348
California bay shrimp	485	112	42	397
Smooth bay shrimp	10	0	34	289
DEEPER-WATER AREA				
Longfin smelt	28	13	86	345
Eulachon	127	0	0	0
Unidentified juvenile smelt	0	159	52	29
Pacific tomcod	28	38	242	813
Dungeness crab (includes megalops)	14	64	9	252
California bay shrimp	1,146	1,438	86	460
Smooth bay shrimp	47	0	523	921

Most dominant taxa collected by trawling at and adjacent to the proposed Area D (all areas combined) were represented by one to two size classes (Figs. 3-6). Total lengths of dominant fish rarely exceeded 250 mm. California bay shrimp and smooth bay shrimp were generally $\leq$ 85 mm long.

Sediments

Median grain size was significantly higher in the reference area than in the proposed disposal and deeper-water areas (ANOVA, FPLSD; $P < 0.05$) (Table 8; Appendix Table 6). There was no significant difference in median grain size between the proposed disposal area and the deeper-water area ($P > 0.05$). In addition, median grain size was not significantly different between surveys ($P > 0.05$). No statistical comparisons of the area immediately downstream from the proposed Area D were made because there was only one station (Station 7) in this area. Combining data for all surveys, median grain sizes averaged 0.1671 mm in the proposed Area D, 0.2085 mm in the area immediately downstream from the proposed Area D, 0.3163 mm in the reference area, and 0.2108 mm in the deeper-water area.

Silt/clay and volatile solid analyses indicated that the substrate in the proposed Area D was not homogeneous. Mean percent silt/clay in the substrate was higher in the proposed Area D (overall 13.4%) than in the downstream, reference, and deeper-water areas (overall 0.6, 1.2 and 0.4%, respectively), largely due to one or two unusually high values from samples in the proposed Area D during each survey (Table 8; Appendix Table 6). Mean percent volatile solids in the substrate were also higher in the proposed Area D (overall 1.5%) than in the downstream, reference, and deeper-water areas (overall 0.8, 0.7 and 0.7%, respectively); however, these differences were not as great as those for

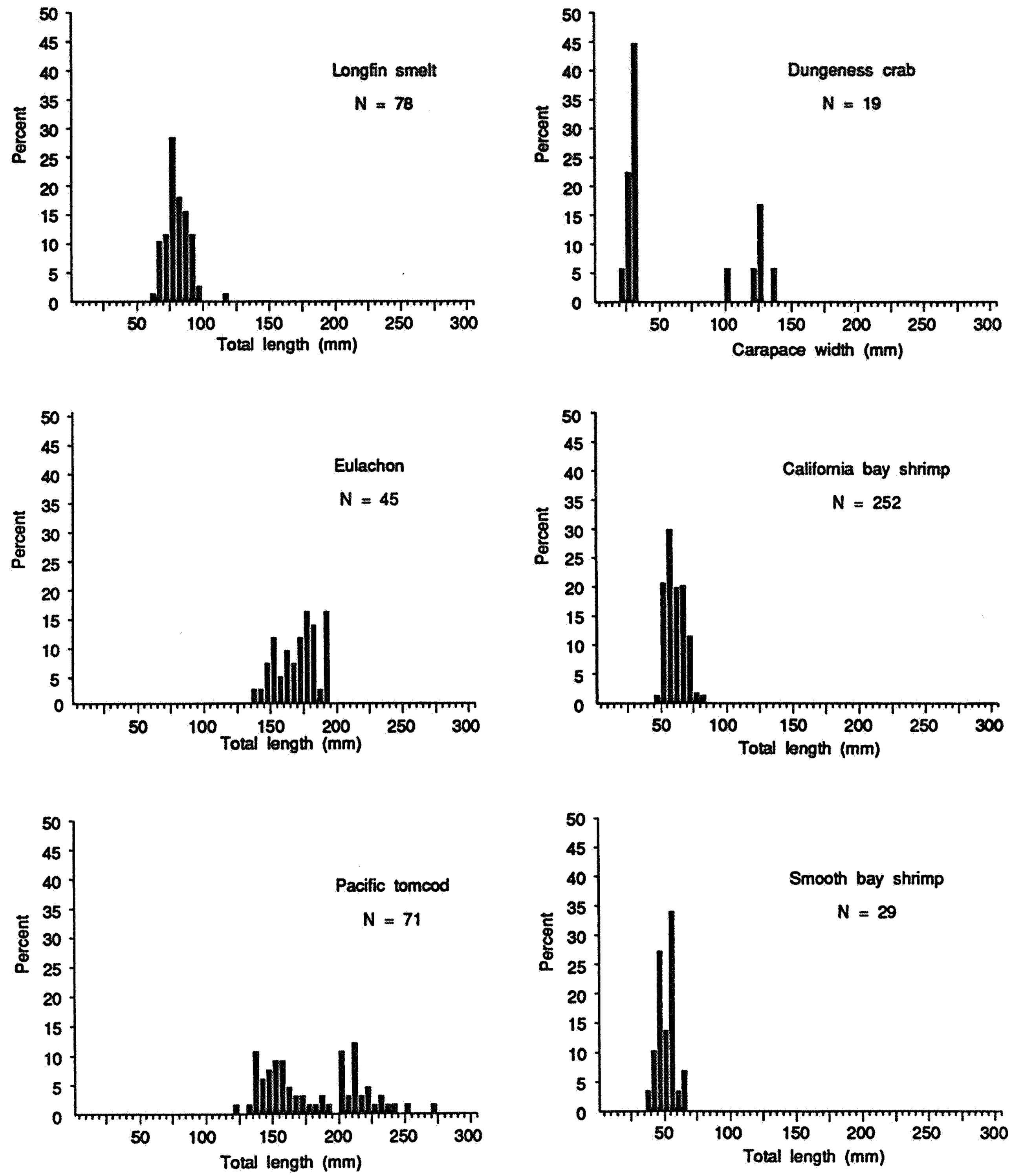

Figure 3.--Length-frequency distributions of dominant taxa captured at five trawling areas at and adjacent to a proposed new site for Area D, lower Columbia River, March 1991.

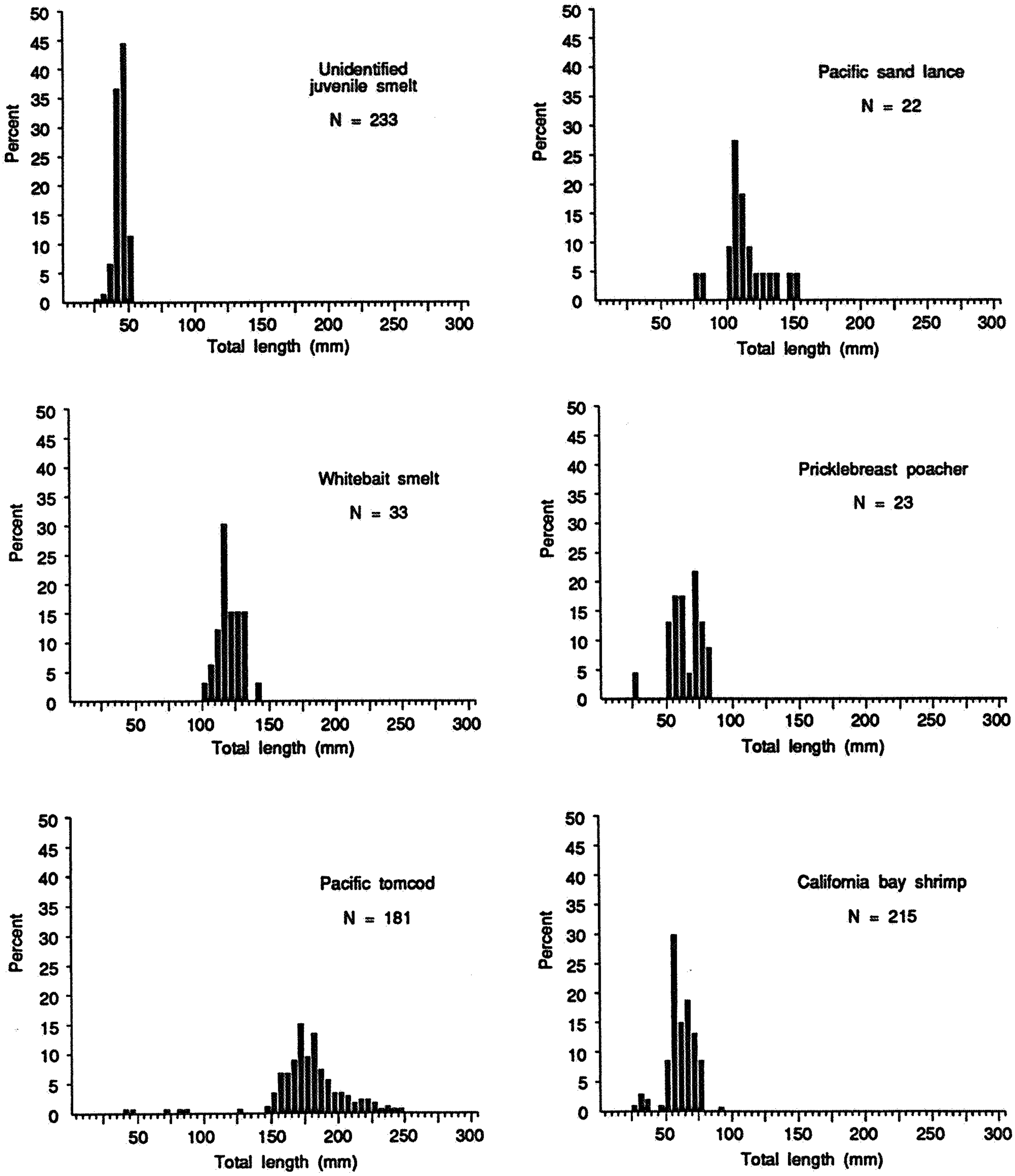

Figure 4.--Length-frequency distributions of dominant taxa captured at five trawling areas at and adjacent to a proposed new site for Area D, lower Columbia River, June 1991.

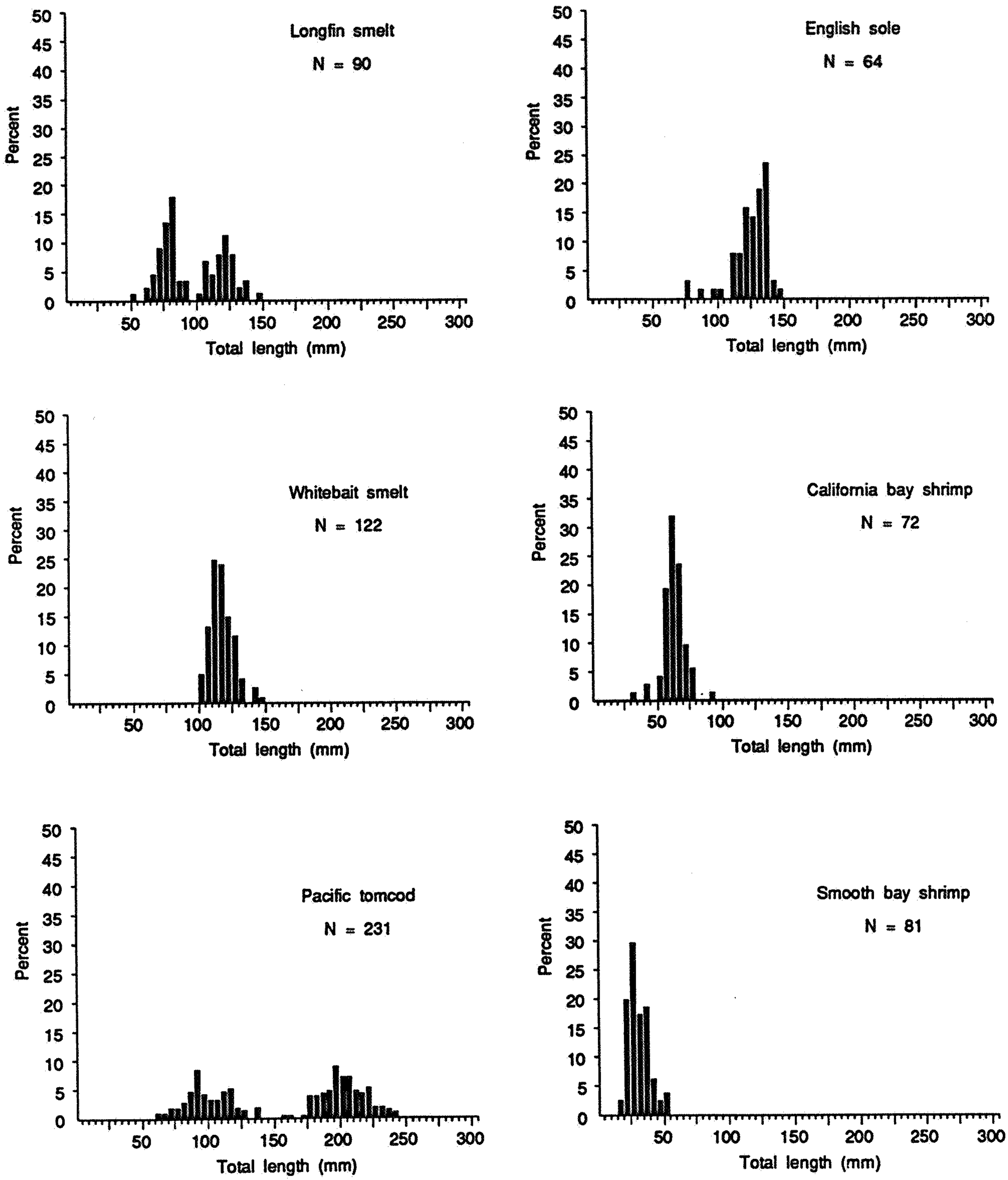

Figure 5.--Length-frequency distributions of dominant taxa capured at five trawling areas at and adjacent to a proposed new site for Area D, lower Columbia River, September 1991.

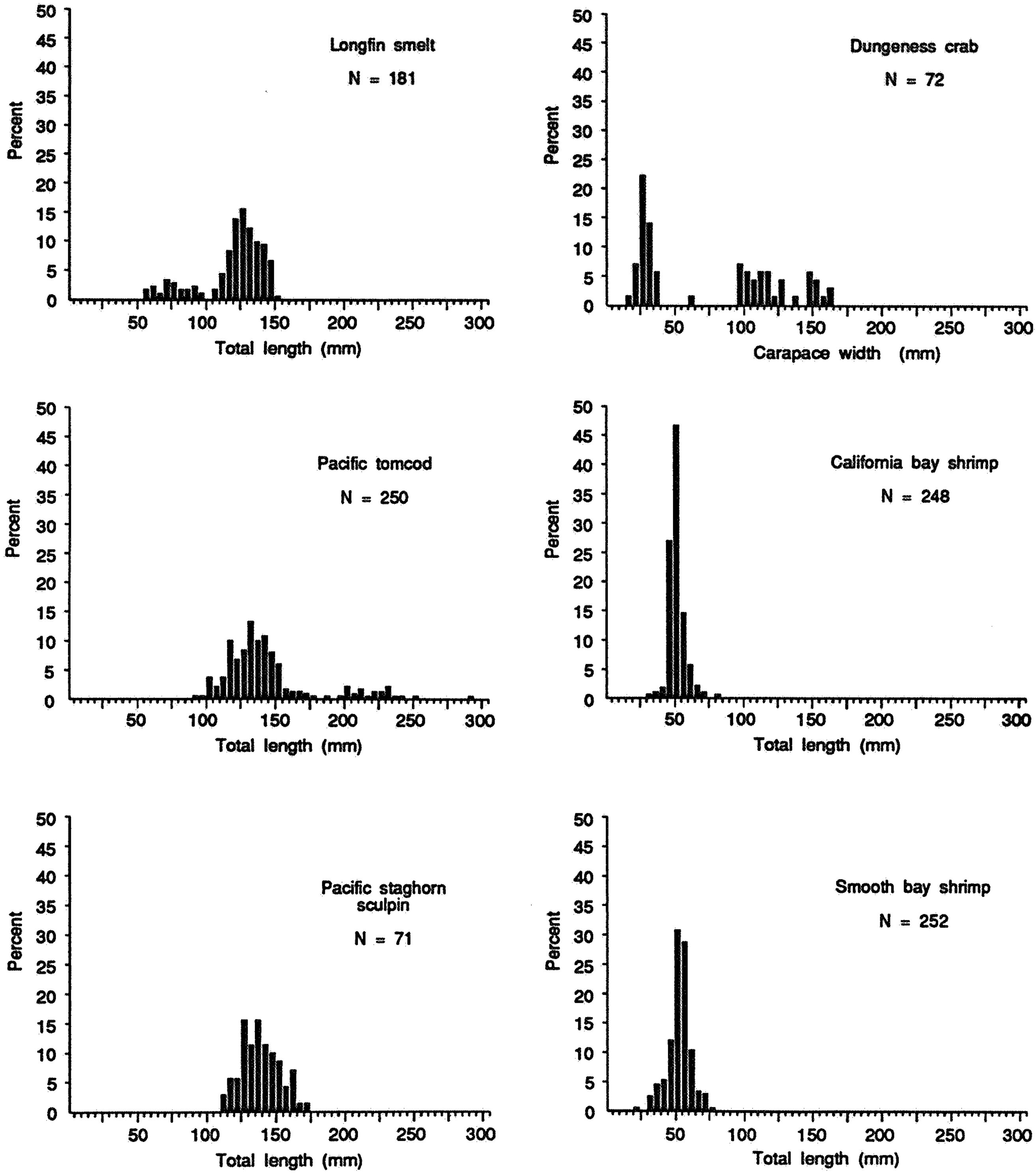

Figure 6.--Length-frequency distributions of dominant taxa capured at five trawling areas at and adjacent to a proposed new site for Area D, lower Columbia River, December 1991.

Table 8.--Sediment characteristics at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991. All numbers are mean values, except for values for the area downstream from the proposed disposal area; values for other individual stations are presented in Appendix Table 6.

Month	Median grain size (mm)	Percent silt/clay	Percent volatile solids
PROPOSED DISPOSAL AREA			
Mar	0.1528	10.6	1.3
Jun	0.1995	15.2	1.5
Sep	0.1553	15.1	1.6
Dec	0.1608	12.6	1.6
DOWNSTREAM FROM PROPOSED DISPOSAL AREA			
Mar	0.1768	0.6	0.7
Jun	0.1895	1.1	0.8
Sep	0.2176	0.0	0.8
Dec	0.2500	0.5	0.7
REFERENCE AREA			
Mar	0.3481	0.7	0.6
Jun	0.3005	3.2	0.9
Sep	0.3194	0.4	1.0
Dec	0.2971	0.4	0.5
DEEPER-WATER AREA			
Mar	0.2074	0.4	0.6
Jun	0.2257	0.7	0.9
Sep	0.2236	0.2	0.8
Dec	0.1864	0.3	0.4

percent silt/clay. The highest values of percent silt/clay were associated with the highest values of percent volatile solids.

DISCUSSION

The benthic invertebrate communities in the proposed Area D and reference area were different, as evidenced by significant differences ($P < 0.05$) in densities and community structure indices (H and E). The differences between these two areas were probably due in part to the substrates; median grain size was significantly larger in the reference area than in the proposed Area D ($P < 0.05$). Initially, we anticipated that the reference area could be used as a "control" for future assessments of the impacts of disposed dredged material on the benthos in the proposed Area D. However, because of the dissimilarities between the two areas, we concluded that the reference area would not be an appropriate "control" in future assessments.

Benthic invertebrate densities in the proposed Area D in June and September averaged 3,481 and 1,035 organisms/m^2, respectively. These values were higher than those observed at an offshore area (Hinton et al. 1992) and the lower Columbia River estuary (Jones et al. 1990) during comparable months. Hinton et al. (1992) reported mean benthic invertebrate densities of 1,074 and 2,565 organisms/m^2 in June 1989 and June 1990, respectively, at an area offshore from the Columbia River. Benthic invertebrate densities in main channel habitat of the plume and ocean zone of the Columbia River estuary averaged 520 organisms/m^2 in September 1981 (Jones et al. 1990). Of all the habitats sampled by Jones et al. (1990) in the plume and ocean zone of the Columbia River estuary, main channels had the lowest densities of benthic invertebrates; highest densities occurred in protected flats where the density averaged 12,280 organisms/m^2 in September 1981.

Data collected by trawling in this study provide only a general characterization of the demersal fish and epibenthic invertebrate communities. In contrast to benthic invertebrate communities, which are relatively stable on a short-term basis, demersal fish and epibenthic invertebrate communities in the lower Columbia River estuary change rapidly, often daily.

CONCLUSIONS AND RECOMMENDATIONS

Benthic invertebrate densities were significantly higher in the proposed Area D than in the deeper-water area, and significantly lower than in the reference area ($P < 0.05$). Fishes were generally more abundant in the proposed Area D than in the reference and deeper-water areas. Juvenile or adult Dungeness crabs were generally not abundant in any of the areas during the four surveys. In three of the surveys, shrimp densities were higher in the deeper-water area than in the proposed Area D.

The data indicate that the deeper-water area has lower standing crops of benthic invertebrates and fishes than the proposed Area D, and may be a more suitable site for relocating the present Area D. In assessing the potential of the deeper-water area as a dredged-material disposal site, it is essential to determine the direction of sediment movement out of this area. The deeper-water area is located southwest of the opening between East and West Sand Islands. If it is determined that dredged material deposited in the deeper-water area would be carried by tidal currents through this opening into Baker Bay, then the deeper-water area should not be considered for disposal of dredged material.

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

Appendix Table 1.--Locations of benthic and bottom trawling stations at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Benthic Station Locations

Station	Latitude	Longitude
1	46°14'24"N	123°59'09"W
2	46°14'23"N	123°58'38"W
3	46°14'22"N	123°58'06"W
4	46°14'37"N	123°59'06"W
5	46°14'32"N	123°58'39"W
6	46°14'32"N	123°58'11"W
7	46°14'39"N	123°59'39"W
8	46°14'53"N	123°58'51"W
9	46°14'50"N	123°58'17"W
10	46°15'04"N	123°58'45"W
11	46°15'02"N	123°58'11"W
12	46°15'27"N	124°00'44"W
13	46°15'21"N	124°00'27"W
14	46°15'14"N	124°00'08"W

Trawling Locations

Station	Latitude	Longitude
TR1	46°14'23"N	123°59'04"W
TR2	46°14'36"N	123°59'00"W
TR3	46°14'53"N	123°58'47"W
TR4	46°15'04"N	123°58'40"W
TR5	46°15'21"N	124°00'27"W

Appendix Table 2.--Taxa collected by 0.1-m^2 Van Veen grab sampler at and adjacent to the proposed new Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Taxon	Mar	Jun	Sep	Dec
Coelenterata				
Hydrozoa		x		
Hydroida	x			
Turbellaria	x	x	x	x
Nemertea	x	x	x	x
Annelida				
Polychaeta	x	x		x
Phyllodocidae	x			x
Eteone spp.	x	x		
Eteone longa	x	x	x	x
Phyllodoce spp.	x	x		
Hesionidae				
Gyptis brevipalpa	x			
Syllidae	x	x		x
Syllis spp.	x	x	x	
Exogone spp.	x			
Nephtyidea				
Nephtys spp.		x		
Nephtys cornuta cornuta	x			
Nephtys cornuta franciscana	x			
Nephtys ferruginea	x	x	x	
Nephtys californiensis	x	x	x	x
Glyceridae				
Glycera spp.	x	x	x	x
Glycera americana	x		x	
Glycera capitata		x		
Glycera tenius				x
Glycera convoluta	x	x	x	x
Glycinde spp.	x			x
Glycinde armigera	x	x		x
Glycinde picta	x	x	x	x
Orbiniidae		x		
Leitoscoloplos spp.		x		
Leitoscoloplos pugettensis	x		x	
Scoloplos armiger				x
Paraonidae				
Paraonella platybranchia	x	x	x	x
Spionidae	x	x	x	
Polydora spp.	x			x
Polydora brachycephala		x	x	x

Appendix Table 2.--Continued.

Taxon	Mar	Jun	Sep	Dec
Prionospio spp.	x	x		
Prionospio lighti			x	x
Spiophanes spp.	x	x	x	x
Spiophanes bombyx	x	x	x	x
Pygospio californica			x	
Scolelepis spp.		x		x
Scolelepis squamata	x	x	x	x
Scolelepis foliosa				x
Magelonidae				
Magelona spp.		x		x
Magelona sacculata	x	x	x	x
Magelona hobsonia				x
Cirratulidae				x
Tharyx spp.	x			
Chaetozone spinosa			x	
Opheliidae		x	x	x
Ophelina spp.				x
Ophelina breviata				x
Ophelina acuminata	x			
Ophelina limacina		x		x
Armandia brevis			x	
Capitellidae		x		x
Capitella capitata complex	x	x		x
Heteromastus spp.	x		x	
Heteromastus filobranchus		x		
Mediomastus spp.	x	x		x
Mediomastus californiensis	x			x
Archiannelida				
Polygordiidae				
Polygordius spp.	x	x	x	x
Oligochaeta			x	x
Mollusca				
Gastropoda	x			
Olividae				
Olivella biplicata				x
Pelecypoda	x	x	x	
Mytilidae	x			x
Mytilus spp.	x	x	x	x
Modiolus spp.			x	
Cariidae				
Clinocardium nuttalli			x	

Appendix Table 2.--Continued.

Taxon	Mar	Jun	Sep	Dec
Cultellidae				
Siliqua patula	x	x	x	x
Tellinidae				
Macoma spp.		x		x
Macoma balthica	x	x	x	x
Tellina spp.	x		x	x
Corbiculidae				
Corbicula fluminea		x		
Myidae				
Mya arenaria			x	x
Arthropoda				
Arachnida	x	x	x	
Halacaridae	x	x	x	x
Cladocera		x		
Daphnidae				
Daphnia spp.	x	x		
Daphnia pulex	x			
Cylindroleberididae				x
Copepoda				
Calanoida	x	x	x	
Epilabidocera longipedata	x			
Harpactacoida				
Scottolana canadensis		x		
Cyclopoida	x	x		
Cirripedia	x	x		x
Balanus spp.		x	x	
Mysidacea				
Mysidae				
Exacanthomysis spp.			x	
Alienacanthomysis macropsis	x		x	x
Archaeomysis grebnitzkii	x	x	x	x
Neomysis spp.	x			x
Neomysis rayii		x		
Neomysis kadiakensis				x
Cumacea		x		x
Lampropidae	x	x		
Diastylidae	x			
Diastylopsis spp.	x			
Diastylopsis dawsoni		x		x

Appendix Table 2.--Continued.

Taxon	Mar	Jun	Sep	Dec
Colurostylis spp.		x		
Colurostylis occidentalis	x			
Nannastacidae				
Cummella vulgaris		x		x
Isopoda		x		
Sphaeromidae				
Gnorimosphaeroma oregonensis	x	x	x	x
Idoteidae				
Saduria entomon		x		
Synidotea spp.		x		
Synidotea angulata		x		x
Idotea fewkesi				x
Liriopsidae				
Liriopsis pygmaea		x		
Amphipoda				
Gammaridea		x		x
Atylidae				
Atylus tridens	x	x		x
Corophiidae				
Corophium spp.		x	x	x
Corophium salmonis	x	x	x	x
Gammaridae		x		
Anisogammaridae				
Eogammarus spp.		x		x
Eogammarus confervicolus	x	x		
Eogammarus oclairi	x	x	x	x
Haustoridae				
Eohaustorius spp.				x
Eohaustorius washingtonianus	x	x	x	x
Hyalidae				
Allorchestes angustus				x
Isaedae				
Photis spp.				x
Photis macinerneyi				x
Oedicerotidae				
Monoculodes spp.				x
Monoculodes spinipes	x		x	x
Phoxocephalidae		x	x	
Mandibulophoxus gilesi	x	x	x	
Rhepoxynius spp.	x	x		
Rhepoxynius abronius	x			
Rhepoxynius daboius	x			

Appendix Table 2.--Continued.

Taxon	Mar	Jun	Sep	Dec
Rhepoxynius heterocuspidata	x			
Rhepoxynius tridentatus	x			
Grandifoxus grandis	x	x	x	x
Hyperiidae		x		
Hyperoche spp.	x			
Caprellidae				
Caprella spp.		x		
Decapoda	x	x	x	
Crangonidae			x	
Crangon spp.		x		
Crangon franciscorum	x			
Crangon nigricauda		x		
Lissocrangon stylirostris			x	x
Upogebiidae				
Upogebia pugettensis	x			
Brachyura	x	x	x	
Canceridae				
Cancer spp.	x	x		
Cancer magister	x	x		
Porcellanidae	x	x		
Insecta				
Collembola	x		x	x
Plecoptera larvae	x			
Homoptera			x	
Aphididae			x	
Coleoptera		x	x	
Tipulidae pupae		x		
Heleidae larvae		x	x	x
Chironomidae	x	x	x	
Chironomidae larvae		x	x	x
Sipuncula				
Sipunculidae	x	x		
Osteichthyes				
Ammodytes hexapterus	x	x	x	x
Unid. Osteichthyes eggs	x			
Unid. Osteichthyes larvae	x			
Echinodermata		x	x	
Dendrasteridae				

Appendix Table 2.--Continued.

Taxon	Mar	Jun	Sep	Dec
Dendraster excentricus				x
Miscellaneous				
Bryozoan statoblast	x	x		
Bryozoan colony	x			
Unid. invertebrate eggs	x			
Total number of taxa	92	95	63	78

Appendix Table 3.--Summaries of benthic invertebrate surveys (by station) conducted in March, June, September, and December 1991 at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River (available upon request from NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121).

Appendix Table 4.--Fishes and epibenthic invertebrates captured by 8-m trawl at and adjacent to proposed Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Scientific name	Common name	Mar	Jun	Sep	Dec
Petromyzontidae					
Lampetra tridentata	Pacific lamprey				x
Squalidae					
Squalus acanthias	Spiny dogfish		x	x	
Rajidae					
Raja binoculata	Big skate		x		
Clupeidae					
Alosa sapidissima	American shad	x			x
Clupea pallasi	Pacific herring	x	x	x	x
Salmonidae					
Oncorhynchus spp.	Unid. salmon	x			
Osmeridae	Unid. juv. smelt	x	x	x	x
Allosmerus elongatus	Whitebait smelt	x	x	x	
Hypomesus pretiosus	Surf smelt			x	x
Spirinchus thaleichthys	Longfin smelt	x	x	x	x
Thaleichthys pacificus	Eulachon	x			
Gadidae					
Merluccius productus	Pacific hake		x		
Microgadus proximus	Pacific tomcod	x	x	x	x
Syngnathidae					
Syngnathus leptorhynchus	Bay pipefish	x			x
Embiotocidae					
Cymatogaster aggregata	Shiner perch	x	x	x	x
Stichaeidae					
Lumpenus sagitta	Snake prickleback	x	x	x	x
Pholidae					
Pholis ornata	Saddleback gunnel	x	x		x
Ammodytidae					
Ammodytes hexapterus	Pacific sand lance	x	x	x	x

Appendix Table 4.--Continued.

Scientific name	Common name	Mar	Jun	Sep	Dec
Scorpaenidae					
Sebastes spp.	Unid. rockfish	x			
Sebastes melanops	Black rockfish		x		
Cottidae					
Artedius fenestralis	Padded sculpin		x		x
Enophrys bison	Buffalo sculpin				x
Hemilepidotus spinosus	Brown Irish lord		x		
Leptocottus armatus	Pacific staghorn sculpin	x	x	x	x
Agonidae					
Occella verrucosa	Warty poacher				x
Pallasina barbata	Tubenose poacher				x
Stellerina xyosterna	Pricklebreast poacher		x		x
Cyclopteridae	Unid. snailfish		x		
Liparis fucensis	Slipskin snailfish	x	x		
Liparis pulchellus	Showy snailfish		x		x
Liparis rutteri	Ringtail snailfish		x		
Bothidae					
Citharichthys stigmaeus	Speckled sanddab		x		x
Pleuronectidae	Unid. sole	x	x		
Isopsetta isolepis	Butter sole	x			x
Pleuronectes vetulus	English sole	x	x	x	x
Psettichthys melanostictus	Sand sole	x	x	x	x
Platichthys stellatus	Starry flounder	x	x	x	x
Canceridae					
Cancer magister	Dungeness crab	x	x	x	x
Crangonidae					
Crangon alaskensis	Northern crangon				x
Crangon franciscorum	California bay shrimp	x	x	x	x
Lissocrangon stylirostris	Smooth bay shrimp	x		x	x
Hippolytidae					
Heptacarpus brevirostris	Stout coastal shrimp				x

Appendix Table 4.--Continued.

Scientific name	Common name	Mar	Jun	Sep	Dec
Octopus					
Octopus dofleini	Giant octopus			x	
	Total number of taxa	24	28	18	29

Appendix Table 5.--Summaries of individual trawling efforts (by station) conducted in March, June, September, and December 1991 at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River (available upon request from NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121).

Appendix Table 6.--Sediment characteristics at and adjacent to a proposed new site for Area D, an in-water dredged-material disposal site in the lower Columbia River, 1991.

Month	Station	Median grain size (mm)	Percent silt/clay	Percent volatile solids
		PROPOSED DISPOSAL AREA		
Mar	1	0.2333	0.6	0.7
Mar	2	0.1768	1.8	1.1
Mar	3	0.0625	59.5	3.4
Mar	4	0.2176	0.1	0.8
Mar	5	0.1250	0.9	1.0
Mar	6	0.1015	1.0	0.8
Jun	1	0.0359	87.7	5.4
Jun	2	0.2031	1.7	1.1
Jun	3	0.2872	0.4	0.6
Jun	4	0.2500	0.3	0.4
Jun	5	0.2031	0.8	0.8
Jun	6	0.2176	0.1	0.5
Sep	1	0.1768	0.2	0.7
Sep	2	0.0544	63.5	4.6
Sep	3	0.2333	1.3	0.5
Sep	4	0.1250	24.9	2.1
Sep	5	0.1088	0.4	0.8
Sep	6	0.2333	0.1	0.6
Dec	1	0.2176	0.7	0.6
Dec	2	0.2176	10.5	0.9
Dec	3	0.0508	63.6	6.1
Dec	4	0.1768	0.5	0.8
Dec	5	0.1250	0.4	0.9
Dec	6	0.1768	0.1	0.6
		DOWNSTREAM FROM PROPOSED DISPOSAL AREA		
Mar	7	0.1768	0.6	0.7
Jun	7	0.1895	1.1	0.8
Sep	7	0.2176	0.0	0.8
Dec	7	0.2500	0.5	0.7
		REFERENCE AREA		
Mar	8	0.2500	1.4	0.7
Mar	9	0.4353	0.5	0.5
Mar	10	0.3536	0.3	0.6
Mar	11	0.3536	0.7	0.5
Jun	8	0.3789	0.0	0.6
Jun	9	0.2679	3.0	0.9
Jun	10	0.2679	6.9	1.2
Jun	11	0.2872	2.8	0.9

Appendix Table 6.--Continued.

Month	Station	Median grain size (mm)	Percent silt/clay	Percent volatile solids
Sep	8	0.2872	0.7	0.7
Sep	9	0.4353	0.1	1.6
Sep	10	0.2679	0.7	0.6
Sep	11	0.2872	0.2	1.1
Dec	8	0.3536	0.3	0.5
Dec	9	0.2176	0.5	0.5
Dec	10	0.2872	0.3	0.5
Dec	11	0.3299	0.4	0.5
		DEEPER-WATER AREA		
Mar	12	0.1895	0.3	0.5
Mar	13	0.1649	0.5	0.7
Mar	14	0.2679	0.4	0.5
Jun	12	0.1340	0.1	0.8
Jun	13	0.1895	1.8	0.9
Jun	14	0.3536	0.1	1.0
Sep	12	0.2031	0.0	1.0
Sep	13	0.2176	0.6	0.8
Sep	14	0.2500	0.1	0.5
Dec	12	0.1768	0.4	0.5
Dec	13	0.1649	0.3	0.4
Dec	14	0.2176	0.3	0.4