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Fish Ecology Division

Northwest Fisheries Science Center

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Seattle, Washington

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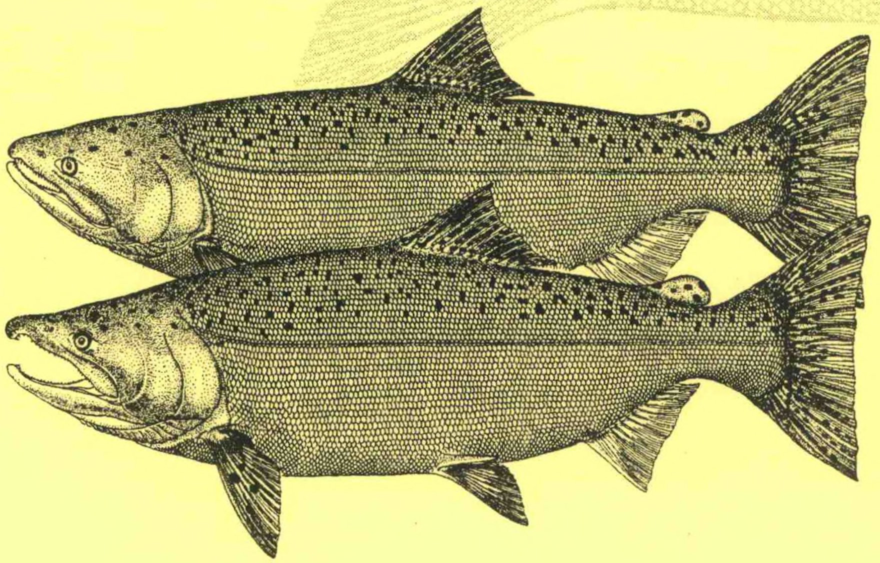

BENTHIC INVERTEBRATES AND SEDIMENT CHARACTERISTICS IN AND ADJACENT TO A PROPOSED CHANNEL WIDENING AREA (RIVER MILE 31-34), COLUMBIA RIVER ESTUARY

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EXECUTIVE SUMMARY

In 1996 and 1997, the National Marine Fisheries Service (NMFS) studied the benthic invertebrates and sediments in subtidal areas between River Mile 31 and 34 (River Kilometer 50 and 55) in the Columbia River estuary in cooperation with the Portland District of the U.S. Army Corps of Engineers (COE). The COE is considering widening the navigation channel in this reach of the estuary by up to 91 m (300 ft). The proposed widening project could impact an area 183 m (600 ft) wide by over 4 km (2.5 mi) long. Benthic invertebrates, particularly the amphipod *Corophium salmonis*, found in intertidal and subtidal habitats of the Columbia River estuary are seasonally important in the diets of juvenile salmonids. The goal of the study was to collect baseline benthic invertebrate and sediment data in and adjacent to the proposed channel widening area prior to any habitat modification.

Benthic invertebrate and sediment samples were collected in October 1996 and January, April, and July 1997 at 20 stations in or just south of the potential impact area. Ten of the sampling stations (North Transect) were located along an east-west transect that was completely within the potential impact area (i.e., within 183 m of the present channel), and the other 10 sampling stations (South Transect) were located along an east-west transect that ran along the southern boundary of the potential impact area or just south of the area. An additional three reference stations (Reference Area) were located north of the potential impact area in the adjacent navigation channel, which is maintained by dredging.

Diversity (H) and equitability (E) were not significantly different (Analysis of Variance (ANOVA), $P > 0.05$) between surveys or areas. Overall, mean H values were relatively low in all three areas, ranging from 1.13 to 1.74. Mean E values were generally in

the medium range in the three areas, ranging from 0.42 to 0.68. The number of taxa/categories was significantly different both by area and survey (ANOVA, $P < 0.05$); the number of taxa/categories was highest in the Reference Area and during the October 1996 survey.

Results from the ANOVA comparing $\log_{10}$benthic invertebrate densities (total) indicated a significant interaction between the two factors, survey and area. In all areas, $\log_{10}$benthic invertebrate densities (total) were significantly higher in October 1996 than in any of the other surveys. In all surveys, mean benthic invertebrate densities (total) in the Reference Area were higher or similar to those in the North and South Transects. Major benthic invertebrate taxa collected during the study included Turbellaria (flatworms), the bivalve *Corbicula fluminea*, *Corophium* spp. (primarily *C. salmonis*), Chironomidae larvae (midges), and Ceratopogonidae larvae (biting midges).

In all surveys, except in October 1996, mean densities of *Corophium* spp. in all three areas were low. Densities of *Corophium* spp. ($\log_{10}$(value + 1)) were significantly different between surveys (ANOVA, $P < 0.05$), but not between areas. In October 1996, densities of *Corophium* spp. averaged more than 650 organisms/m^2 in each of the three areas; however, mean densities in each of the areas during the other three surveys were less than 50 organisms/m^2.

Three sediment characteristics--median grain size (mm), percent silt/clay, and percent volatile solids--were described and compared for each area. Median grain size was significantly different between areas (ANOVA, $P < 0.05$), but not significantly different between surveys. In the North Transect, South Transect, and Reference Area, median grain sizes (all surveys combined) averaged 0.34, 0.35, and 0.42 mm, respectively. Results from the ANOVA comparing $\sin^{-1}\sqrt{}$ percent silt/clay indicated a significant interaction ($P < 0.05$) between the two factors, survey and area. In the North Transect and Reference Area, $\sin^{-1}\sqrt{}$ percent silt/clay was significantly higher in January 1997 than in October 1996 and April 1997 ($P \leq 0.05$). The ANOVA comparing $\sin^{-1}\sqrt{}$ percent volatile solids indicated a significant difference ($P < 0.05$) between surveys, but not between areas. Mean percent volatile solids were highest in each area in July 1997.

CONTENTS

INTRODUCTION

In 1996 and 1997, the National Marine Fisheries Service (NMFS) studied the benthic invertebrates and sediments in subtidal areas between River Mile 31 and 34 (River Kilometer 50 and 55; COE charts of the Columbia River use RM rather than River Kilometer) in the Columbia River estuary in cooperation with the Portland District of the U.S. Army Corps of Engineers (COE). The COE is considering widening the navigation channel in this reach of the estuary by up to 91 m (300 ft). The proposed widening project could impact an area 183 m (600 ft) wide by over 4 km (2.5 mi) long. Benthic invertebrates, particularly the amphipod *Corophium salmonis*, found in intertidal and subtidal habitats of the Columbia River estuary are seasonally important in the diets of juvenile salmonids (McCabe et al. 1983, 1986; Kirn et al. 1986). Muir and Emmett (1988) found that *C. salmonis* and *C. spinicorne* were the dominant prey for juvenile salmonids collected during the spring of 1984 at Bonneville Dam. The goal of the present study was to collect baseline benthic invertebrate and sediment data in and adjacent to the proposed channel widening area prior to any habitat modification.

METHODS

Sampling

Benthic invertebrate and sediment samples were collected in October 1996 and January, April, and July 1997 at 20 stations in or just south of the potential impact area (Fig. 1). Ten of the sampling stations (North Transect) were located along an east-west transect that was completely within the potential impact area (i.e., within 183 m of the present channel), and the other 10 sampling stations (South Transect) were located along an east-west

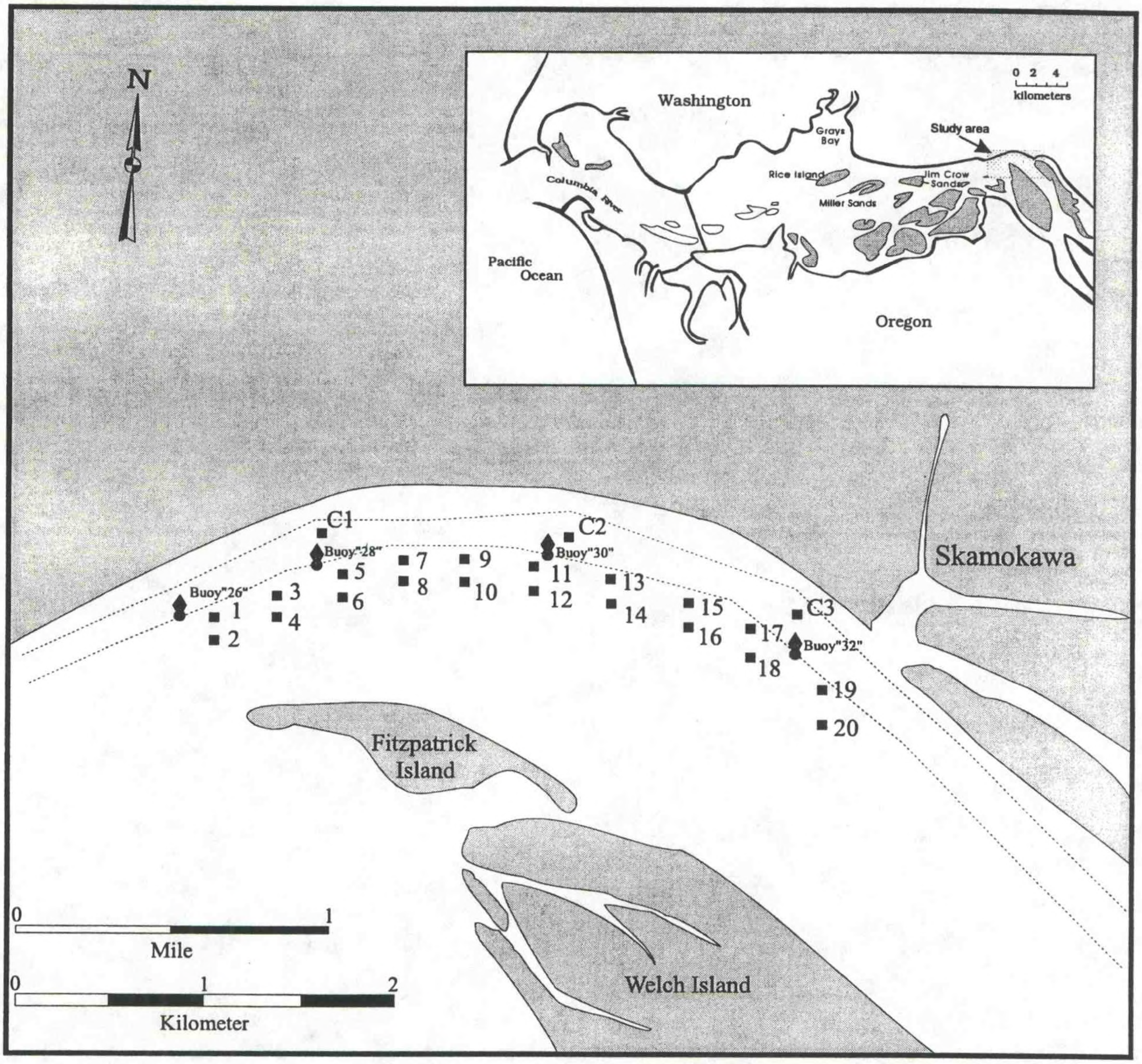

Figure 1. Locations of benthic invertebrate and sediment sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary. The North Transect stations (odd-numbered) were completely within the potential impact area, and the South Transect stations (even-numbered) were located along the southern boundary of the potential impact area or just south of the area. Stations C1-C3 were reference stations located in the navigational channel; the channel is indicated with dotted lines.

transect that ran along the southern boundary of the potential impact area or just south of the area. An additional three reference stations (Reference Area) were located north of the potential impact area in the adjacent navigation channel, which is maintained by dredging. Sampling stations were located using a radar range-finder (Table 1).

A 0.1-m^2 Van Veen grab sampler was used to collect 4 samples at each of the 23 stations, for a total of 92 samples per survey. Three of the four samples collected at each station were analyzed for benthic invertebrates and the fourth sample was analyzed for sediment type. The benthic invertebrate samples were preserved in a buffered formaldehyde solution ($\geq$4%) containing rose bengal, an organic stain. Each sample was later washed with water through a 0.5-mm sieve, and the residue preserved in 70% ethanol. In the laboratory, benthic invertebrates were sorted from each sample, identified to the lowest practical taxon, counted, and stored in 70% ethanol. The fourth benthic sample was placed in a labeled plastic bag and refrigerated for later analysis of grain size, percent silt/clay, and percent volatile solids.

Data Analyses

Benthic Invertebrates

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

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

Table 1. Geographic locations of benthic sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, 1996-1997. Stations beginning with "C" were reference stations located in the navigational channel. The depth (mean lower low water) is a mean from four surveys.

Station	Mean depth (m)	Latitude	Longitude
1	11.0	46°16.036'N	123°30.543'W
2	4.7	46°15.980'N	123°30.484'W
3	1.8	46°16.090'N	123°30.185'W
4	2.4	46°16.060'N	123°30.189'W
5	2.0	46°16.184'N	123°29.879'W
6	2.2	46°16.130'N	123°29.889'W
7	2.8	46°16.203'N	123°29.606'W
8	2.9	46°16.150'N	123°29.575'W
9	3.3	46°16.218'N	123°29.275'W
10	3.1	46°16.161'N	123°29.248'W
11	4.6	46°16.211'N	123°28.955'W
12	4.1	46°16.155'N	123°28.964'W
13	7.1	46°16.185'N	123°28.745'W
14	5.4	46°16.133'N	123°28.762'W
15	9.4	46°16.134'N	123°28.430'W
16	7.5	46°16.080'N	123°28.473'W
17	10.7	46°15.994'N	123°28.157'W
18	10.2	46°15.955'N	123°28.164'W
19	12.3	46°15.881'N	123°27.810'W
20	13.4	46°15.820'N	123°27.849'W
C1	20.0	46°16.292'N	123°29.975'W
C2	17.7	46°16.310'N	123°28.924'W
C3	13.1	46°16.036'N	123°27.989'W

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 all individuals in the sample) and *s* = number of taxa. Equitability (E) was the second community structure index determined; E measures the proportional abundances among the various taxa in a sample (Krebs 1978) and ranges from 0.00 to 1.00, with 1.00 indicating all taxa in the sample are numerically equal. Equitability is expressed as follows:

$$E = H/\log_2 s$$

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

Total benthic invertebrate densities (number/m^2), *Corophium* spp. densities, number of taxa/categories, H, and E were each compared between areas (i.e., North Transect, South Transect, and Reference Area) and surveys using two-way analysis of variance (ANOVA) (Cruze and Hartzell 1991). The Fisher's Protected Least Significant Difference (FPLSD) multiple comparison procedure was used to compare means when significant interaction ($P \leq 0.05$) occurred in the ANOVA (Petersen 1985). Invertebrate densities were tested for normality, and, if necessary, transformed ($\log_{10}$) prior to performing ANOVA. Normality was tested by calculating normal scores of the data, then conducting a correlation test between the normal scores and the data (Cruze and Hartzell 1991). Means from the three samples collected at each sampling station provided the data for all statistical tests.

Sediments

Median grain size (mm), percent silt/clay, and percent volatile solids for samples were compared between areas (i.e., North Transect, South Transect, and Reference Area) and surveys using two-way ANOVA. The FPLSD multiple comparison procedure was used to compare means when significant interaction ($P \leq 0.05$) occurred in the ANOVA. Sediment characteristics were tested for normality, and, if necessary, transformed ($\sin^{-1}\sqrt{}$) prior to performing ANOVA.

RESULTS

Benthic Invertebrates

Diversity (H) and equitability (E) were not significantly different (ANOVA, $P > 0.05$) between surveys or areas (Table 2). Overall, mean H values were relatively low in all three areas, ranging from 1.13 to 1.74 (Table 3). Mean E values were generally in the medium range in the three areas, ranging from 0.42 to 0.68. The number of taxa/categories was significantly different both by area and survey (ANOVA, $P < 0.05$); the number of taxa/categories was highest in the Reference Area and during the October 1996 survey (Tables 2-3).

Results from the ANOVA comparing $\log_{10}$benthic invertebrate densities (total) indicated a significant interaction ($P < 0.05$) between the two factors, survey and area (Table 2). In all areas, $\log_{10}$benthic invertebrate densities (total) were significantly higher in October 1996 than in any of the other surveys (FPLSD, $P \leq 0.05$) (Table 4). In the North and South Transects, $\log_{10}$benthic invertebrate densities (total) were significantly lower in January 1997 than in April and July 1997. Also in the South Transect, $\log_{10}$benthic invertebrate densities were significantly lower in April than in July 1997. In all surveys, mean benthic invertebrate densities (total) in the Reference Area were higher or similar to those in the North and South Transects (Table 4). Major benthic invertebrate taxa collected during the study included Turbellaria (flatworms), the bivalve *Corbicula fluminea*, *Corophium* spp.

Table 2. Results of two-way analysis of variance for selected benthic invertebrate parameters measured in three areas in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, October 1996 through July 1997. The North Transect (N) stations were completely within the potential impact area, and the South Transect (S) stations were located along the southern boundary of the potential impact area or just south of the area. All Reference Area (C) stations were located in the navigational channel. Results from four surveys--October 1996, January, April, and July 1997--were used in the analyses. A significant difference ($P \leq 0.05$) is indicated with an *.

Parameter	Source	Degrees of freedom	F	P value
Diversity (H)	Survey	3	2.68	0.053
	Area (N, S, C)	2	0.50	0.606
	Survey x area	6	1.53	0.178
	Total (deg. freedom)	91		
Equitability (E)	Survey	3	2.67	0.053
	Area (N, S, C)	2	2.46	0.092
	Survey x area	6	1.85	0.100
	Total (deg. freedom)	91		
No. of taxa/categories	Survey	3	5.96	0.001*
	Area (N, S, C)	2	3.62	0.031*
	Survey x area	6	1.19	0.318
	Total (deg. freedom)	91		
Benthic invertebrate density ($\log_{10}$), total	Survey	3	67.80	0.000*
	Area (N, S, C)	2	4.45	0.015*
	Survey x area	6	2.55	0.026*
	Total (deg. freedom)	91		
Corophium spp. density ($\log_{10}$ (value +1))	Survey	3	79.85	0.000*
	Area (N, S, C)	2	0.98	0.378
	Survey x area	6	0.59	0.741
	Total (deg. freedom)	91		

Table 3. Numbers of taxa/categories, Diversities (H), and Equitabilities (E) at benthic sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, October 1996 through July 1997. The North Transect stations were completely within the potential impact area, and the South Transect stations were located along the southern boundary of the potential impact area or just south of the area. All Reference Area stations were located in the navigational channel.

	October			January			April			July		
Station	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E
					NORTH TRANSECT							
1	11	1.24	0.36	9	1.78	0.56	7	1.91	0.68	9	1.92	0.61
3	9	1.39	0.44	6	1.48	0.57	7	1.99	0.71	5	1.43	0.62
5	5	1.41	0.61	6	2.15	0.83	7	1.59	0.57	5	1.21	0.52
7	7	1.62	0.58	7	2.06	0.73	4	0.85	0.42	6	1.28	0.50
9	6	1.52	0.59	6	2.21	0.86	6	0.89	0.35	5	1.22	0.53
11	6	1.50	0.58	6	1.91	0.74	7	1.25	0.45	5	1.34	0.58
13	9	1.53	0.48	8	2.03	0.68	5	0.91	0.39	8	1.47	0.49
15	7	1.41	0.50	7	1.67	0.60	7	1.76	0.63	5	1.14	0.49
17	7	1.44	0.51	4	0.79	0.39	5	1.53	0.66	8	1.51	0.50
19	8	1.25	0.42	8	1.29	0.43	6	1.08	0.42	6	0.56	0.22
Mean	8	1.43	0.51	7	1.74	0.64	6	1.38	0.53	6	1.31	0.51
					SOUTH TRANSECT							
2	7	1.82	0.65	6	1.82	0.70	9	2.04	0.64	9	1.93	0.61
4	8	1.60	0.53	5	1.28	0.55	5	1.65	0.71	6	1.34	0.52
6	7	1.15	0.41	5	1.77	0.76	6	1.44	0.56	5	1.31	0.56
8	4	1.44	0.72	7	1.87	0.66	6	1.33	0.51	7	1.27	0.45
10	8	1.40	0.47	5	1.31	0.57	5	1.14	0.49	6	1.32	0.51
12	8	1.16	0.39	6	1.70	0.66	5	1.30	0.56	6	1.08	0.42
14	5	1.42	0.61	8	2.18	0.73	5	0.69	0.30	3	1.05	0.66
16	5	1.64	0.71	6	1.99	0.77	5	1.17	0.50	7	1.47	0.52
18	7	1.47	0.52	5	1.72	0.74	6	1.48	0.57	7	1.36	0.48
20	8	1.23	0.41	6	1.78	0.69	5	1.49	0.64	7	1.46	0.52
Mean	7	1.43	0.54	6	1.74	0.68	6	1.37	0.55	6	1.36	0.52
					REFERENCE AREA							
C1	10	1.33	0.40	8	1.40	0.47	7	1.27	0.45	5	0.62	0.27
C2	9	1.40	0.44	7	1.37	0.49	5	1.89	0.81	5	1.67	0.72
C3	9	1.49	0.47	8	0.94	0.31	8	1.97	0.66	7	1.10	0.39
Mean	9	1.41	0.44	8	1.24	0.42	7	1.71	0.64	6	1.13	0.46

Table 4. Benthic invertebrate densities (number/m^2) at sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, October 1996 through July 1997. The North Transect stations were completely within the potential impact area, and the South Transect stations were located along the southern boundary of the potential impact area or just south of the area. All Reference Area stations were located in the navigational channel. Each density is the mean of three replicates collected at a station; the standard deviation (SD) is also shown for each density.

	Oct 96		Jan 97		Apr 97		Jul 97	
Sta.	Mean no. organisms/m^2	SD	Mean no. organisms/m^2	SD	Mean no. organisms/m^2	SD	Mean no. organisms/m^2	SD
			NORTH TRANSECT					
1	6,330	2,205	350	113	668	158	576	244
3	2,962	3,644	242	44	350	136	546	162
5	1,512	94	114	37	405	84	678	166
7	800	518	126	101	254	51	785	189
9	1,098	172	74	64	583	203	518	180
11	1,524	494	138	58	442	102	396	180
13	3,294	3,450	279	101	304	82	466	468
15	2,650	972	482	313	291	53	616	181
17	1,901	1,250	432	221	371	74	712	309
19	4,707	948	678	435	748	741	1,478	460
Mean	2,678		291		442		677	
			SOUTH TRANSECT					
2	1,312	212	80	28	374	86	484	98
4	1,653	1,041	120	56	215	42	684	137
6	2,637	1,030	166	88	276	40	484	206
8	914	423	141	117	561	216	659	157
10	1,058	595	160	129	408	148	586	365
12	1,224	185	331	51	552	124	800	287
14	1,276	1,092	353	166	319	86	944	318
16	2,874	870	193	42	405	329	684	277
18	1,944	1,460	123	19	475	346	714	496
20	2,134	748	193	64	426	195	558	318
Mean	1,703		186		401		660	
			REFERENCE AREA					
C1	8,390	4,448	445	270	334	128	794	35
C2	3,616	316	319	218	205	30	184	128
C3	2,956	1,721	1,055	729	488	121	1,239	84
Mean	4,987		606		342		739	

(primarily *C. salmonis*), Chironomidae larvae (midges), and Ceratopogonidae larvae (biting midges) (Table 5). Summaries by station for all four benthic invertebrate surveys are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, Oregon 97121.

In all surveys, except in October 1996, mean densities of *Corophium* spp. in all three areas were low. Densities of *Corophium* spp. ($\log_{10}$(value + 1)) were significantly different between surveys (ANOVA, $P < 0.05$), but not between areas (Table 2). In October 1996, densities of *Corophium* spp. averaged more than 650 organisms/m^2 in each of the three areas; however, mean densities in each of the areas during the other three surveys were less than 50 organisms/m^2 (Table 5).

Sediments

Median grain size (mm) was significantly different between areas (ANOVA, $P < 0.05$), but not significantly different between surveys. In the North Transect, South Transect, and Reference Area, median grain sizes (all surveys combined) averaged 0.34, 0.35, and 0.42 mm, respectively (Table 6). Results from the ANOVA comparing $\sin^{-1}\sqrt{}$ percent silt/clay indicated a significant interaction ($P < 0.05$) between the two factors, survey and area. In the North Transect and Reference Area, $\sin^{-1}\sqrt{}$ percent silt/clay was significantly higher in January 1997 than in October 1996 and April 1997 (FPLSD, $P \leq 0.05$) (Table 6). Also, in the Reference Area, $\sin^{-1}\sqrt{}$ percent silt/clay was significantly higher in January 1997 than in July 1997. In the South Transect, $\sin^{-1}\sqrt{}$ percent silt/clay was significantly higher in October 1996 than in July 1997. The ANOVA comparing $\sin^{-1}\sqrt{}$ percent volatile solids indicated a significant

Table 5. Mean densities (number/m^2) and standard deviations (SD) of benthic invertebrates collected at sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, October 1996 through July 1997. The North Transect stations were completely within the potential impact area, and the South Transect stations were located along the southern boundary of the potential impact area or just south of the area. All Reference Area stations were located in the navigational channel. Each density represents the mean of all samples collected in that particular area (by survey). Any addition discrepancies in totals are due to rounding.

Taxon/category	October		January		April		July	
	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
NORTH TRANSECT								
Nemertea	1	2	0	0	0	0	1	5
Turbellaria	9	18	18	22	30	35	1	2
Neanthes limnicola	<1	2	0	0	0	0	0	0
Oligochaeta	10	14	1	3	1	3	3	5
Gastropoda	<1	2	0	0	0	0	0	0
Fluminicola virens	<1	2	0	0	0	0	0	0
Corbicula fluminea	129	111	30	26	56	42	233	144
Gammaridae Amphipoda	<1	2	0	0	0	0	1	3
Corophium spp.	82	190	5	10	2	4	<1	2
Corophium salmonis	1,356	1,646	28	27	18	16	22	26
Corophium spinicorne	5	13	4	10	1	4	1	2
Pontoporeia hoyi	<1	2	0	0	0	0	0	0
Harpacticoida	<1	2	0	0	0	0	0	0
Chironomidae larvae	27	27	15	28	36	97	16	39
Chironomidae pupae	<1	2	0	0	0	0	6	12
Ceratopogonidae larvae	1,056	985	189	226	297	254	393	374
Odonata nymph	<1	2	0	0	0	0	0	0
Trichoptera larvae	0	0	<1	2	<1	2	0	0
Ephemeroptera nymph	0	0	<1	2	<1	2	0	0
Plecoptera nymph	0	0	1	2	0	0	0	0
Hydracarina	1	5	0	0	0	0	<1	2
Total	2,678	2,272	291	248	442	270	677	374

Table 5. Continued.

Taxon/category	October		January		April		July	
	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
SOUTH TRANSECT								
Nemertea	2	5	0	0	0	0	1	4
Turbellaria	4	8	8	11	32	57	<1	2
Neanthes limnicola	0	0	0	0	0	0	1	2
Oligochaeta	4	6	1	3	1	3	2	6
Gastropoda	0	0	0	0	0	0	<1	2
Corbicula fluminea	147	135	46	43	72	53	279	125
Gammaridae Amphipoda	0	0	0	0	<1	2	0	0
Corophium spp.	26	44	4	8	<1	2	1	2
Corophium salmonis	663	731	22	25	22	23	17	13
Corophium spinicorne	1	4	5	10	0	0	1	3
Chironomidae larvae	36	55	3	5	9	12	8	13
Chironomidae pupae	<1	2	0	0	0	0	9	10
Ceratopogonidae larvae	819	498	98	60	265	163	341	196
Coleoptera larvae	0	0	0	0	<1	2	0	0
Collembola adult	1	3	0	0	0	0	0	0
Hydracarina	0	0	0	0	<1	2	0	0
Total	1,703	966	186	113	401	192	660	276

Table 5. Continued.

Taxon/category	October No./m²	October SD	January No./m²	January SD	April No./m²	April SD	July No./m²	July SD
				REFERENCE AREA				
Nemertea	0	0	0	0	0	0	4	12
Turbellaria	41	92	38	54	79	67	4	7
Neanthes limnicola	1	3	0	0	0	0	0	0
Oligochaeta	20	20	2	4	24	53	5	9
Gastropoda	1	3	0	0	0	0	0	0
Corbicula fluminea	311	216	36	30	22	6	151	121
Ostracoda	1	3	0	0	0	0	0	0
Corophium spp.	98	82	1	3	1	3	0	0
Corophium salmonis	1,223	778	15	14	13	10	15	15
Corophium spinicorne	4	5	8	8	0	0	0	0
Pontoporeia hoyi	1	3	0	0	0	0	0	0
Tipulidae larvae	0	0	0	0	1	3	0	0
Chironomidae larvae	18	28	15	17	9	11	1	3
Ceratopogonidae larvae	3,267	2,670	489	523	192	129	556	375
Ephemeroptera nymph	0	0	2	4	1	3	0	0
Hydracarina	1	3	0	0	0	0	2	4
Total	4,987	3,508	606	528	342	151	739	465

Table 6. Sediment characteristics at benthic sampling stations in and adjacent to a proposed channel widening area (River Mile 31-34) in the Columbia River estuary, October 1996 through July 1997. The North Transect stations were completely within the potential impact area, and the South Transect stations were located along the southern boundary of the potential impact area or just south of the area. All Reference Area stations were located in the navigational channel.

	Median grain size (mm)				Silt/clay (%)				Volatile solids (%)			
Station	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul
NORTH TRANSECT												
1	0.20	0.19	0.18	0.21	0.1	0.4	0.2	0.2	0.7	0.6	0.5	1.1
3	0.23	0.30	0.33	0.33	0.1	0.0	0.0	0.0	0.7	0.5	0.7	1.1
5	0.33	0.32	0.34	0.33	0.1	0.2	0.0	0.0	0.7	0.5	0.6	0.6
7	0.34	0.35	0.35	0.35	0.0	0.1	0.0	0.0	0.8	0.7	0.7	0.7
9	0.33	0.34	0.35	0.33	0.0	0.3	0.1	0.1	0.5	0.6	0.6	0.8
11	0.35	0.33	0.37	0.35	0.0	0.3	0.2	0.0	0.5	0.5	0.6	1.0
13	0.35	0.37	0.38	0.35	0.0	0.0	0.2	0.1	0.6	0.5	0.5	0.9
15	0.34	0.34	0.36	0.37	0.2	0.0	0.0	0.0	0.5	0.5	0.5	0.9
17	0.37	0.43	0.42	0.38	0.0	0.1	0.0	0.1	0.3	0.6	0.5	1.4
19	0.42	0.38	0.48	0.50	0.0	0.6	0.0	0.1	0.4	0.6	0.5	1.0
Mean	0.33	0.34	0.36	0.35	<0.1	0.2	0.1	0.1	0.6	0.6	0.6	1.0
SOUTH TRANSECT												
2	0.29	0.29	0.28	0.29	0.0	0.1	0.0	0.0	0.6	0.5	0.7	0.8
4	0.32	0.30	0.32	0.33	0.1	0.0	0.1	0.0	0.9	0.4	0.6	0.6
6	0.30	0.32	0.33	0.32	0.1	0.0	0.0	0.0	0.5	0.4	0.6	1.1
8	0.35	0.35	0.35	0.33	0.2	0.1	0.1	0.1	0.5	0.4	0.8	0.7
10	0.34	0.35	0.38	0.35	0.1	0.0	0.0	0.0	0.6	0.5	0.6	0.9
12	0.40	0.38	0.36	0.40	0.0	0.4	0.2	0.0	0.4	0.6	0.7	1.0
14	0.37	0.39	0.35	0.37	0.1	0.1	0.1	0.1	0.5	0.7	0.5	0.9
16	0.33	0.33	0.38	0.40	0.4	0.0	0.0	0.0	0.4	0.5	0.3	1.0
18	0.37	0.41	0.40	0.37	0.1	0.0	0.0	0.0	0.6	0.5	0.5	0.8
20	0.36	0.36	0.36	0.36	0.1	0.4	0.0	0.1	0.3	0.5	0.5	0.7
Mean	0.34	0.35	0.35	0.35	0.1	0.1	<0.1	<0.1	0.5	0.5	0.6	0.8
REFERENCE AREA												
C1	0.39	0.36	0.40	0.41	0.0	1.2	0.0	0.1	0.5	0.5	0.7	0.7
C2	0.36	0.31	0.36	0.37	0.1	0.7	0.0	0.0	0.5	0.5	0.5	1.0
C3	0.37	0.56	0.57	0.55	0.0	0.2	0.0	0.1	0.5	0.6	0.6	0.9
Mean	0.37	0.41	0.44	0.44	<0.1	0.7	0.0	0.1	0.5	0.5	0.6	0.9

difference ($P < 0.05$) between surveys, but not between areas. Mean percent volatile solids were highest in each area in July 1997 (Table 6).

DISCUSSION

Mean densities of *Corophium* spp. (primarily *C. salmonis*) in the proposed channel widening area and adjacent Reference Area were low (<50 organisms/m^2) during all surveys, except the October 1996 survey. Even in October 1996, mean densities of *Corophium* spp. were not high, ranging from 689 organisms/m^2 in the South Transect to 1,442 organisms/m^2 in the North Transect. With the exception of the October 1996 survey, mean densities of *C. salmonis* were lower than those observed in other research studies conducted in the Columbia River estuary (Table 7). For example, mean densities of *C. salmonis* in beach habitat at RM 34 (about 30 m from the high tide mark on the beach) ranged from 5,583 organisms/m^2 in July 1994 to 33,834 organisms/m^2 in January 1995.

Apparently, the river bottom in the proposed channel widening area does not provide ideal habitat for *Corophium* spp. Higher river flows in the proposed channel widening area than in other estuarine habitats may preclude the establishment of large standing crops of *Corophium* spp. River flows in the Columbia River were seasonably higher than normal during 1997. Higher water velocities could limit standing crops of benthic invertebrates, including *Corophium* spp., by periodically scouring them out of the proposed channel widening area during periods of high river flow. Periodic scouring and disruption of the bottom sediments may also not allow sufficient buildup of detritus and fine material to support high standing crops of benthic invertebrates.

Table 7. Mean densities of *Corophium salmonis* (number/m^2) at various areas in the Columbia River estuary. The locations of the areas are shown in River Miles (RM).

Year Area	Jan	Apr/May	Jul	Sep/Oct
1991[a]				
RM 21-22	------	------	8,407	31,418
1992[b]				
RM 26(deep)	------	------	1,168	8,195
RM 26(shallow)	------	------	9,134	27,801
1993[b]				
RM 26(deep)	------	9,110	1,298	10,978
RM 26(shallow)	------	18,611	6,958	20,062
1988[c]				
RM 28	------	2,420	------	2,229
1989[c]				
RM 28	------	221	------	1,792
1994-95[d]				
RM 34	33,834	18,537	5,583	6,064
1993-94[e]				
Rice Island (RM 20-22)	1,594	17,300	2,878	20,886
Harr. Sump (RM 20-21)	41	226	1,717	109
Miller Sands (RM 22-25)	95	3,018	2,112	5,057
1996-97[f]				
North Transect (RM 31-34)	28	18	22	1,356
South Transect (RM 31-34)	22	22	17	663
Reference Area (RM 32-33)	15	13	15	1,223

[a] Hinton et al. 1992; sampled in intertidal and shallow subtidal habitats north of Rice Island.
[b] Hinton et al. 1995; sampled in an erosive, deeper area and an adjacent shallow subtidal habitat.
[c] McCabe et al. 1993; sampled in channel areas away from the shoreline.
[d] McCabe and Hinton 1996; sampled about 30 m from high tide mark on beach.
[e] McCabe et al. 1996; sampled in subtidal areas adjacent to Rice Island and Miller Sands. Harrington (Harr.) Sump is a dredged-material disposal site.
[f] Present study.

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

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