Benthic invertebrates and sediment characteristics in subtidal areas adjacent to Rice Island and Miller Sands, 1993-94

Coastal Zone and Estuarine Studies Division

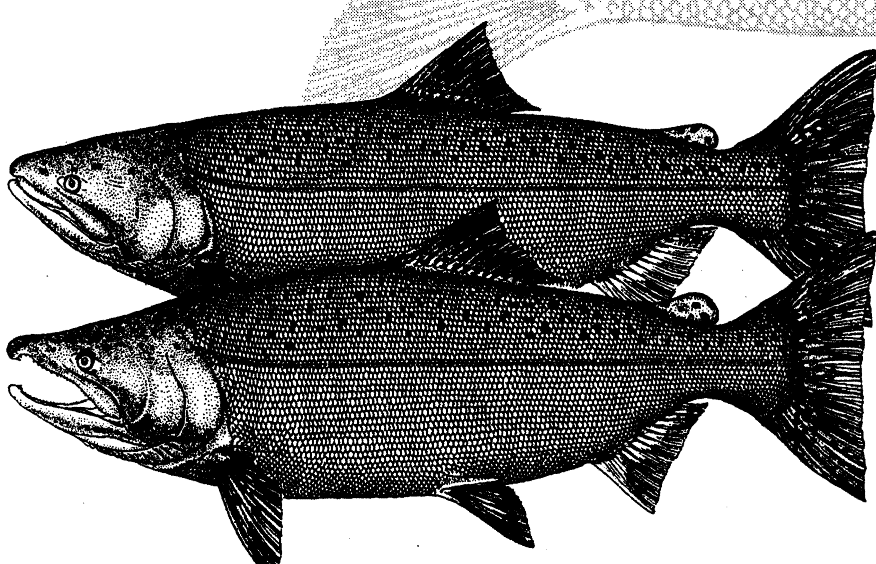
Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
George T. McCabe, Jr., Susan A. Hinton, and Robert L. Emmett

October 1996



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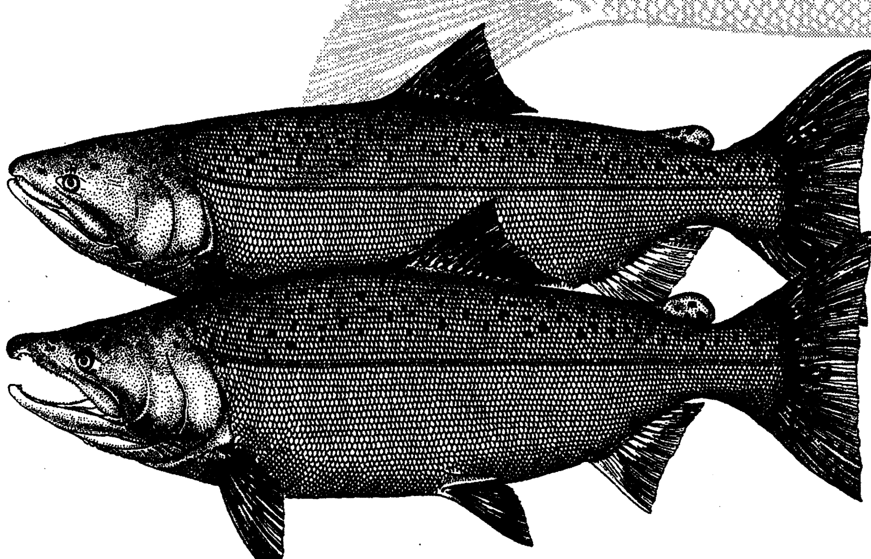

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BENTHIC INVERTEBRATES AND SEDIMENT CHARACTERI AREAS ADJACENT TO RICE ISLAND AND MILLER SA

by

George T. McCabe, Jr.,
Susan A. Hinton,
and
Robert L. Emmett

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Northwest Fisheries Science Center
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EXECUTIVE SUMMARY

In 1993, the Portland District of the U.S. Army Corps of Engineers (COE) contracted with the National Marine Fisheries Service (NMFS) to study benthic invertebrates and sediments in subtidal areas adjacent to Rice Island and Miller Sands in the Columbia River estuary. The COE is considering modification of the aquatic habitats adjacent to Rice Island and Miller Sands to provide additional area for dredged-material disposal and to reduce the volume of material dredged annually from the navigation channel. Projects under consideration are the filling of Harrington Sump (an in-water, dredged-material disposal site near Rice Island) and the construction of pile dikes along the navigation channel sides of Rice Island and Miller Sands. The goal of the NMFS research study was to collect baseline benthic invertebrate and sediment data in these areas prior to any habitat modification.

Benthic invertebrate and sediment samples were collected during 4 surveys at 22 stations near Rice Island (4 in Harrington Sump and 18 outside Harrington Sump) and 19 stations near Miller Sands. Surveys were conducted in October 1993 and January, April, and July 1994.

Benthic invertebrate densities (total) at the 18 sampling stations near Rice Island (outside Harrington Sump) were not significantly different between surveys (ANOVA, $P > 0.05$); mean densities, by survey, ranged from 4,590 invertebrates/m^2 in July 1994 to 28,094 invertebrates/m^2 in October 1993. Densities of benthic invertebrates at individual stations varied widely during each survey. Benthic invertebrate densities (total) were significantly different between surveys in Harrington Sump (ANOVA, $P < 0.05$). Mean densities of benthic invertebrates in Harrington Sump, by survey, were lower than those

outside it, ranging from 511 invertebrates/m^2 in January 1994 to 3,007 invertebrates/m^2 in July 1994.

Major benthic invertebrate taxa collected at sampling stations near Rice Island (outside Harrington Sump) included Turbellaria, Oligochaeta, the amphipod *Corophium salmonis*, and Ceratopogonidae larvae. Major benthic invertebrate taxa collected in Harrington Sump included the bivalve *Corbicula fluminea*, *Corophium salmonis*, and Ceratopogonidae larvae. At stations outside and inside Harrington Sump, densities of *Corophium* spp. were significantly different between surveys (ANOVA, $P < 0.05$). At stations outside Harrington Sump, mean densities of *Corophium* spp. ranged from 1,659 organisms/m^2 in January 1995 to 21,890 organisms/m^2 in October 1993. Inside Harrington Sump, mean densities of *Corophium* spp. were much less, ranging from 44 organisms/m^2 in January 1994 to 1,717 organisms/m^2 in July 1994.

In the area adjacent to Miller Sands, benthic invertebrate densities (total) were not significantly different between surveys (ANOVA, $P > 0.05$); mean densities, by survey, ranged from 2,008 invertebrates/m^2 in January 1994 to 6,554 invertebrates/m^2 in October 1993. Densities of benthic invertebrates at individual stations varied widely during each survey. Major benthic invertebrate taxa collected at sampling stations adjacent to Miller Sands included Oligochaeta, *Corbicula fluminea*, *Corophium salmonis*, and Ceratopogonidae larvae. Densities of *Corophium* spp. were significantly different between surveys (ANOVA, $P < 0.05$), ranging from 100 organisms/m^2 in January 1994 to 5,084 organisms/m^2 in October 1993.

Three sediment characteristics--median grain size (mm), percent silt/clay, and percent volatile solids--were described and compared for each area. Median grain size and percent silt/clay were not significantly different (Kruskal-Wallis, $P > 0.05$) between surveys in the area outside Harrington Sump, in Harrington Sump, or in the area adjacent to Miller Sands. Percent volatile solids were significantly different (Kruskal-Wallis, $P < 0.05$) between surveys in all three areas.

We concluded that the study areas near Rice Island (not including Harrington Sump) and Miller Sands support substantial standing crops of benthic invertebrates, including *Corophium salmonis*, which is an important prey for migrating juvenile salmonids and other fishes. Construction of pile dikes along Rice Island and Miller Sands and filling of Harrington Sump to create a shallow, stable subtidal habitat could increase standing crops of benthic invertebrates, including *C. salmonis*. Pile dikes should help stabilize bottom sediments in the areas immediately downstream and upstream from them, creating more favorable habitat for *C. salmonis*.

CONTENTS

INTRODUCTION

In 1993, the Portland District of the U.S. Army Corps of Engineers (COE) contracted with the National Marine Fisheries Service (NMFS) to study benthic invertebrates and sediments in subtidal areas adjacent to Rice Island and Miller Sands in the Columbia River estuary. The COE is considering modification of the aquatic habitats adjacent to Rice Island and Miller Sands to provide additional area for dredged-material disposal and to reduce the volume of material dredged annually from the navigation channel. Potential projects include filling Harrington Sump (an in-water, dredged-material disposal site near Rice Island) and constructing up to six pile dikes along the navigation channel side of Rice Island. In addition, the COE is considering the construction of up to eight pile dikes along the navigation channel side of Miller Sands. The goal of the NMFS research study was to collect baseline benthic invertebrate and sediment data in the these areas prior to any habitat modification.

METHODS

Sampling

Benthic invertebrate and sediment samples were collected at 41 stations in subtidal areas adjacent to Rice Island and Miller Sands in October 1993, January, April, and July 1994 (Fig. 1). At Rice Island, 22 sampling stations were located along 6 transects that ran roughly north to south. The length of the transect and the number of sampling stations along each transect varied depending upon the maximum potential length of the pile dike for that section of the island. Maximum lengths of pile dikes considered for Rice Island ranged from

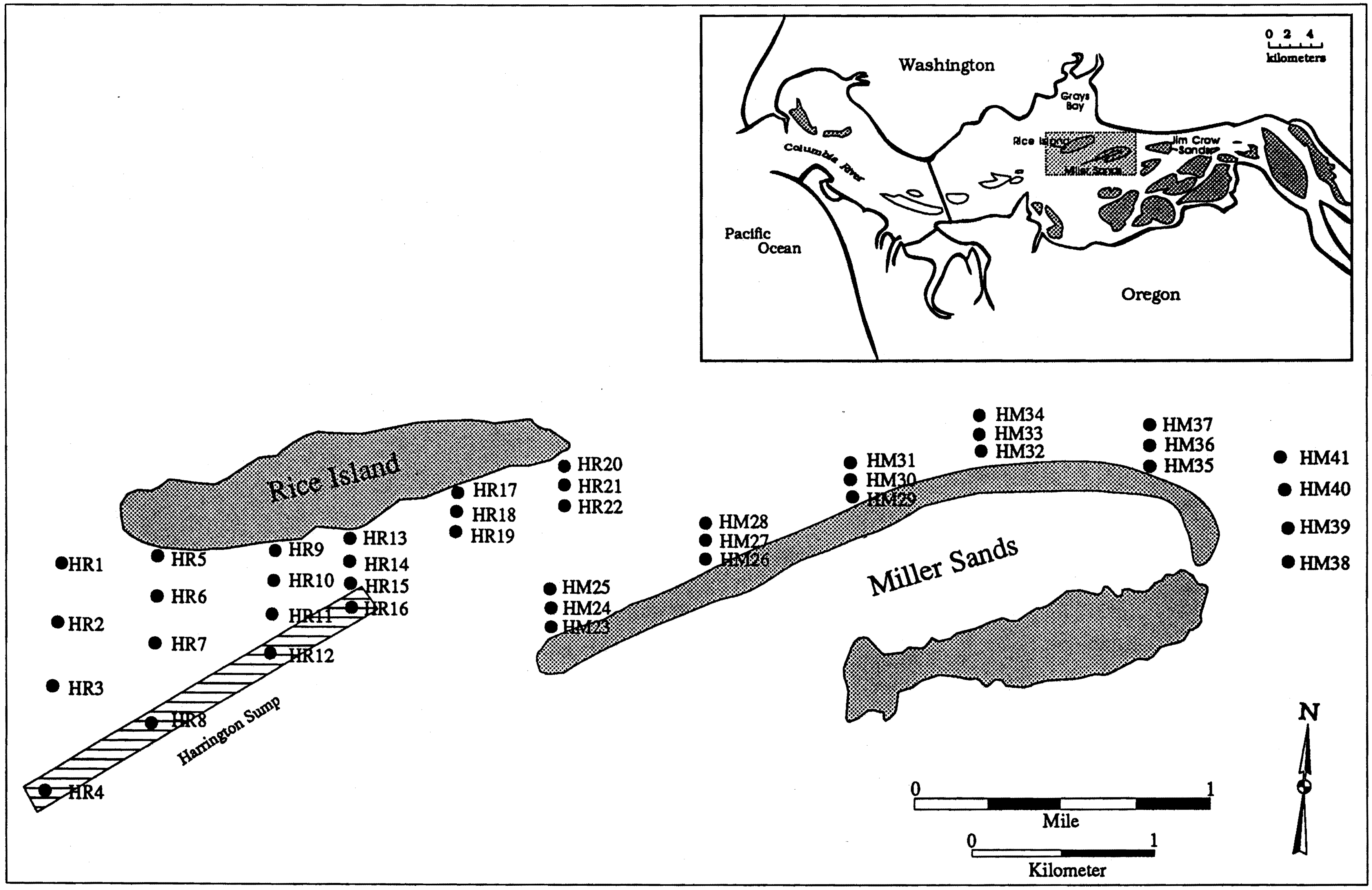

Figure 1. Locations of benthic invertebrate and sediment sampling stations adjacent to Rice Island and Miller Sands in the Columbia River estuary. Stations HR4, HR8, HR12, and HR16 were in Harrington Sump, an in-water, dredged-material disposal area.

152 m (500 ft) to 610 m (2,000 ft), with the longest pile dikes adjacent to the downstream end of the island. Four of the 22 sampling stations at Rice Island were located in the Harrington Sump (HR4, HR8, HR12, and HR16); however, most of the pile dikes being considered for Rice Island would probably not extend into Harrington Sump. At Miller Sands, 19 stations were established along 6 north-south transects. Maximum lengths of the eight pile dikes considered for Miller Sands ranged from 122 m (400 ft) to 457 m (1,500 ft). Sampling stations in both areas were located using a radar range-finder and the Global Positioning System (GPS) (Appendix Table 1).

At each of the 41 stations, a 0.1-m^2 Van Veen grab sampler was used to collect 4 samples; 3 were analyzed for benthic invertebrates and 1 for sediment type. Each benthic invertebrate sample was initially preserved in a buffered formaldehyde solution ($\geq$4%) containing rose bengal, an organic stain. Later, each benthic invertebrate sample was 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 sediment sample from each station was placed in a labeled plastic bag and refrigerated for analysis of grain size, percent silt/clay, and percent volatile solids by the COE North Pacific Division Materials Laboratory in Troutdale, Oregon.

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:

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

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.

For both Rice Island and Miller Sands, total benthic invertebrate densities, *Corophium* spp. densities, H, and E were each compared between surveys using analysis of variance (ANOVA) (Cruze and Hartzell 1991). Data for Rice Island were separated into two groups: Harrington Sump (Stations HR4, HR8, HR12, and HR16) and all other stations (18 stations). 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 basic data entries for all statistical tests.

Sediments

Median grain size, percent silt/clay, and percent volatile solids for samples from both Rice Island and Miller Sands were each compared between surveys using the nonparametric Kruskal-Wallis test (Cruze and Hartzell 1991). Data for Rice Island were separated into two groups: Harrington Sump (Stations HR4, HR8, HR12, and HR16) and all other stations (18 stations).

RESULTS

Rice Island

Benthic Invertebrates

Benthic invertebrate densities (total) at the 18 sampling stations adjacent to Rice Island (not including Harrington Sump) were not significantly different between surveys (ANOVA, $P > 0.05$); mean densities, by survey, ranged from 4,590 invertebrates/m^2 in July 1994 to 28,094 invertebrates/m^2 in October 1993 (Table 1). Densities of benthic invertebrates at individual stations varied widely during each survey. In three of the four surveys, benthic invertebrate densities were highest at Stations HR17 and HR18, which were located along the eastern end of the island (Fig. 1). Benthic invertebrate densities (total) in Harrington Sump (Stations HR4, HR8, HR12, and HR16) were significantly different between surveys (ANOVA, $P < 0.05$). In Harrington Sump, mean densities of benthic invertebrates, by survey, were lower than mean densities at stations outside Harrington Sump, ranging from 511 invertebrates/m^2 in January 1994 to 3,007 invertebrates/m^2 in July 1994 (Table 1).

Mean numbers of taxa/categories, by survey, collected at sampling stations outside Harrington Sump were similar, ranging from 10 in April and July 1994 to 13 in October 1993

Table 1. Benthic invertebrate densities (number/m^2) at 22 sampling stations adjacent to Rice Island in the Columbia River estuary, October 1993 through July 1994. Generally, each density is the mean of three replicate samples collected at a station; the standard deviation is also shown for each density.

Station	October		January		April		July	
	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
STATIONS OUTSIDE HARRINGTON SUMP								
HR1	33,500	54,319	12,218	5,437	25,763	35,344	6,845	389
HR2	69,741	98,004 [a]	549	124	1,306	889	1,224	229
HR3	1,598	961	687	281	3,413	2,251	7,247	5,829
HR5	57,359	54,452	2,582	1,376	32,583	36,248	6,100	341
HR6	708	226	2,815	2,420	2,184	324	2,331	80
HR7	25,674	31,303	935	436	3,536	864	2,671	2,786
HR9	350	109	1,503	1,193	804	367	3,205	1,096
HR10	52,845	48,734	2,502	1,875	4,158	4,416	1,911	640
HR11	896	51	730	502	2,257	423	2,757	1,598
HR13	7,507	1,066	3,266	3,710	543	128	8,608	2,082
HR14	1,190	545	687	302	1,996	1,435	3,766	489
HR15	926	80	751	334	1,678	1,068	1,862	235
HR17	103,653	48,313	35,488	54,269	191,743	80,722	9,804	4,022
HR18	138,972	10,457	24,003	7,872 [a]	131,039	90,587	4,993	1,110
HR19	1,540	230	1,233	437	2,242	194	12,264	7,782
HR20	2,913	1,069	1,742	640	1,573	211	4,888	1,541
HR21	3,818	1,010	4,640	2,005	1,837	399	896	139
HR22	2,496	1,146	1,233	134	2,389	959	1,239	722
Mean	28,094		5,420		22,836		4,590	
HARRINGTON SUMP								
HR4	718	395	702	511	1,395	672	3,153	3,994
HR8	638	157	488	300	905	340	960	463
HR12	1,227	94	215	108	500	14	4,312	4,380
HR16	715	212	638	233	2,358	364	3,603	2,333
Mean	824		511		1,290		3,007	

[a] Only two replicate samples were analyzed.

(Table 2). Major benthic invertebrate taxa collected at sampling stations outside Harrington Sump included Turbellaria, Oligochaeta, the amphipod *Corophium salmonis*, and Ceratopogonidae larvae (Table 3). In Harrington Sump, mean numbers of taxa/categories ranged from 8 in July 1994 to 12 in October 1993 (Table 2); major benthic invertebrate taxa in Harrington Sump included the bivalve *Corbicula fluminea*, *Corophium salmonis*, and Ceratopogonidae larvae (Table 4). Summaries of taxa collected by station for all surveys are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, Oregon 97121.

In the area outside Harrington Sump and in Harrington Sump, densities of *Corophium* spp. were significantly different between surveys (ANOVA, $P < 0.05$). Outside Harrington Sump, mean densities of *Corophium* spp. ranged from 1,659 organisms/m^2 in January 1995 to 21,890 organisms/m^2 in October 1993 (Table 3). There was large variation in the numbers of *Corophium* spp. collected at individual stations outside Harrington Sump, as evidenced by the large standard deviations. For example, densities of *Corophium* spp. at individual stations in October 1993 ranged from 46 to 126,338 organisms/m^2. Mean densities of *Corophium* spp. in Harrington Sump were much less than those at stations outside Harrington Sump. In Harrington Sump, mean densities of *Corophium* spp. ranged from 44 organisms/m^2 in January 1994 to 1,717 organisms/m^2 in July 1994 (Table 4).

Diversity (H) was significantly different (ANOVA, $P < 0.05$) between surveys in the area outside Harrington Sump and in Harrington Sump. Mean H values, by survey, ranged from 1.60 (April 1994) to 2.20 (January 1994) in the area outside Harrington Sump (Table 2). In Harrington Sump, mean H values ranged from 1.66 (July 1994) to 2.70 (October 1993). Equitability (E) was significantly different (ANOVA, $P < 0.05$) between surveys in the area

Table 2. Numbers of taxa/categories, Diversities (H), and Equitabilities (E) at 22 sampling stations adjacent to Rice Island in the Columbia River estuary, October 1993 through July 1994.

	October			January			April			July		
Station	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E
STATIONS OUTSIDE HARRINGTON SUMP												
HR1	10	0.50	0.15	13	2.12	0.57	8	1.29	0.43	8	1.65	0.55
HR2	13	0.44	0.12	11	2.57	0.74	10	1.73	0.52	7	1.74	0.62
HR3	13	2.46	0.66	10	2.71	0.81	9	1.17	0.37	11	1.29	0.37
HR5	13	0.76	0.20	11	2.79	0.81	12	1.11	0.31	10	1.65	0.50
HR6	12	2.78	0.78	13	2.21	0.60	8	1.64	0.55	10	2.20	0.66
HR7	14	1.01	0.27	10	2.16	0.65	9	0.93	0.29	10	2.11	0.64
HR9	11	2.79	0.81	12	2.55	0.71	8	2.07	0.69	10	1.53	0.46
HR10	15	0.95	0.24	10	2.37	0.71	9	1.05	0.33	8	1.90	0.63
HR11	13	2.24	0.61	12	2.61	0.73	9	1.18	0.37	7	1.79	0.64
HR13	11	2.06	0.60	10	2.45	0.74	8	2.46	0.82	8	1.57	0.52
HR14	12	2.78	0.78	11	2.68	0.78	10	2.11	0.63	10	1.44	0.43
HR15	12	2.36	0.66	10	1.76	0.53	9	1.88	0.59	10	2.30	0.69
HR17	16	2.02	0.51	13	1.85	0.50	16	1.14	0.29	13	1.57	0.42
HR18	14	0.94	0.25	11	2.20	0.63	16	0.90	0.22	9	1.70	0.54
HR19	13	2.68	0.73	10	2.44	0.73	11	2.63	0.76	12	1.18	0.33
HR20	13	2.24	0.60	10	2.38	0.72	11	2.07	0.60	15	2.44	0.63
HR21	10	0.70	0.21	10	0.46	0.14	9	1.41	0.44	10	1.92	0.58
HR22	11	0.76	0.22	8	1.20	0.40	9	1.96	0.62	6	1.80	0.70
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Mean	13	1.69	0.47	11	2.20	0.64	10	1.60	0.49	10	1.77	0.55
HARRINGTON SUMP												
HR4	13	2.70	0.73	11	1.96	0.57	11	1.97	0.57	8	1.55	0.52
HR8	13	2.71	0.73	10	2.43	0.73	7	2.15	0.76	8	1.93	0.64
HR12	12	2.63	0.73	8	2.29	0.76	10	2.16	0.65	8	1.15	0.38
HR16	11	2.75	0.80	9	1.57	0.50	8	2.10	0.70	8	2.01	0.67
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Mean	12	2.70	0.75	10	2.06	0.64	9	2.10	0.67	8	1.66	0.55

Table 3. Mean densities (number/m^2) and standard deviations (SD) of benthic invertebrates collected at 18 sampling stations adjacent to Rice Island, Columbia River estuary, October 1993 through July 1994. Each density represents the mean of all samples collected at the 18 sampling stations. Any addition discrepancies in totals are due to rounding.

	October		January		April		July	
Taxon	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
Nemertea	198	813	151	270	55	368	3	20
Turbellaria	730	1,961	653	2,695	1,230	3,785	4	13
Neanthes limnicola	582	938	283	557	238	458	233	414
Oligochaeta	862	2,947	1,273	2,783	1,118	2,826	287	479
Hirudinea	<1	1	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	<1	3
Fluminicola virens	0	0	<1	1	0	0	0	0
Corbicula fluminea	274	214	331	429	246	244	499	348
Ostracoda	1	7	0	0	3	11	1	3
Gammaridae Amphipoda	1	2	0	0	0	0	0	0
Hyalella azteca	0	0	1	5	0	0	0	0
Eogammarus confervicolus	23	52	3	8	0	0	1	5
Eohaustorius estuaris	142	204	110	154	48	75	29	59
Corophium spp.	750	2,836	1	5	0	0	19	79
Corophium salmonis	20,886	38,922	1,594	8,489	17,300	47,199	2,878	3,244
Corophium spinicorne	254	1,055	64	414	1,380	4,863	19	88
Pontoporeia hoyi	0	0	0	0	14	61	<1	2
Ramellogammarus oregonensis	0	0	1	3	0	0	0	0
Gnorimosphaeroma oregonensis	1	3	1	2	1	3	1	5
Saduria entomon	7	12	7	9	4	8	11	20
Harpacticoida	2,064	8,951	9	40	1	6	4	16
Chironomidae larvae	23	98	7	13	23	76	9	23
Chironomidae pupae	0	0	0	0	<1	1	35	58
Ceratopogonidae larvae	510	946	581	1,074	1,173	1,347	556	345
Empididae larvae	0	0	0	0	<1	1	0	0
Coleoptera larvae	0	0	0	0	<1	1	0	0
Odonata nymph	<1	1	<1	1	0	0	0	0
Ephemeroptera nymph	0	0	<1	1	<1	3	0	0
Collembola adult	1	4	0	0	0	0	0	0
Hydracarina	<1	1	0	0	1	5	<1	2
Total	27,308	47,494	5,070	14,064	22,836	57,247	4,590	3,912

Table 4. Mean densities (number/m^2) and standard deviations (SD) of benthic invertebrates collected at four sampling stations in Harrington Sump, Columbia River estuary, October 1993 through July 1994. Each density represents the mean of all samples collected at the four sampling stations. Any addition discrepancies in totals are due to rounding.

	October		January		April		July	
Taxon	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
Nemertea	30	31	6	7	0	0	0	0
Turbellaria	27	38	4	5	18	23	7	14
Neanthes limnicola	19	16	2	6	23	41	206	508
Oligochaeta	86	68	12	13	173	373	52	107
Corbicula fluminea	275	142	234	205	233	312	669	923
Ostracoda	0	0	0	0	1	3	0	0
Eogammarus confervicolus	20	22	5	13	0	0	2	4
Eohaustorius estuaris	172	205	13	27	75	56	35	45
Corophium spp.	2	4	2	6	0	0	0	0
Corophium salmonis	109	78	41	33	226	73	1,717	2,136
Corophium spinicorne	0	0	1	3	2	4	0	0
Pontoporeia hoyi	0	0	0	0	1	3	0	0
Paraphoxus milleri	1	3	0	0	0	0	0	0
Ramellogammarus oregonensis	0	0	17	58	0	0	0	0
Saduria entomon	26	21	17	17	4	6	21	21
Harpacticoida	25	29	0	0	0	0	0	0
Chironomidae larvae	1	3	0	0	3	6	0	0
Ceratopogonidae larvae	32	40	156	186	530	462	298	375
Collembola adult	1	3	0	0	1	3	0	0
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Total	824	320	511	338	1,290	808	3,007	3,021

outside Harrington Sump, but not significantly different (ANOVA, $P > 0.05$) between surveys in Harrington Sump. Mean E values, by survey, ranged from 0.47 (October 1993) to 0.64 (January 1994) in the area outside Harrington Sump (Table 2). In Harrington Sump, mean E values ranged from 0.55 (July 1994) to 0.75 (October 1993).

Sediments

Median grain size was not significantly different (Kruskal-Wallis, $P > 0.05$) between surveys in either the area outside Harrington Sump or in Harrington Sump. Mean median grain sizes ranged from 0.31 mm (October 1993 and January 1994) to 0.33 mm (April and July 1994) in the area outside Harrington Sump (Table 5). In Harrington Sump, mean median grain sizes ranged from 0.32 mm (January and July 1994) to 0.35 mm (October 1993 and April 1994).

Similarly, percent silt/clay was not significantly different (Kruskal-Wallis, $P > 0.05$) between surveys in either the area outside Harrington Sump or in Harrington Sump. Mean values of percent silt/clay were lower in Harrington Sump than in the area outside Harrington Sump (Table 5). In Harrington Sump, mean values ranged from 0.2% (October 1993, January 1994, and July 1994) to 0.3% (April 1994); whereas in the area outside Harrington Sump, mean values ranged from 0.5% (July 1994) to 3.2% (October 1993).

Percent volatile solids were significantly different (Kruskal-Wallis, $P < 0.05$) between surveys in both the area outside Harrington Sump and in Harrington Sump. Mean percent volatile solids ranged from 0.5% (January 1994) to 0.9% (April 1994) in the area outside Harrington Sump (Table 5). In Harrington Sump, mean percent volatile solids ranged from 0.4% (July 1994) to 0.8% (April 1994).

Table 5. Sediment characteristics at 22 sampling stations adjacent to Rice Island in the Columbia River estuary, October 1993 through July 1994. Depth (dep.) is corrected to mean lower low water and is the average depth from four surveys.

Sta.	Dep. (m)	Median grain size (mm)				Silt/clay (%)				Volatile solids (%)			
		Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul
STATIONS OUTSIDE HARRINGTON SUMP													
HR1	1.4	0.35	0.29	0.35	0.32	0.1	0.1	0.0	0.4	0.5	0.4	0.5	0.3
HR2	5.2	0.27	0.33	0.40	0.45	1.0	0.0	0.1	0.3	0.8	0.3	0.6	0.4
HR3	9.8	0.38	0.37	0.54	0.27	0.0	0.0	1.3	0.2	0.5	0.3	0.4	0.6
HR5	2.4	0.34	0.31	0.34	0.33	0.2	0.1	0.2	0.0	0.5	0.3	0.9	0.5
HR6	7.8	0.57	0.24	0.33	0.39	0.2	3.5	0.4	0.1	0.5	0.7	1.1	0.5
HR7	11.2	0.34	0.40	0.40	0.29	0.9	0.0	0.1	0.6	0.5	0.5	0.6	0.5
HR9	3.4	0.29	0.29	0.29	0.25	0.7	0.0	0.3	0.5	0.7	0.6	0.6	0.5
HR10	12.3	0.27	0.35	0.38	0.41	6.3	0.1	0.8	0.4	0.4	0.3	0.9	0.5
HR11	11.9	0.41	0.40	0.35	0.38	0.7	0.1	0.5	0.7	0.5	0.4	1.1	2.0
HR13	4.1	0.29	0.32	0.33	0.27	0.3	0.0	0.1	0.1	0.7	0.5	0.8	0.3
HR14	11.7	0.25	0.25	0.34	0.26	0.2	1.1	0.3	0.4	0.8	0.7	0.7	0.6
HR15	12.1	0.43	0.37	0.33	0.36	0.0	0.0	0.2	0.0	0.7	0.5	0.8	0.5
HR17	3.0	0.08	0.32	0.14	0.27	35.9	0.0	24.6	0.6	2.2	0.5	2.5	0.7
HR18	7.1	0.15	0.14	0.14	0.17	8.7	17.6	9.1	1.6	1.3	1.4	1.6	0.9
HR19	11.2	0.27	0.23	0.33	0.45	0.7	0.6	0.1	0.5	0.5	0.7	0.6	0.5
HR20	0.7	0.32	0.27	0.33	0.38	0.3	2.2	0.1	0.0	0.7	0.5	0.7	0.4
HR21	1.6	0.37	0.36	0.30	0.31	0.4	1.2	0.1	2.0	0.8	0.6	0.7	0.6
HR22	2.7	0.28	0.31	0.40	0.32	0.7	2.4	0.1	0.2	0.6	0.6	0.6	0.6
Mean		0.31	0.31	0.33	0.33	3.2	1.6	2.1	0.5	0.7	0.5	0.9	0.6
HARRINGTON SUMP													
HR4	11.8	0.30	0.29	0.38	0.25	0.2	0.1	0.6	0.3	0.5	0.4	0.8	0.6
HR8	13.0	0.33	0.32	0.36	0.31	0.1	0.5	0.1	0.1	0.8	0.6	0.8	0.3
HR12	13.9	0.32	0.27	0.30	0.30	0.0	0.0	0.2	0.0	0.8	0.4	0.8	0.3
HR16	12.8	0.45	0.41	0.36	0.41	0.3	0.3	0.2	0.3	0.4	0.5	0.7	0.4
Mean		0.35	0.32	0.35	0.32	0.2	0.2	0.3	0.2	0.6	0.5	0.8	0.4

Miller Sands

Benthic Invertebrates

Benthic invertebrates densities (total) at the 19 sampling stations adjacent to Miller Sands were not significantly different between surveys (ANOVA, $P > 0.05$); mean densities, by survey, ranged from 2,008 invertebrates/m^2 in January 1994 to 6,554 invertebrates/m^2 in October 1993 (Table 6). Densities of benthic invertebrates at individual stations varied widely during each survey.

Mean numbers of taxa/categories, by survey, collected at sampling stations adjacent to Miller Sands were similar, ranging from 9 in April 1994 to 11 in October 1993 (Table 7). Major benthic invertebrate taxa collected at sampling stations adjacent to Miller Sands included Oligochaeta, *Corbicula fluminea*, *Corophium salmonis*, and Ceratopogonidae larvae (Table 8). Densities of *Corophium* spp. were significantly different between surveys (ANOVA, $P < 0.05$), ranging from 100 organisms/m^2 in January 1994 to 5,084 organisms/m^2 in October 1993. There was large variation in the numbers of *Corophium* spp. collected at individual stations adjacent to Miller Sands, as evidenced by the large standard deviations (Table 8). For example, densities of *Corophium* spp. at individual stations in October 1993 ranged from 0 to 58,046 organisms/m^2.

Diversity (H) and Equitability (E) were not significantly different between surveys (ANOVA, $P > 0.05$) at sampling stations adjacent to Miller Sands. Mean H values ranged from 1.52 in April 1994 to 1.82 in October 1993, and mean E values ranged from 0.48 in April 1994 to 0.54 in October 1993 (Table 7).

Table 6. Benthic invertebrate densities (number/m^2) at 19 sampling stations adjacent to Miller Sands in the Columbia River estuary, October 1993 through July 1994. Generally, each density is the mean of three replicate samples collected at a station; the standard deviation is also shown for each density. An * indicates that no sample was collected due to dredging activities.

Station	October		January		April		July	
	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
HM23	1,987	1,414	1,561	103	2,070	821	13,303	4,941
HM24	1,147	306	1,055	316	1,359	231	2,334	628
HM25	1,006	273	712	158	2,726	1,586	908	363
HM26	218	174	472	126	788	539	770	171
HM27	1,521	258	853	310	2,665	399	905	355
HM28	1,303	558	199	77	1,083	699	399	246
HM29	33,605	11,872	5,713	979	850	398	15,122	5,328
HM30	1,322	742	972	704	1,653	182	2,539	927
HM31	1,291	269	316	47	1,319	585	994	221
HM32	4,260	639	199	170	70,546	53,379	702	676
HM33	1,141	538	635	384	681	496	423	42
HM34	1,024	702	1,009	51	1,441	123	1,297	568
HM35	1,398	973	601	192	727	304	*	*
HM36	2,184	197	3,634	3,084	2,683	282	*	*
HM37	1,733	162	3,432	3,789	4,091	1,487	*	*
HM38	62,600	5,746	6,869	1,650	5,048	209	6,146	724
HM39	3,186	542	4,033	3,738	997	83	1,306	888
HM40	2,358	2,001	497	152	997	359	1,622	1,056
HM41	1,251	250	5,387	501[a]	500	350	2,257	1,248
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Mean	6,554		2,008		5,380		3,189	

[a] Only two replicate samples were analyzed.

Table 7. Numbers of taxa/categories, Diversities (H), and Equitabilities (E) at 19 sampling stations adjacent to Miller Sands in the Columbia River estuary, October 1993 through July 1994. An * indicates that no sample was collected due to dredging activities.

	October			January			April			July		
Station	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E	No. taxa	H	E
HM23	8	1.34	0.45	9	1.33	0.42	7	0.98	0.35	12	0.86	0.24
HM24	12	2.26	0.63	9	1.16	0.36	11	1.70	0.49	10	1.75	0.53
HM25	11	2.24	0.65	11	1.96	0.57	11	1.03	0.30	8	2.20	0.73
HM26	8	2.18	0.73	10	2.00	0.60	4	1.31	0.65	9	1.96	0.62
HM27	12	2.50	0.70	11	1.97	0.57	11	1.65	0.48	8	1.56	0.52
HM28	11	2.18	0.63	8	2.46	0.82	8	1.69	0.56	10	1.97	0.59
HM29	15	0.65	0.17	9	1.60	0.50	9	1.66	0.52	7	1.20	0.43
HM30	11	2.50	0.72	12	2.23	0.62	10	1.66	0.50	10	1.55	0.47
HM31	13	2.03	0.55	12	2.15	0.60	11	1.83	0.53	12	1.95	0.54
HM32	11	1.60	0.46	9	2.33	0.74	18	1.39	0.33	8	1.03	0.34
HM33	11	2.18	0.63	11	2.28	0.66	10	1.74	0.52	8	2.18	0.73
HM34	10	2.06	0.62	7	1.34	0.48	8	0.87	0.29	10	1.96	0.59
HM35	6	1.74	0.67	9	1.99	0.63	8	1.91	0.64	*	*	*
HM36	9	1.35	0.43	8	0.68	0.23	7	0.82	0.29	*	*	*
HM37	11	1.69	0.49	11	0.94	0.27	8	0.36	0.12	*	*	*
HM38	11	0.55	0.16	12	1.85	0.52	11	2.53	0.73	16	1.73	0.43
HM39	11	1.54	0.45	10	1.12	0.34	10	1.93	0.58	8	1.46	0.49
HM40	12	1.52	0.42	7	2.00	0.71	8	1.75	0.58	10	1.70	0.51
HM41	13	2.43	0.66	10	0.89	0.27	8	2.04	0.68	9	1.43	0.45
Mean	11	1.82	0.54	10	1.70	0.52	9	1.52	0.48	10	1.66	0.51

Table 8. Mean densities (number/m^2) and standard deviations (SD) of benthic invertebrates collected at 19 sampling stations adjacent to Miller Sands, Columbia River estuary, October 1993 through July 1994. Each density represents the mean of all samples collected at the 19 sampling stations. Any addition discrepancies in totals are due to rounding.

	October		January		April		July	
Taxon	No./m^2	SD	No./m^2	SD	No./m^2	SD	No./m^2	SD
Nemertea	49	122	46	90	3	16	1	7
Nematomorpha	<1	1	0	0	0	0	0	0
Turbellaria	30	72	54	106	398	1,743	6	16
Neanthes limnicola	36	84	17	44	14	48	24	37
Oligochaeta	239	727	235	720	600	2,276	154	368
Hirudinea	0	0	0	0	<1	1	0	0
Gastropoda	1	3	0	0	0	0	3	8
Juga plicifera	0	0	0	0	0	0	<1	1
Fluminicola virens	0	0	1	4	1	4	1	5
Corbicula fluminea	441	353	301	895	255	461	343	302
Ostracoda	0	0	<1	1	1	5	2	7
Hemileucon comes	0	0	0	0	<1	1	0	0
Hyalella azteca	0	0	0	0	<1	1	0	0
Eogammarus confervicolus	2	5	<1	1	0	0	0	0
Eohaustorius estuaris	166	256	69	212	9	17	5	9
Corophium spp.	22	116	1	3	0	0	3	20
Corophium salmonis	5,057	14,466	95	139	3,018	13,797	2,112	4,009
Corophium spinicorne	5	29	4	7	91	454	1	6
Ramellogammarus oregonensis	0	0	<1	1	0	0	0	0
Pontoporeia hoyi	0	0	0	0	4	13	5	15
Porcellio scaber	<1	1	0	0	0	0	<1	1
Gnorimosphaeroma oregonensis	<1	2	<1	1	<1	1	0	0
Saduria entomon	10	14	6	9	2	5	7	19
Harpacticoida	11	20	0	0	0	0	1	3
Tipulidae larvae	0	0	0	0	<1	1	<1	1
Chironomidae larvae	17	34	20	42	44	131	31	97
Chironomidae pupae	<1	1	0	0	<1	2	17	28
Ceratopogonidae larvae	467	546	1,099	1,790	939	1,049	472	370
Trichoptera larvae	0	0	0	0	<1	1	0	0
Coleoptera larvae	<1	1	0	0	<1	2	<1	1
Ephemeroptera nymph	<1	1	0	0	0	0	0	0
Collembola adult	1	2	0	0	0	0	<1	2
Hydracarina	<1	2	0	0	1	3	1	3
	------	------	------	------	------	------	------	------
Total	6,554	15,380	1,947	2,407	5,380	18,536	3,189	4,708

Sediments

Median grain size and percent silt/clay were not significantly different (Kruskal-Wallis, $P > 0.05$) between surveys at sampling stations adjacent to Miller Sands. Mean median grain sizes ranged from 0.30 mm in January and July 1994 to 0.34 mm in October 1993 and April 1994 (Table 9). Mean percent silt/clay values ranged from 0.3% in January 1994 to 1.7% in July 1994. Percent volatile solids were significantly different (Kruskal-Wallis, $P < 0.05$) between surveys, with mean values ranging from 0.5% in January and April 1994 to 0.7% in October 1993 and July 1994.

DISCUSSION

Benthic invertebrates in the Columbia River and its estuary are important prey for fishes. For example, the tube-dwelling amphipod *Corophium salmonis* is an important food for migrating juvenile salmonids (*Oncorhynchus* spp.), peamouth (*Mylocheilus caurinus*), threespine stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*), Pacific staghorn sculpin (*Leptocottus armatus*), starry flounder (*Platichthys stellatus*), and white sturgeon (*Acipenser transmontanus*) (Haertel and Osterberg 1967; McCabe et al. 1983, 1986, 1993a; Muir et al. 1988). *Corophium salmonis* and *C. spinicorne* were the dominant prey for juvenile salmonids collected during spring 1984 at Bonneville Dam, the lowermost dam on the Columbia River (Muir and Emmett 1988). *Corophium* spp. sometimes are the major prey of recreational legal-size white sturgeon (≥1,067 mm total length) caught in the estuary (personal observations by authors).

The sampling area adjacent to Rice Island, not including Harrington Sump, had substantial standing crops of *C. salmonis* (Table 10). Densities of *C. salmonis* in the

Table 9. Sediment characteristics at 19 sampling stations adjacent to Miller Sands in the Columbia River estuary, October 1993 through July 1994. Depth (dep.) is corrected to mean lower low water and is the average depth from four surveys, except for Stations HM35, HM36, and HM37. An * indicates that no sample was collected due to dredging activities.

		Median grain size (mm)				Silt/clay (%)				Volatile solids (%)			
Sta.	Dep. (m)	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul
HM23	1.1	0.23	0.29	0.34	0.32	0.3	0.9	0.5	0.6	0.8	0.4	0.4	0.5
HM24	9.5	0.33	0.33	0.33	0.33	0.4	0.0	1.0	0.1	0.8	0.6	0.4	0.6
HM25	10.4	0.37	0.32	0.37	0.35	0.4	1.1	1.4	0.1	0.7	0.4	0.3	0.5
HM26	1.5	0.67	0.35	0.38	0.34	0.4	0.6	1.5	0.1	0.7	0.4	0.4	0.5
HM27	10.8	0.38	0.34	0.44	0.36	0.1	0.4	0.2	0.5	0.5	0.5	0.3	0.5
HM28	13.3	0.39	0.35	0.47	0.24	0.1	0.8	0.2	0.7	0.7	0.5	0.4	0.7
HM29	2.5	0.31	0.30	0.27	0.33	0.3	0.3	0.5	1.6	0.7	0.4	0.4	1.1
HM30	9.6	0.23	0.20	0.25	0.23	0.3	0.1	0.2	0.6	0.8	0.6	0.5	0.7
HM31	13.5	0.20	0.25	0.28	0.22	0.1	0.0	0.0	1.9	0.8	0.7	0.4	0.7
HM32	1.1	0.23	0.27	0.35	0.25	0.1	0.2	0.7	0.0	0.8	0.6	0.4	0.8
HM33	4.8	0.30	0.20	0.32	0.28	0.3	0.1	0.1	0.4	0.5	0.4	0.4	0.7
HM34	12.2	0.32	0.36	0.37	0.32	0.4	0.1	0.3	0.7	0.7	0.5	0.5	0.6
HM35	1.9	0.37	0.38	0.34	*	0.3	0.1	0.1	*	0.6	0.6	0.7	*
HM36	7.2	0.50	0.42	0.44	*	0.2	0.1	0.1	*	0.7	0.6	0.6	*
HM37	11.0	0.46	0.27	0.44	*	0.4	0.2	0.0	*	0.5	0.0	0.5	*
HM38	2.0	0.19	0.19	0.22	0.14	5.3	0.9	0.3	19.4	1.0	0.7	0.9	1.5
HM39	8.6	0.41	0.34	0.38	0.44	0.4	0.3	0.1	0.4	0.7	0.6	0.5	0.5
HM40	7.8	0.20	0.22	0.19	0.23	0.4	0.2	0.1	0.3	0.6	0.4	0.8	0.6
HM41	7.7	0.28	0.33	0.32	0.36	0.7	0.1	0.1	0.3	0.3	0.2	0.6	0.6
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Mean		0.34	0.30	0.34	0.30	0.6	0.3	0.4	1.7	0.7	0.5	0.5	0.7

Table 10. 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 Kilometers (RKm).

Year Area	Jan	Apr/May	Jul	Sep/Oct
1991[a]				
RKm 34-36	------	------	8,407	31,418
1992[b]				
RKm 40-42(deep)	------	------	1,168	8,195
RKm 40-42(shallow)	------	------	9,134	27,801
1993[b]				
RKm 40-42(deep)	------	9,110	1,298	10,978
RKm 40-42(shallow)	------	18,611	6,958	20,062
1988[c]				
RKm 46	------	2,420	------	2,229
1989[c]				
RKm 46	------	221	------	1,792
1994-95[d]				
RKm 55	33,834	18,537	5,583	6,064
1993-94[e]				
Rice Island (18 stations)	1,594	17,300	2,878	20,886
Harrington Sump	41	226	1,717	109
Miller Sands	95	3,018	2,112	5,057

[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. 1993b; sampled in channel areas away from the shoreline.
[d] McCabe and Hinton 1996; sampled about 30 m from high tide mark on beach.
[e] The present study.

sampling area were frequently comparable to or higher than those observed in recent studies conducted in various habitats of the Columbia River estuary. It should be noted that the values presented in Table 10 are mean values, by survey. A detailed examination of individual station densities at the sampling area adjacent to Rice Island indicated a patchy distribution of *C. salmonis* in this area. For example, densities at Station HR17 often exceeded 20,000 organisms/m^2; whereas at other stations, densities were frequently less than 1,000 organisms/m^2. In general, standing crops of *Corophium salmonis* in Harrington Sump were low compared to those observed in recent studies conducted in various habitats of the Columbia River estuary (Table 10). Benthic invertebrate densities at Station HR 4 in Harrington Sump could have been impacted by dredging conducted in early July 1994.

Standing crops of *C. salmonis* at sampling stations adjacent to Miller Sands were generally lower than those in the sampling area adjacent to Rice Island. Mean densities of *C. salmonis* in the area adjacent to Miller Sands were often lower than those observed in recent studies conducted in various habitats of the Columbia River estuary (Table 10). Individual station densities at the sampling area adjacent to Miller Sands indicated a patchy distribution of *C. salmonis* in this area. Benthic invertebrate densities at Station HM32 could have been impacted by disposal of dredged material along the beach in June 1994.

The study areas adjacent to Rice Island and Miller Sands support substantial standing crops of benthic invertebrates. Construction of pile dikes along Rice Island and Miller Sands could increase standing crops of benthic invertebrates, including *C. salmonis*. The pile dikes would help stabilize bottom sediments immediately downstream and upstream, creating more favorable habitat for *C. salmonis*, which is a tube-building amphipod. Filling of Harrington Sump to create a shallow, stable subtidal habitat could also benefit benthic invertebrates, including *C. salmonis*. Benthic invertebrates in channel areas beyond the ends of the pile dikes could be adversely impacted by higher water velocities resulting from pile dike construction. However, results from our study indicate that densities of *C. salmonis* in the areas beyond the ends of the potential pile dikes (maximum lengths) at Miller Sands were generally low, with mean station densities usually less than 300 organisms/m^2. Similar results were observed in the areas beyond the ends of the potential pile dikes (maximum lengths) at Rice Island in three of the four surveys; densities in July 1994 were higher than those in the three preceding surveys. Prior to any habitat modification at Rice Island, Harrington Sump, or Miller Sands, hydraulic modeling studies should be completed to determine if any adverse changes in water circulation in the Columbia River estuary would result from any proposed action.

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

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REFERENCES

Cruze, E., and B. Hartzell. 1991. Minitab reference manual, PC version, release 8. Quickset Inc., Rosemont, PA.

Haertel, L., and C. Osterberg. 1967. Ecology of zooplankton, benthos and fishes in the Columbia River estuary. Ecology 48(3):459-472.

Hinton, S. A., R. L. Emmett, and G. T. McCabe, Jr. 1992. Fishes, shrimp, benthic invertebrates, and sediment characteristics in intertidal and subtidal habitats at Rice Island and Miller Sands, Columbia River estuary, 1991. Report to U.S. Army Corps of Engineers, Contract E96910025, 53 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112.)

Hinton, S. A., G. T. McCabe, Jr., and R. L. Emmett. 1995. In-water restoration between Miller Sands and Pillar Rock Island, Columbia River: Environmental surveys, 1992-93. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-23, 47 p.

Krebs, C. J. 1978. Ecology: the experimental analysis of distribution and abundance. Harper and Row. New York, 678 p.

McCabe, G. T., Jr., R. L. Emmett, and S. A. Hinton. 1993a. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Sci. 67(3):170-180.

McCabe, G. T., Jr., R. L. Emmett, W. D. Muir, and T. H. Blahm. 1986. Utilization of the Columbia River estuary by subyearling chinook salmon. Northwest Sci. 60(2):113-124.

McCabe, G. T., Jr., and S. A. Hinton. 1996. Benthic invertebrates and sediment characteristics in freshwater, beach habitats of the lower Columbia River, 1994-95. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-26, 111 p.

McCabe, G. T., Jr., S. A. Hinton, and R. L. Emmett. 1993b. Report P. Distribution, abundance, and community structure of benthic invertebrates in the lower Columbia River. *In* R. C. Beamesderfer and A. A. Nigro (editors), Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam, p. 265-284. Report to Bonneville Power Administration, Contract DE-AI79-86BP63584, 421 p. (Available from Bonneville Power Administration, Division of Fish and Wildlife-PJ, P.O. Box 3621, Portland, OR 97208.)

McCabe, G. T., Jr., W. D. Muir, R. L. Emmett, and J. T. Durkin. 1983. Interrelationships between juvenile salmonids and nonsalmonid fish in the Columbia River estuary. Fish. Bull., U.S. 81(4):815-826.

Muir, W. D., and R. L. Emmett. 1988. Food habits of migrating salmonid smolts passing Bonneville Dam in the Columbia River, 1984. Regul. Rivers: Res. and Manage. 2:1-10.

Muir, W. D., R. L. Emmett, and R. J. McConnell. 1988. Diet of juvenile and subadult white sturgeon in the lower Columbia River and its estuary. Calif. Fish and Game 74(1):49-54.

APPENDIX

Appendix Table 1. Locations of sampling stations adjacent to Rice Island and Miller Sands in the Columbia River estuary, October 1993 through July 1994. Stations HR4, HR8, HR12, and HR16 were located in Harrington Sump, an in-water, dredged-material disposal site.

Area	Station	Latitude	Longitude
Rice Island	HR1	46°14.722'N	123°43.405'W
	HR2	46°14.549'N	123°43.405'W
	HR3	46°14.362'N	123°43.405'W
	HR4	46°14.058'N	123°43.405'W
	HR5	46°14.773'N	123°43.032'W
	HR6	46°14.673'N	123°42.970'W
	HR7	46°14.516'N	123°42.970'W
	HR8	46°14.280'N	123°42.970'W
	HR9	46°14.846'N	123°42.500'W
	HR10	46°14.732'N	123°42.500'W
	HR11	46°14.632'N	123°42.500'W
	HR12	46°14.525'N	123°42.500'W
	HR13	46°14.903'N	123°42.180'W
	HR14	46°14.852'N	123°42.190'W
	HR15	46°14.770'N	123°42.190'W
	HR16	46°14.687'N	123°42.190'W
	HR17	46°15.037'N	123°41.716'W
	HR18	46°15.005'N	123°41.725'W
	HR19	46°14.924'N	123°41.708'W
	HR20	46°15.125'N	123°41.313'W
	HR21	46°15.144'N	123°41.259'W
	HR22	46°15.073'N	123°41.237'W
Miller Sands	HM23	46°14.704'N	123°41.067'W
	HM24	46°14.768'N	123°41.070'W
	HM25	46°14.791'N	123°41.052'W
	HM26	46°14.936'N	123°40.538'W
	HM27	46°14.957'N	123°40.595'W
	HM28	46°15.003'N	123°40.610'W
	HM29	46°15.144'N	123°39.998'W
	HM30	46°15.160'N	123°40.013'W
	HM31	46°15.214'N	123°40.011'W
	HM32	46°15.281'N	123°39.471'W
	HM33	46°15.354'N	123°39.484'W
	HM34	46°15.383'N	123°39.473'W
	HM35	46°15.278'N	123°38.770'W
	HM36	46°15.360'N	123°38.816'W
	HM37	46°15.404'N	123°38.798'W
	HM38	46°15.105'N	123°38.087'W
	HM39	46°15.155'N	123°38.102'W
	HM40	46°15.243'N	123°38.149'W
	HM41	46°15.329'N	123°38.196'W