Fishes, Shrimp, Benthic Invertebrates, and Sediment Characteristics in Intertidal and Subtidal Habitats at Rice Island and Miller Sands, Columbia River Estuary, 1991

by
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COASTAL ZONE AND ESTUARINE STUDIES

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Final Report

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INTRODUCTION

The U.S. Army Corps of Engineers (COE), Portland District is responsible for annually dredging and disposing of more than 1.5 million m^3 (2 million yd^3) of bottom sediments from the navigation channel between River Miles (RM) 4.4 and 28.8 in the Columbia River estuary. Existing island and shoreline dredged-material disposal sites are nearly filled to capacity, and options for new disposal sites for such volumes of sediment are extremely limited. One potential disposal site is the area just north of Rice Island, an island created with dredged material. Proposals for expanding Rice Island with dredged material include creating a 3,048-m (10,000-ft) long by 152-m (500-ft) to 305-m (1,000-ft) wide spit to the north of the present island. The south side of the proposed spit would be about 305-m from the island, creating an island-spit configuration similar to that at Miller Sands, which is slightly upstream from Rice Island.

Major concerns associated with new dredged-material disposal sites, especially when creating islands, are the effects of such activities on aquatic biological communities. Therefore, in 1991, the COE contracted the National Marine Fisheries Service (NMFS) to assess the aquatic biological communities just north of Rice Island. The NMFS was also asked to continue monitoring the biological communities at Miller Sands, an island-spit complex created with dredged material, to add to the long-term data base for this area. Biological sampling was conducted at Miller Sands in 1975-1977 (McConnell et al. 1978) and in 1988-1989 (Hinton et al. 1990).

METHODS

Study Areas

Benthic invertebrate and sediment samples, fishes, and shrimp were collected at two areas in the Columbia River estuary, Rice Island and Miller Sands, in July and September 1991. Also, a limited amount of fish sampling was conducted at Rice Island in August 1991. Station locations (latitude and longitude) were established using the Global Positioning System, which also allowed all stations to be easily reoccupied (Appendix Table 1).

Rice Island

Rice Island, which is located between RM 21.0 and 22.6, is a 101-ha (250-acre) man-made island that has been used for dredged-material disposal for at least the last 27 years (U.S. Army Corps of Engineers 1989). The intertidal and shallow subtidal areas adjacent to the island are freshwater environments throughout the year (Fox et al. 1984). In the present study, all sampling was conducted in the subtidal and intertidal areas north of the island. Benthic invertebrate and sediment samples were collected at 5 shoreline intertidal stations and 20 subtidal or intertidal sites; fishes and shrimp were collected by beach seine at 5 intertidal sites and by purse seine at 8 subtidal sites (Fig. 1). In August, beach seining was conducted at Stations BS2, BS3, and BS5, and purse seining at Stations PS2, PS4, PS6, and PS8 to monitor juvenile salmonid abundance.

Miller Sands

Located between Rm 21.4 and 25.2, Miller Sands is a 130-ha (320-acre) island and spit complex that was constructed with sediments dredged from the navigation channel. Main island construction was initiated and completed in

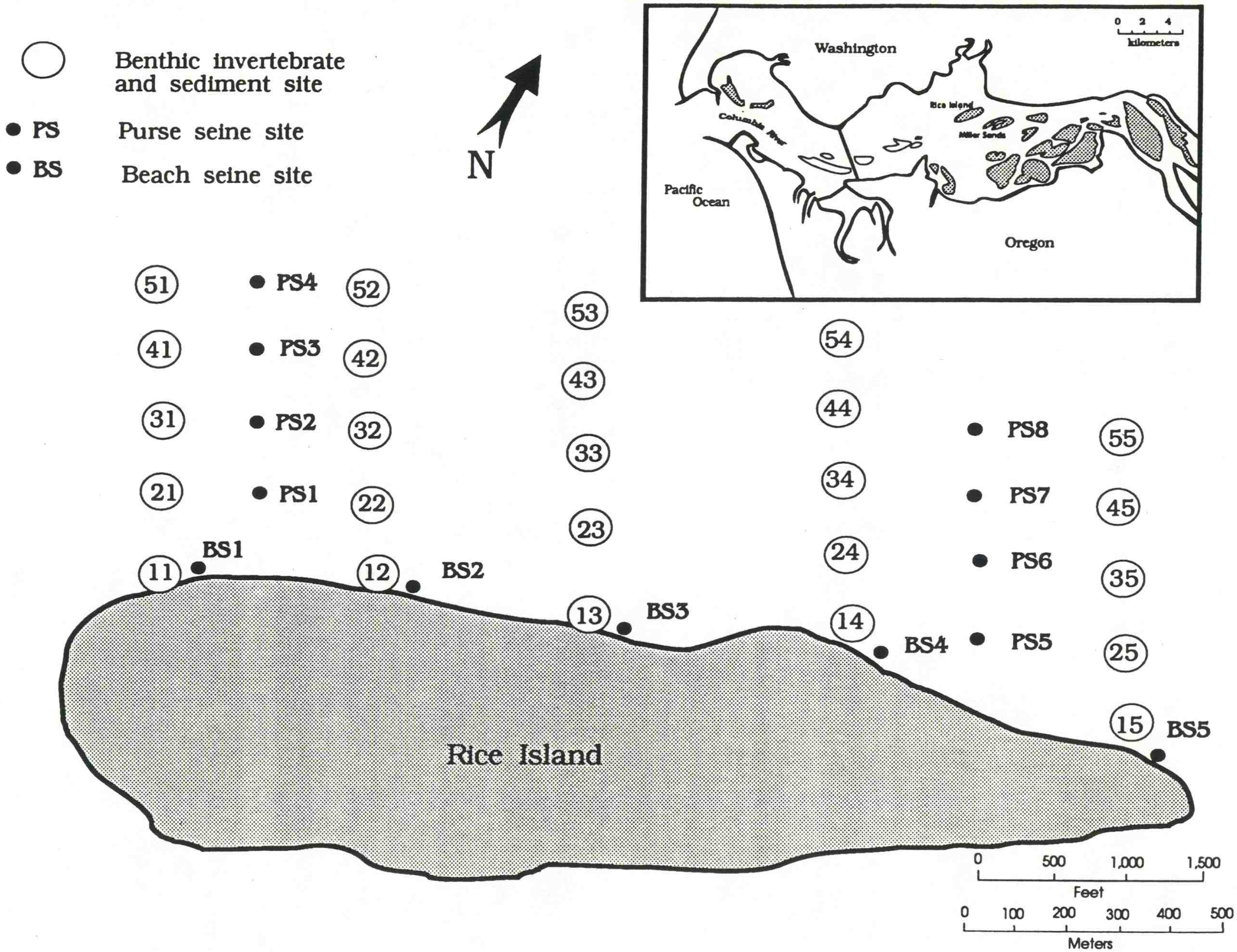

Figure 1.--Sampling locations for benthic invertebrates, sediments, fishes, and shrimp at Rice Island, Columbia River estuary, 1991.

the 1930s. In 1975-1976, the COE added a 36-ha (90-acre), nearly 4.8-km (3-mile) long spit, creating a horseshoe-shaped complex with a protected shallow-water interior. Miller Sands receives approximately 305,800 m^3 (400,000 yd^3) of dredged material annually. The intertidal and shallow subtidal areas along the island are freshwater environments, except during periods of low river flow (Fox et al. 1984). In shallow subtidal areas during low river flows, which typically occur in the late summer and early fall, salinities range from <0.5 to 5 ppt at maximum salinity intrusion. In the present study, benthic invertebrate and sediment samples were collected at nine intertidal sites, and fishes and shrimp were collected by beach seine at eight intertidal sites (Fig. 2).

Sampling

Benthic Invertebrates and Sediments

Eleven core samples were taken at each station with a polyvinyl chloride (PVC) coring device with an inside diameter of 3.85 cm, a penetrating depth of 15 cm, and which collected a 174.6-cm^3 sample (Fig. 3). Samples were collected by hand at intertidal stations and by scuba divers at subtidal stations. Ten core samples were placed in labeled jars and preserved in a buffered formaldehyde solution ($\geq$4%) containing rose bengal, a protein stain. In the laboratory, samples were washed with water through a 0.5-mm screen. All invertebrates were sorted from the preserved sample, identified to the lowest practical taxonomic level (usually species), and counted. The specimens were then stored in labeled vials containing 70% ethyl alcohol. The eleventh core sample was saved in a labeled plastic bag and refrigerated for sediment analysis. The COE North Pacific Division Materials Laboratory, Troutdale, Oregon, analyzed the sediment samples for grain size and total volatile solids.

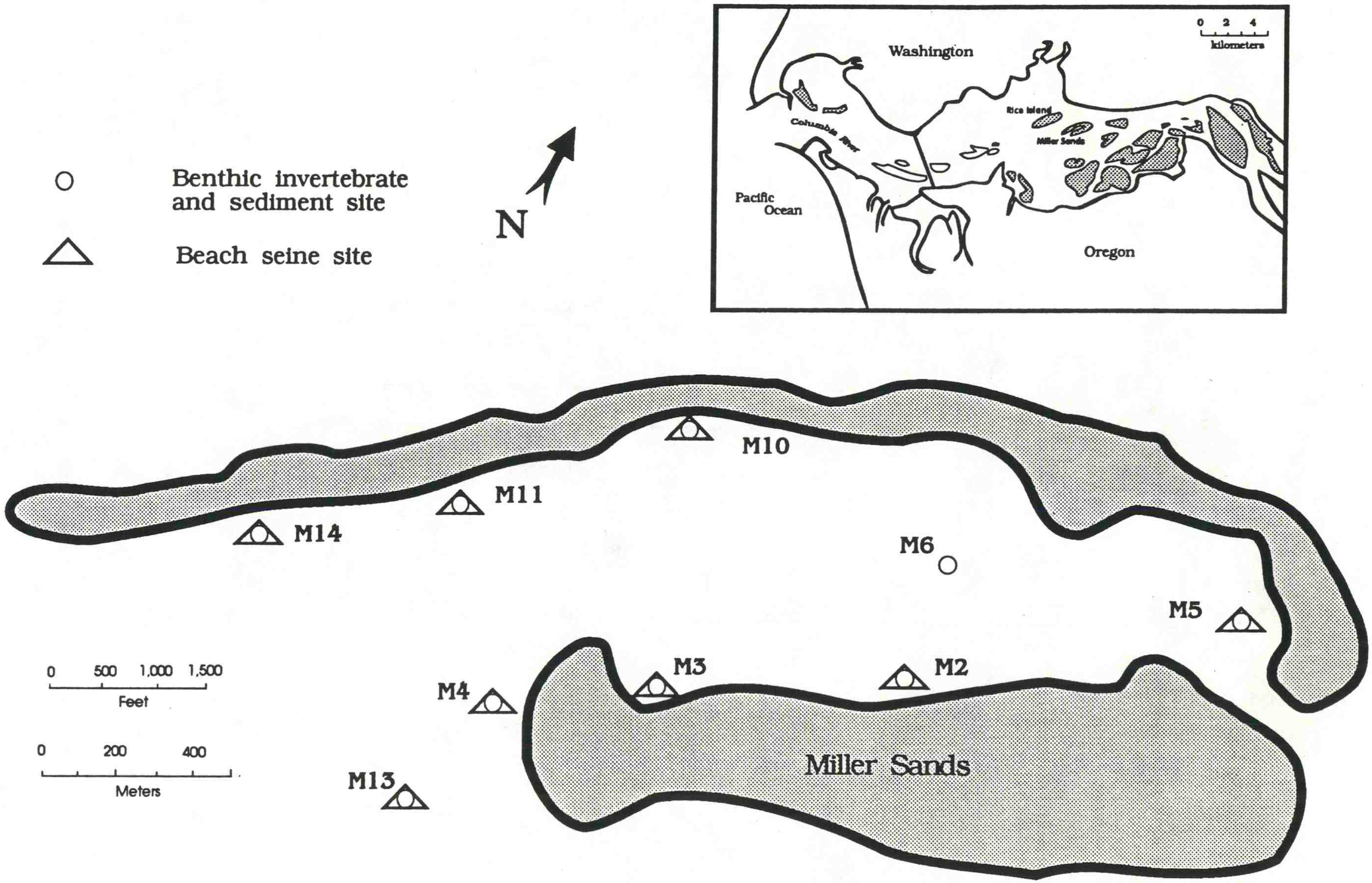

Figure 2.--Sampling locations for benthic invertebrates, sediments, fishes, and shrimp at Miller Sands, Columbia River estuary, 1991.

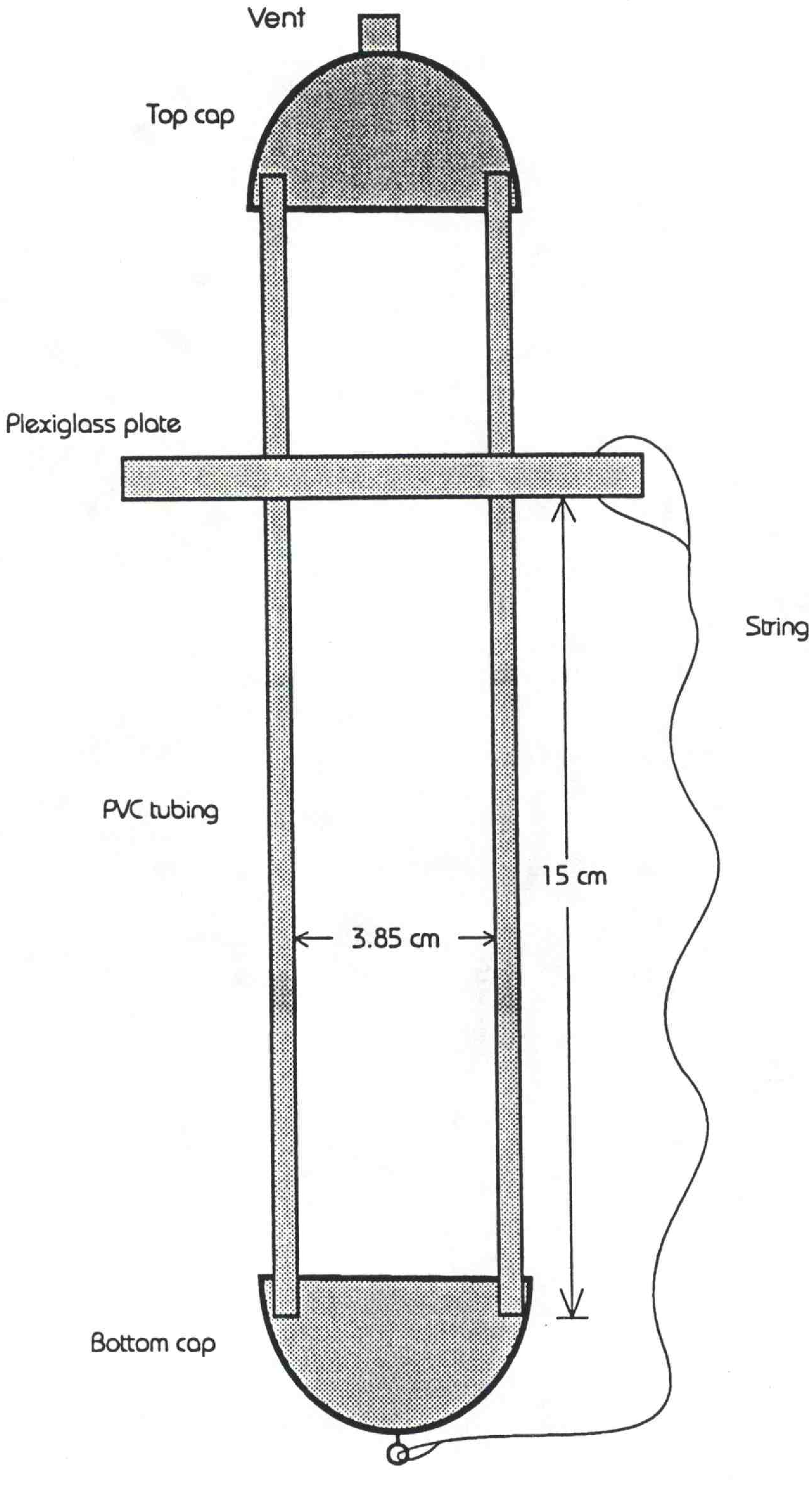

Figure 3.--PVC coring device used to collect benthic invertebrate and sediment samples in the Columbia River estuary, 1991.

Fishes and Shrimp

At intertidal sites of Rice Island and Miller Sands, fishes and shrimp were collected with a 50-m variable mesh (19.0, 12.7, and 9.5 mm) beach seine; all mesh sizes are stretched measurements. Knotless web was used in the beach seine bunt to reduce descaling of fish. Typically, one end of the seine was anchored in the dry sand, and the net was extended in a downstream direction along the waterline. Then, using a 5-m boat, the free end of the net was pulled off the beach in a wide arc and completed a semicircle upon returning to the beach at an upstream point. Seining was usually done on a flood tide.

At the subtidal sites of Rice Island, a shallow-water purse seine (100 x 4.6 m) was used to sample for fishes and shrimp. The seine was constructed of knotless nylon mesh, 17 mm (11/16 in) in the body and 13 mm (1/2-in) in the bunt. A round-haul technique was used to deploy the net. Typically, the net, which was stacked on the stern of an 8-m boat, was pulled off by a 5-m boat. During deployment, both boats traveled in a wide arc in opposite directions (beginning upstream), completing a full circle by the time the net was fully extended (downstream). The net was then closed and pulled aboard the 8-m boat; fishes were hand-forced into the bunt where they could be collected before bringing the bunt aboard. Purse seining was done on the flood tide.

At the collection sites, fishes were identified, counted, and a maximum of 50 individuals of each species was measured (total length in mm) and weighed (g). When more than 50 individuals of a species were collected at a site, the excess was counted.

In August, eight juvenile chinook salmon, Oncorhynchus tshawytscha, that were collected with the purse seine at Rice Island, were sacrificed to determine what they were eating.

Data Analyses

Benthic Invertebrates

Past benthic invertebrate research showed that ten core replicates would adequately describe the benthic invertebrate community at each station. This was verified by plotting the number of taxa collected, the mean total benthic invertebrate density and standard deviation, and diversity (H) using 1 to 10 replicates at Station R25 at Rice Island. For example, the number of taxa at a selected station was calculated and plotted using data from one replicate, then using two replicates, and so forth until data from all ten replicates were used.

The ten benthic invertebrate samples from each station were treated as replicates, allowing calculation of a mean number/m^2 and standard deviation for each species, and total mean number/m^2 and standard deviation for each station. Within each area, both total mean number of invertebrates/m^2 and total mean number of Corophium salmonis/m^2 were compared between surveys using a paired t-test (Ryan et al. 1985). All data were transformed to $\log_{10}$ of (density + 1) prior to the t-tests; 1 was added to the number because of some 0 values (Sokal and Rohlf 1969).

Two community structure indices, diversity and equitability, were calculated for each sampling station. Diversity was calculated using the Shannon-Wiener function (H) (Krebs 1978).

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

where p_i = Xa/n (Xa is the number of individuals of a particular species in the sample, and n is the total number of all individuals in the sample) and s = number of species. Equitability (E), the second community structure index, measures the proportional abundances among the various species in a sample (Krebs 1978). E 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. For each area, comparisons for both H and E were made between surveys using a paired t-test.

Fishes and Shrimp

For each station, individual species and total fish and shrimp densities (number/ha) and weights (g/ha) were estimated using the catch data and area sampled. We estimated the beach seine sampled 2,540 m^2 during a typical set; this estimate assumes the effective sampling length of the net was 42 m and an arc of 165° was sampled. One exception occurred at Miller Sands, Station M5, where the effective sampling length of the net was shortened to 30 m due to the shoreline configuration; the total area sampled at Station M5 was estimated to be 1,296 m^2. The estimated sampling area of the purse seine was 795 m^2, which is the area of a circle having a 100-m (length of purse seine) circumference.

The two previously described community structure indices, H and E, were also calculated for each station. The paired t-test was used for comparing fish and shrimp densities, H, and E between surveys for each area.

The stomach contents of the eight juvenile chinook salmon collected at Rice Island were analyzed using two approaches. An Index of Relative Importance (IRI) was determined for each prey using a modified IRI (Pinkas et al. 1971).

$$IRI = (N+W)F$$

where N = the percent number of a prey item, W = the percent weight of a prey item, and F = the frequency of occurrence of a prey item.

An Index of Feeding (IF) was calculated for each fish to determine how well it was feeding.

$$IF = (WS/WF)\ (100\%)$$

where WS = the weight of the stomach contents and WF = the wet weight of the fish.

Sediments

Median grain size (mm), percent silt/clay, and percent volatile solids were calculated for each station. Comparisons (paired t-test) were made between surveys for each area using each sediment characteristic. All values were $\log_{10}$ transformed prior to testing because they were not normally distributed.

RESULTS

Rice Island

Number of Replicates

Based on the cumulative analysis of 10 replicates collected at a Rice Island benthic invertebrate station, we verified that 10 replicates per individual station were adequate to describe the benthic invertebrate community. The number of taxa collected at the station did not increase appreciably after analyzing four replicates (Appendix Fig. 1). Density of benthic invertebrates and standard deviation fluctuated very little after analyzing six replicates, and diversity (H) varied little after three replicates (Appendix Fig. 1).

Benthic Invertebrates

For July 1991, 21 different invertebrate taxa were identified at Rice Island (Appendix Table 2). Benthic invertebrate densities ranged from a low of 601 organisms/m^2 at Station R11, an intertidal station, to 42,472 organisms/m^2 at Station R51, a shallow subtidal station (Table 1). The 5 shoreline intertidal stations had the lowest benthic invertebrate densities of all 25 stations. The highest benthic invertebrate densities occurred at stations greater than 1 m in depth (mean lower low water). In July, diversity (H) was less than 1.83 at all stations and often less than 1.00. The lower diversity values resulted from a small number or low equitability (E) (i.e., unequal proportional abundances among the taxa) of taxa at a station.

In September 1991, 25 different invertebrate taxa were identified (Appendix Table 2). Benthic invertebrate densities in September 1991 ranged from a low of 172 organisms/m^2 at Station R11 to a high of 86,930 organisms/m^2 at Station R25, a shallow subtidal station (Table 1). Similar to July, the shoreline intertidal stations on Rice Island had the lowest benthic invertebrate densities of all stations, with the exception of Station R14. In September, the highest benthic invertebrate densities occurred at shallow subtidal sites ($\geq$ 0.3 m in depth). Diversity (H) at 80% of the stations was less than 1.00. The lower diversity values were generally caused by low equitability (E).

The mean benthic invertebrate density in September was significantly higher than the density in July (t-test, $P < 0.05$), whereas H and E were significantly higher in July than in September. The higher densities in September were a result of increased numbers of the amphipod *Corophium salmonis*. *Corophium salmonis* was by far the dominant species at Rice Island during July and September (Table 2, Figs. 4-5, Appendix Table 3).

Table 1.--Summary of benthic invertebrates at Rice Island, Columbia River estuary, July and September 1991. Depths are corrected to mean lower low water.

Station	Depth (m)	Number of taxa	Number per/m^2	Standard deviation	Diversity (H)	Equitability (E)
			JULY			
R11	0.0	2	601	707	0.99	0.99
R21	0.0	6	12,198	3,707	1.50	0.58
R31	0.6	10	21,732	7,210	1.43	0.43
R41	0.3	9	18,125	5,209	1.83	0.58
R51	2.1	6	42,472	16,602	1.17	0.45
R12	0.0	3	2,062	1,293	0.89	0.56
R22	0.0	4	5,669	2,188	1.16	0.58
R32	0.6	8	8,246	2,503	1.32	0.44
R42	2.1	5	3,436	1,568	1.59	0.68
R52	2.7	4	2,749	1,449	1.45	0.73
R13	0.0	4	1,289	1,474	1.53	0.77
R23	3.0	7	10,308	4,563	1.65	0.59
R33	3.4	4	3,780	1,579	1.48	0.74
R43	2.4	8	22,677	7,347	1.52	0.51
R53	1.2	8	39,256	10,752	0.99	0.33
R14	0.0	2	945	854	0.85	0.85
R24	0.6	7	16,493	7,241	1.38	0.49
R34	4.6	8	33,672	11,742	1.17	0.39
R44	1.5	3	6,442	2,300	0.50	0.32
R54	1.5	3	4,123	1,708	0.56	0.35
R15	0.0	4	1,289	730	1.42	0.71
R25	2.4	7	20,272	7,978	1.10	0.39
R35	2.4	6	34,617	12,990	0.66	0.26
R45	2.4	3	6,614	2,563	0.82	0.52
R55	1.8	4	4,724	1,867	0.70	0.35

Table 1.--Continued.

Station	Depth (m)	Number of taxa	Number per/m^2	Standard deviation	Diversity (H)	Equitability (E)
			SEPTEMBER			
R11	0.0	1	172	362	0.00	0.00
R21	0.0	4	11,081	2,960	0.55	0.27
R31	0.6	11	67,001	17,189	0.83	0.24
R41	0.3	11	70,351	18,107	0.91	0.26
R51	2.1	7	67,345	20,613	0.81	0.29
R12	0.0	2	258	415	0.92	0.92
R22	0.0	3	945	1,028	0.87	0.55
R32	0.6	11	51,282	7,884	0.52	0.15
R42	2.1	7	36,421	12,768	0.59	0.21
R52	2.7	2	3,522	2,760	0.96	0.96
R13	0.0	5	773	854	2.06	0.89
R23	3.0	5	10,136	4,066	0.82	0.35
R33	3.4	9	62,535	13,114	0.34	0.11
R43	2.4	10	60,387	14,595	1.16	0.35
R53	1.2	8	48,189	17,685	1.37	0.46
R14	0.0	7	10,136	2,942	1.16	0.41
R24	0.6	6	26,457	7,230	0.49	0.19
R34	4.6	6	55,233	8,854	0.38	0.15
R44	1.5	8	40,201	10,401	0.64	0.21
R54	1.5	5	48,189	13,966	0.26	0.11
R15	0.0	4	601	815	1.66	0.83
R25	2.4	12	86,930	15,807	0.69	0.19
R35	2.4	8	40,458	11,506	0.89	0.30
R45	2.4	6	41,919	8,385	0.89	0.34
R55	1.8	6	57,381	11,423	0.42	0.16

Table 2.--Abundance of major benthic invertebrate taxa at Rice Island, Columbia River estuary, July and September 1991. All values are mean numbers/m^2; data from 25 stations were combined.

Taxon	Jul 91	Sep 91
Oligocheata	3,022	2,130
Polychaeta		
Neanthes limnicola	14	72
Bivalvia		
Corbicula fluminea	435	354
Amphipoda		
Corophium salmonis	8,407	31,418
misc.	293	127
Insecta		
Chironomidae larvae	41	69
Heleidae larvae	390	677
misc.	79	17
Others	152	1,051
Total	12,833	35,915

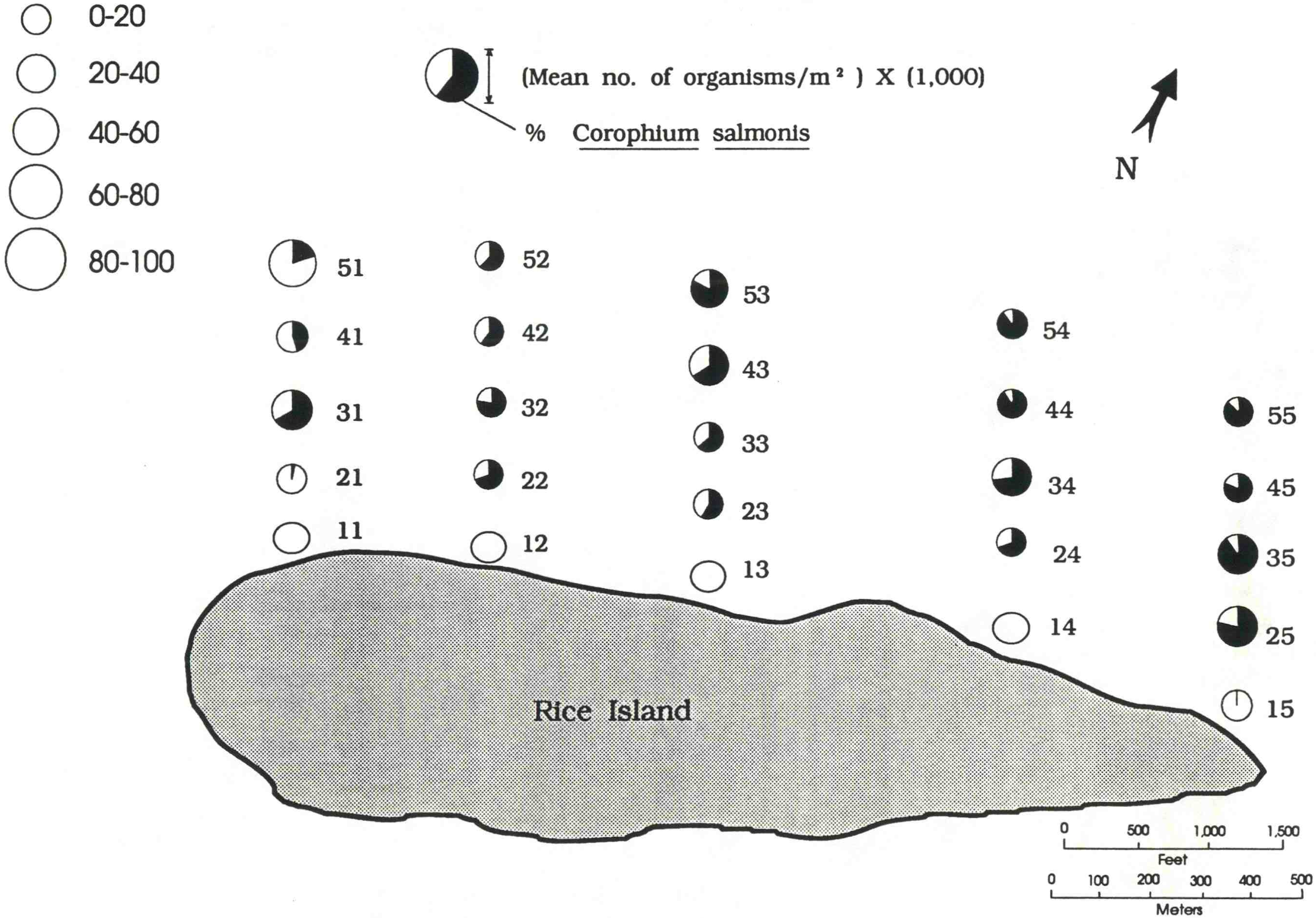

Figure 4.--Benthic invertebrate densities and percent <u>Corophium salmonis</u> for each station at Rice Island, Columbia River estuary, July 1991.

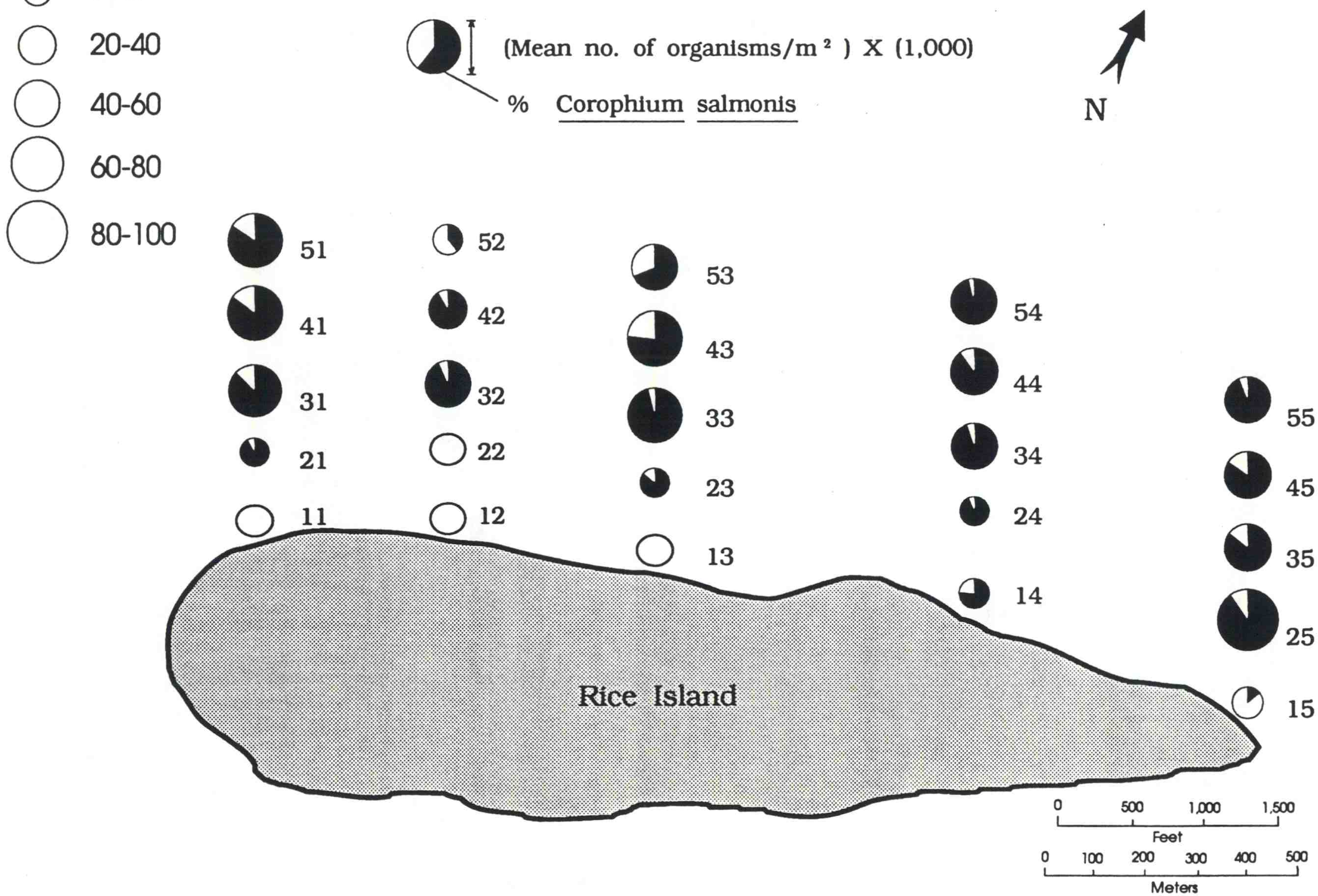

Figure 5.--Benthic invertebrate densities and percent Corophium salmonis for each station at Rice Island, Columbia River estuary, September 1991.

Other abundant taxa consistently found throughout the study area were oligochaetes, the bivalve Corbicula fluminea, and Heleidae (Ceratopogonidae) larvae (Table 2).

Fishes and Shrimp

Eight fish and one shrimp species were captured in seining efforts in July (Appendix Table 4). Fish densities at intertidal stations (beach seine sites) ranged from 51 to 556 fishes/ha (Table 3). At these sites, H ranged from 0.34 to 1.48 and E ranged from 0.17 to 0.74. Purse seine catches during July ranged widely--63 to 2,906 fishes/ha (Table 3); a small number of shrimp (5/ha) are included in the fish densities. At the purse seine stations, H and E also varied greatly, ranging from 0.00 to 1.52 and from 0.00 to 0.72, respectfully.

Eight fish species were captured in seining efforts in August (Appendix Table 4). Fish densities at the three beach seine stations (BS2, BS3, and BS5) ranged from 224 to 429 fishes/ha (Table 3). Diversity (H) at the three sites was similar, ranging from 1.28 to 1.59. Equitability was moderate to high, ranging from 0.55 to 0.94. Fish densities at the four purse seine stations (PS2, PS4, PS6, and PS8) that were sampled in August ranged from 51 to 805 fishes/ha, with the highest density at PS8. Diversity (H) at all sites was low, never exceeding 0.81; E varied considerably, ranging from 0.00 to 0.81.

In September, 10 fish species were collected in seining efforts at Rice Island (Appendix Table 4). No fish were caught at Station BS1, and densities at other beach seine sites ranged from 237 to 559 fishes/ha (Table 3). Excluding Station BS1, H ranged from 0.61 to 1.61 and E ranged from 0.30 to 0.69. Fish densities at the purse seine sites in September also ranged

Table 3.--Summary of fish and shrimp collections at Rice Island, Columbia River estuary by beach and purse seines, July, August, and September 1991.

Station	Mean depth (m)	Number of species	Number per hectare	Weight (g) per hectare	Diversity (H)	Equitability (E)
			JULY			
BS1	1.0	2	51	79	0.39	0.39
BS2	1.0	4	217	741	1.43	0.71
BS3	1.0	4	556	775	0.34	0.17
BS4	1.0	5	410	1,480	1.27	0.55
BS5	1.0	4	326	1,523	1.48	0.74
PS1	2.7	2	63	541	0.72	0.72
PS2	1.8	2	63	528	0.72	0.72
PS3	2.4	2	465	5,145	0.30	0.30
PS4	1.8	6	881	40,679	1.52	0.59
PS5	6.1	2	2,906	39,975	0.04	0.04
PS6	7.0	3	806	9,371	0.23	0.15
PS7	3.0	1	717	8,063	0.00	0.00
PS8	1.5	4	641	87,056	1.40	0.70
			AUGUST			
BS2	1.0	5	224	3,515	1.28	0.55
BS3	1.0	5	429	1,685	1.59	0.69
BS5	1.0	3	284	2,314	1.50	0.94
PS2	2.1	2	51	81,912	0.81	0.81
PS4	4.3	1	252	3,950	0.00	0.00
PS6	3.7	1	113	1,849	0.00	0.00
PS8	2.7	2	805	13,220	0.59	0.59
			SEPTEMBER			
BS1	1.0	0	0	0	0	0
BS2	1.0	4	559	2,453	0.61	0.30
BS3	1.0	5	237	4,505	1.61	0.69
BS4	1.0	7	465	10,811	1.46	0.52
BS5	1.0	5	457	2,409	0.91	0.39
PS1	3.4	2	164	667	0.39	0.39
PS2	2.1	2	76	1,497	0.65	0.65
PS3	3.0	3	126	2,050	1.16	0.73
PS4	4.3	1	226	440	0.00	0.00
PS5	2.4	4	3,409	76,200	0.51	0.26
PS6	3.7	4	516	56,981	1.15	0.57
PS7	3.4	2	38	390	0.92	0.92
PS8	2.7	1	13	138	0.00	0.00

widely--13 to 3,409 fishes/ha. Similar to July, H and E at these sites in September varied greatly, ranging from 0.00 to 1.16 and 0.00 to 0.92, respectfully.

Even though the taxa varied from July to September, there were no significant differences (t-test, $P > 0.05$) in fish and shrimp densities, H, and E between the two surveys.

During July and September, starry flounder, *Platichthys stellatus*, was the most abundant fish captured by beach seine at Rice Island (Table 4, Appendix Table 5). In July, other abundant species were juvenile chinook salmon and threespine stickleback, *Gasterosteus aculeatus*. In September, peamouth, *Mylocheilus caurinus*, and threespine stickleback were relatively abundant.

Juvenile chinook salmon were the most abundant purse seined fish during July and September (Table 4, Figs. 6-7). Starry flounder were the second most abundant fish captured in both surveys. In September, American shad, *Alosa sapidissima*, and threespine stickleback also comprised an important part of the catches.

Results from the limited sampling in August indicated that starry flounder was the most numerous species at the beach seine stations, with densities ranging from 142 to 185 fishes/ha (Table 4, Appendix Table 5). American shad, juvenile chinook salmon, and threespine stickleback were also relatively abundant in the intertidal areas. Only three species of fish were collected in purse seines in August (Table 4, Appendix Table 5). Total fish densities for the purse seines ranged from 51 to 805 fishes/ha, and juvenile chinook salmon was the most common species, occurring at three of the four purse seine stations. Starry flounder was the second most common species and white sturgeon, *Acipenser transmontanus*, was present.

Table 4.--Species composition and abundance of fishes and shrimp captured by beach and purse seines at Rice Island, Columbia River estuary, July, August, and September 1991. Sampling in August was limited to three beach seines and four purse seines. All values are mean numbers/hectare.

Species	Jul 91	Aug 91	Sep 91
BEACH SEINE			
American shad	0	69	13
Chinook salmon (subyearling)	49	51	5
Coho salmon	0	0	1
Peamouth	6	4	28
Largescale sucker	2	1	3
Banded killifish	0	1	2
Threespine stickleback	39	22	34
Pacific staghorn sculpin	11	0	5
Starry flounder	206	163	253
Total	313	311	344
PURSE SEINE			
White sturgeon	3	3	0
American shad	0	0	38
Chinook salmon (subyearling)	728	264	451
Coho salmon	0	0	2
Mountain whitefish	0	0	2
Surf smelt	6	0	0
Threespine stickleback	3	0	33
Pacific staghorn sculpin	9	0	0
Starry flounder	63	38	46
California bay shrimp	5	0	0
Total	817	305	572

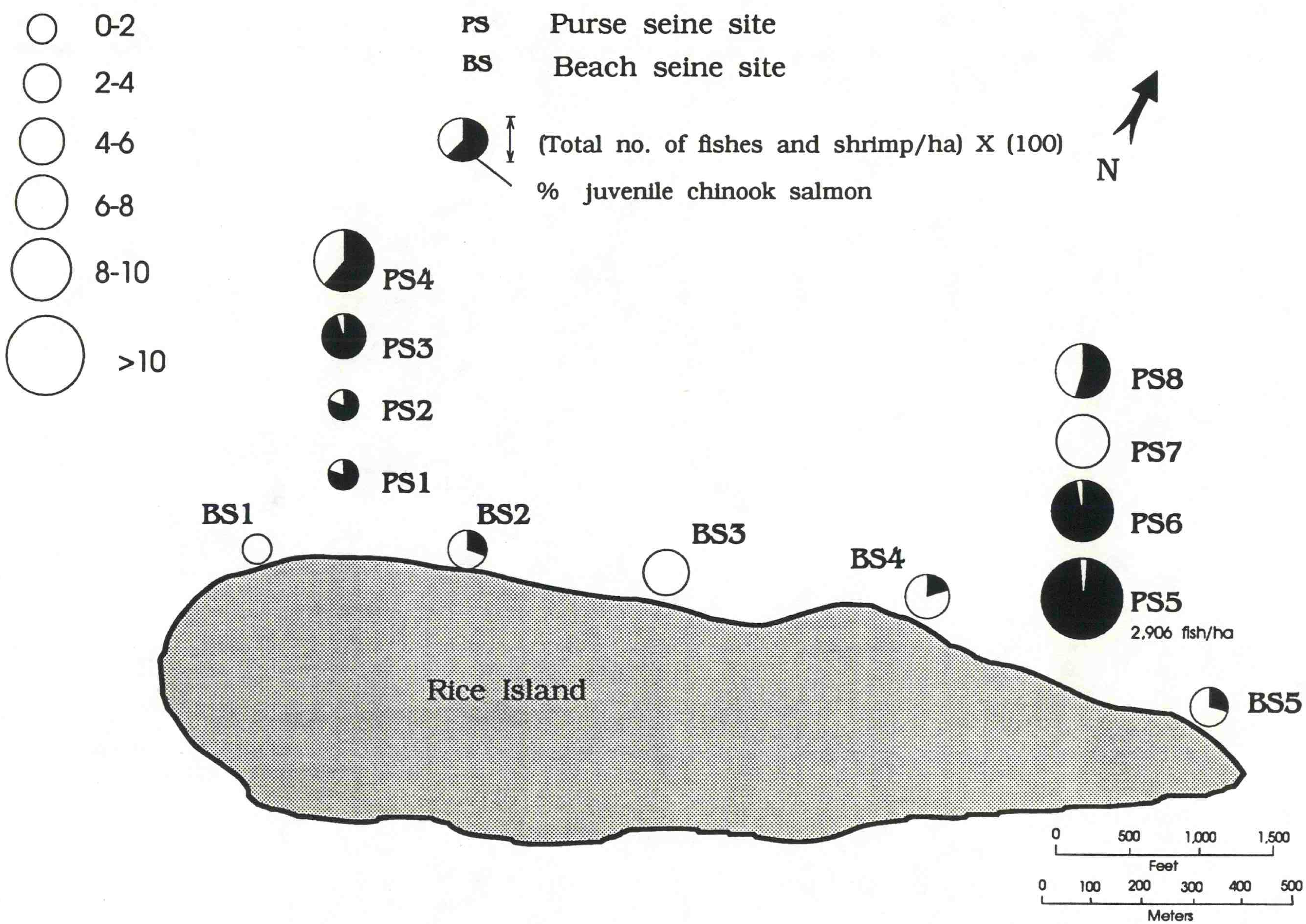

Figure 6.--Fish and shrimp densities and percent juvenile chinook salmon at beach and purse seine stations at Rice Island, Columbia River estuary, July 1991.

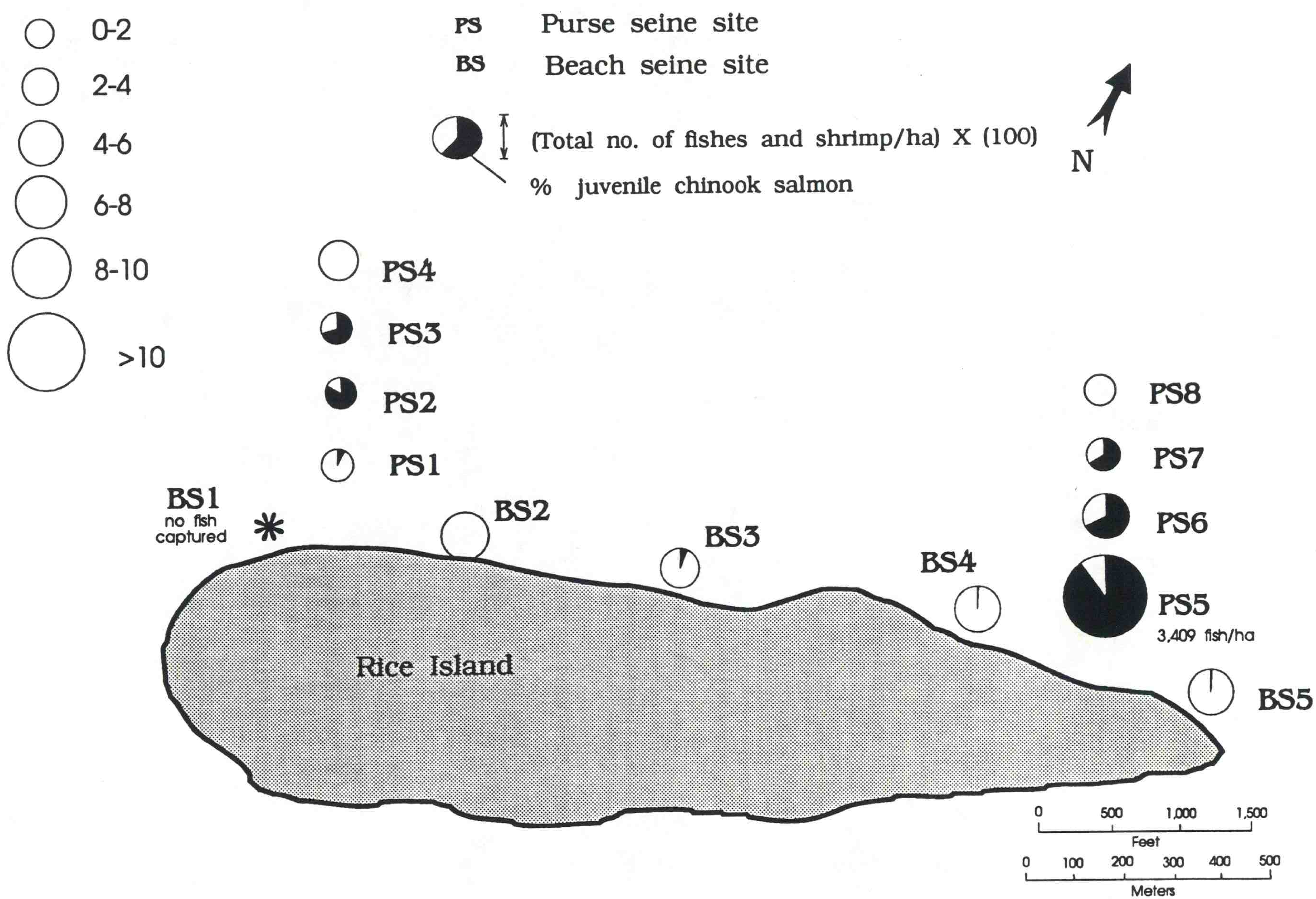

Figure 7.--Fish densities and percent juvenile chinook salmon at beach and purse seine stations at Rice Island, Columbia River estuary, September 1991.

Results from the stomach analyses of eight juvenile chinook salmon collected at Rice Island in August showed that C. salmonis was by far the dominant prey item, representing 75% of the total IRI (Table 5). Daphnia longispina was a minor prey, representing 12% of the total IRI. The mean IF value for the eight juveniles was 3.45% ± 2.58% (SD) (Table 5).

Sediments

The dominant median grain size in the Rice Island study area during July and September was fine sand (0.125 to <0.25 mm in diameter) (Table 6). However, medium sand (0.25 to <0.5 mm) was the median grain size at Stations R11, R52, R13, and R55 in July and September, Station R33 in July, and Stations R42 and R45 in September. Also, very fine sand (0.0625 to <0.125 mm) was the median grain size at Stations R31 and R25 in July and September, Stations R21 and R41 in July, and Station R51 in September. The amount of silt/clay at each station for both surveys was usually less than 5.5% (Table 6). Higher amounts occurred at Stations R41 (52.7%), R43 (9.7%), and R25 (13.4%) in July. In September, only Station R31 had high silt/clay content (12.5%). Percent volatile solids per station for both surveys was never greater than 1.6%, and usually less than 1.0%. There were no significant differences for median grain size, percent silt/clay, and percent volatile solids between the July and September surveys at Rice Island (t-test, $P > 0.05$).

Table 5.--Stomach analysis of eight juvenile chinook salmon collected at Rice Island, Columbia River estuary, August 1991.

Prey item	Frequency of occurence (%)	Percent number	Percent weight	Prey IRI	Percent total IRI
Corophium salmonis	100.00	45.90	77.39	12,329.3	74.95
Digested material	100.00	0.00	20.04	2,004.2	12.18
Chironomidae larvae	37.50	0.64	0.05	25.7	0.16
Chironomidae pupae	50.00	0.81	0.17	49.3	0.30
Chironomidae adult	25.00	0.58	0.24	20.6	0.12
Daphnia longispina	37.50	51.83	1.91	2,015.2	12.25
Neomysis mercedis	12.50	0.06	0.17	2.9	0.02
Homoptera	12.50	0.06	0.02	1.0	0.01
Corbicula fluminea	12.50	0.06	0.00	0.8	0.00
Cyclops vernalis	12.50	0.06	0.00	0.8	0.00

Table 6.--Sediment characteristics at Rice Island, Columbia River estuary, July and September 1991.

Station	July			September		
	Median grain size (mm)	Silt/ clay (%)	Volatile solids (%)	Median grain size (mm)	Silt/ clay (%)	Volatile solids (%)
R11	0.2500	0.3	1.0	0.2500	0.5	0.6
R21	0.1088	0.9	0.9	0.2031	0.5	0.7
R31	0.1088	5.4	1.5	0.0884	12.5	1.4
R41	0.0625	52.7	0.5	0.1340	1.3	1.1
R51	0.1436	0.8	0.9	0.1088	3.3	1.6
R12	0.2031	0.5	1.5	0.2031	0.8	0.6
R22	0.2031	0.4	0.6	0.2176	0.5	0.8
R32	0.2031	0.5	0.7	0.1895	2.5	0.9
R42	0.2333	0.5	0.9	0.2500	0.4	0.7
R52	0.2500	0.2	0.5	0.2500	0.2	0.4
R13	0.3299	0.2	0.4	0.3789	0.2	0.5
R23	0.1768	2.7	0.4	0.2031	0.6	0.7
R33	0.2679	0.2	0.5	0.2333	0.6	0.7
R43	0.1649	9.7	0.7	0.1768	2.2	0.9
R53	0.1895	2.2	0.6	0.1768	1.9	0.8
R14	0.2176	0.2	0.5	0.1768	1.5	1.6
R24	0.1768	1.9	0.4	0.2031	1.2	0.7
R34	0.1768	3.4	0.9	0.1895	1.3	0.7
R44	0.2333	0.2	0.4	0.2176	0.5	0.1
R54	0.2333	0.2	0.5	0.2176	0.4	0.6
R15	0.2031	0.2	0.6	0.1895	0.4	0.5
R25	0.0884	13.4	0.5	0.1088	3.9	1.6
R35	0.2031	2.8	0.9	0.2031	4.6	0.6
R45	0.2176	0.2	0.5	0.2500	0.5	0.4
R55	0.2500	0.1	0.5	0.2500	0.4	0.6

Miller Sands

Benthic Invertebrates

For July 1991, 21 invertebrate taxa were identified (Appendix Table 2). Benthic invertebrate densities ranged from 1,632 (Station M14) to 40,115 organisms/m^2 (Station M11) (Table 7). Diversity (H) ranged from 0.70 to 2.17 and species equitability (E) ranged from 0.22 to 0.95. Diversity was highest at stations where E was highest or relatively high numbers of taxa were collected.

In September, 20 invertebrate taxa were identified (Appendix Table 2). Benthic invertebrate densities ranged from 3,522 (Station M14) to 47,588 organisms/m^2 (Station M5) (Table 7). Diversity (H) ranged from 0.73 to 2.16 and E ranged from 0.31 to 0.80. The highest diversity occurred at Station M4, where a moderate number of taxa was collected and E was the second highest of all stations. The lowest diversity occurred at Station M10, where a small number of taxa was collected and E was the lowest of all stations.

Comparisons of benthic invertebrate densities, H, and E between July and September showed no significant differences (t-test, $P > 0.05$). Oligochaeta was the most abundant taxon in July and September at Miller Sands (Table 8, Appendix Table 4). Although much less abundant than Oligochaeta, *C. salmonis* was the second most numerous taxon for both surveys. The density of *C. salmonis* at any station rarely exceeded 40% of the total density for that station (Figs. 8-9). Other abundant taxa in July included *Corbicula fluminea*, Ostracoda, and Chironomidae larvae; and in September, *Neanthes limnicola*, *C. fluminea*, and Chironomidae larvae (Table 8).

Table 7.--Summary of benthic invertebrates at Miller Sands, Columbia River estuary, July and September 1991.

Station	Number of taxa	Number per/m^2	Standard deviation	Diversity (H)	Equitability (E)
		JULY			
M2	6	1,718	1,425	2.17	0.84
M3	9	37,710	14,726	0.70	0.22
M4	10	19,585	10,314	2.05	0.62
M5	11	27,831	9,464	1.17	0.34
M6	9	25,083	8,217	1.59	0.50
M10	7	21,217	8,319	0.75	0.27
M11	11	40,115	13,196	1.75	0.51
M13	4	4,381	2,905	1.61	0.80
M14	2	1,632	1,592	0.95	0.95
		SEPTEMBER			
M2	9	18,554	4,308	1.39	0.44
M3	10	40,287	36,607	2.03	0.61
M4	8	10,566	4,741	2.16	0.72
M5	11	47,588	20,597	2.15	0.62
M6	12	39,857	7,802	1.91	0.53
M10	5	8,762	7,892	0.73	0.31
M11	9	37,967	21,384	1.59	0.50
M13	4	4,209	945	1.21	0.60
M14	4	3,522	1,692	1.61	0.80

Table 8.--Abundance of major benthic invertebrate taxa at Miller Sands, Columbia River estuary, July and September 1991. All values are mean numbers/m^2; data from nine stations were combined.

Taxon	Jul 91	Sep 91
Oligochaeta	13,995	11,176
Polychaeta		
Neanthes limnicola	386	1,813
Bivalvia		
Corbicula fluminea	985	907
misc.	19	29
Ostracoda	618	296
Amphipoda		
Corophium salmonis	2,683	5,841
misc.	155	134
Insecta		
Chironomidae larvae	492	1,785
Heleidae larvae	97	10
misc.	48	144
Others	647	1,346
Total	20,125	23,481

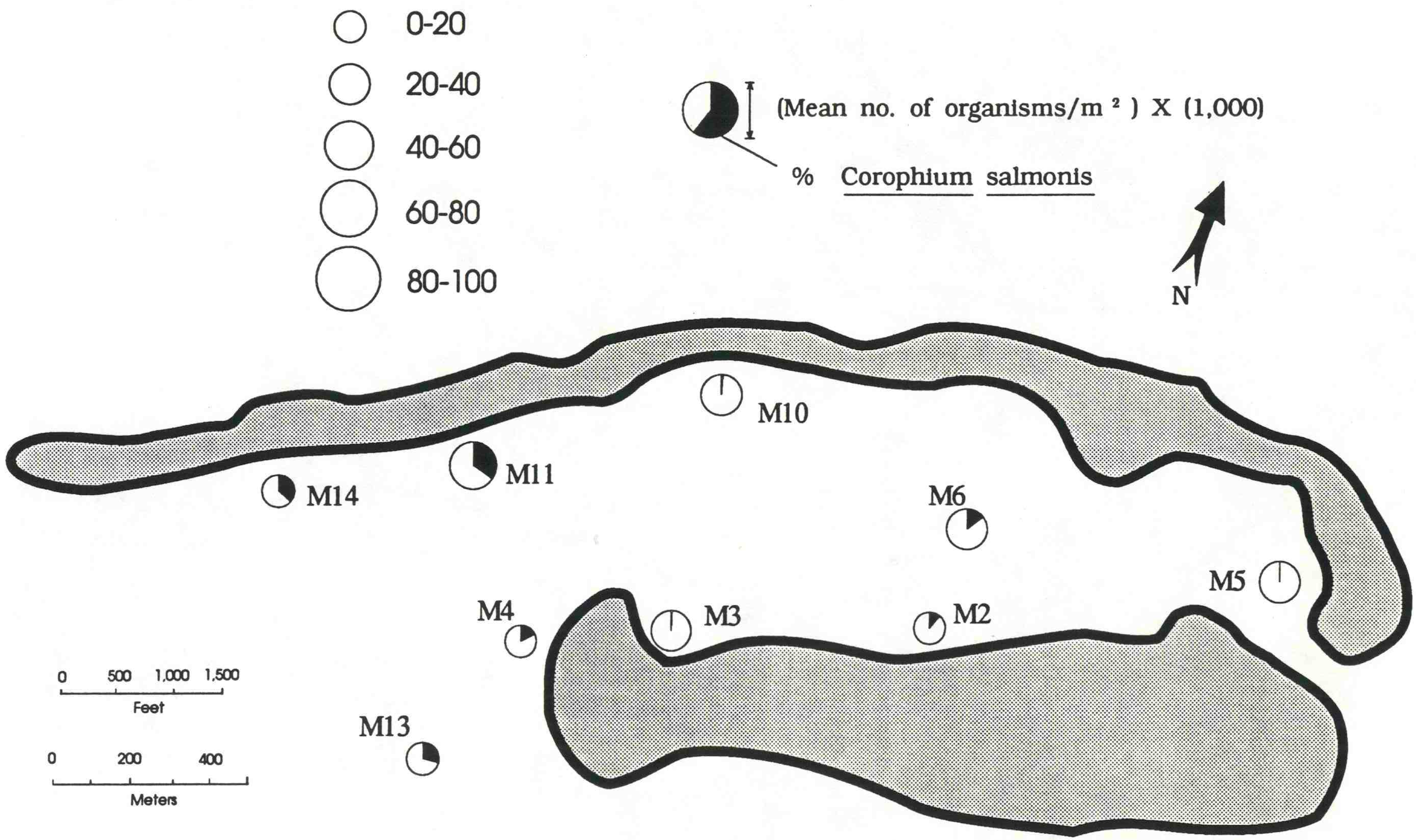

Figure 8.--Benthic invertebrate densities and percent _Corophium salmonis_ for each station at Miller Sands, Columbia River estuary, July 1991.

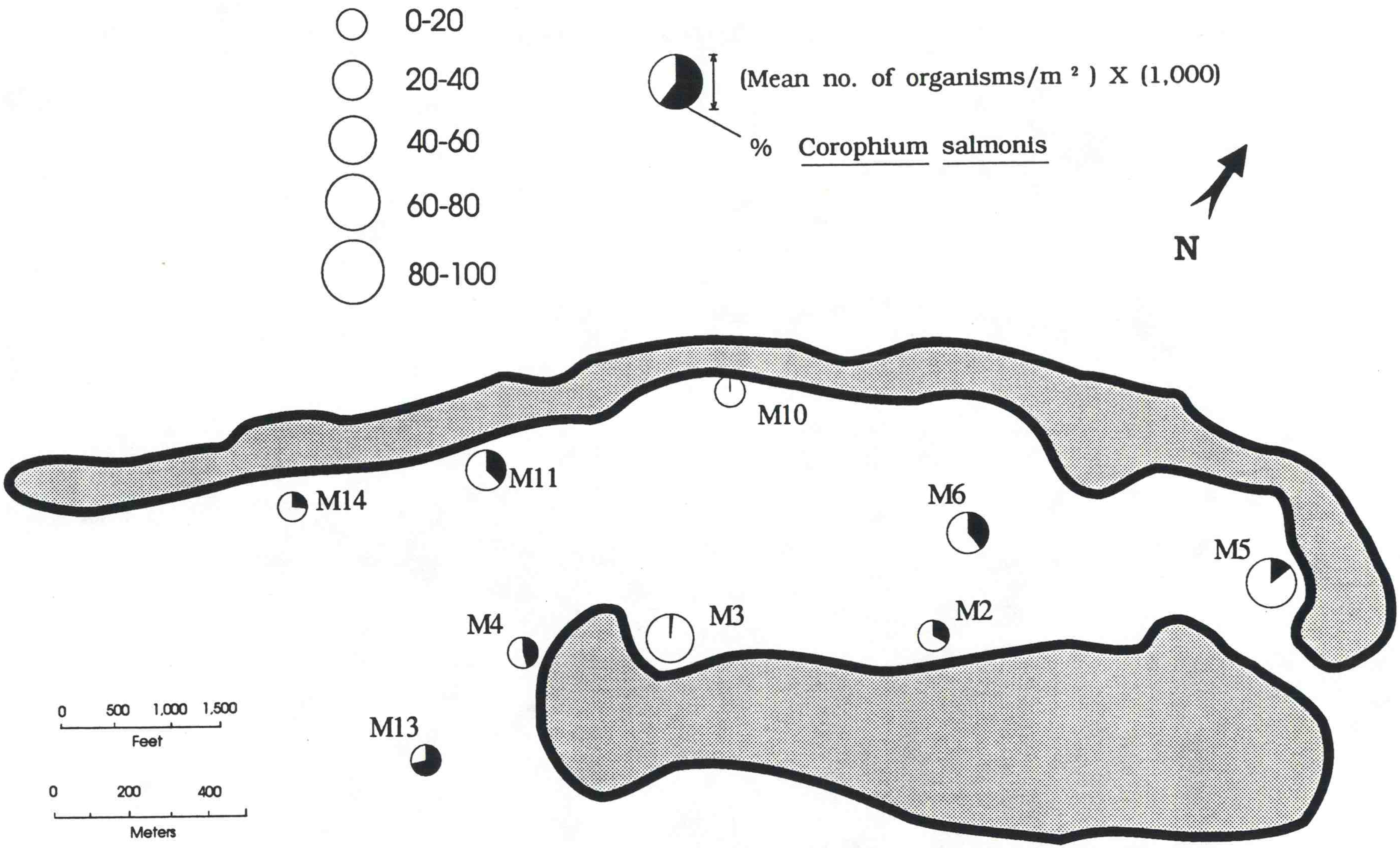

Figure 9.--Benthic invertebrate densities and percent <u>Corophium salmonis</u> for each station at Miller Sands, Columbia River estuary, September 1991.

Fishes and Shrimp

For July 1991 at Miller Sands, ten fish taxa were identified (Appendix Table 3). Densities at the beach seine stations ranged from 264 to 1,772 fishes/ha (Table 9). H ranged from 0.26 to 1.83 and E ranged from 0.16 to 0.91. The lowest diversities, which occurred at Stations M2 and M10, resulted largely from low E values. Diversity was highest at Stations M3 and M5, where relatively high numbers of taxa occurred and E values were moderate to high.

For September, nine fish and one shrimp species were identified (Appendix Table 3). Densities ranged tremendously, from 51 to 7,546 fishes and shrimp/ha (Table 9). H and E also varied widely, ranging from 0.39 to 1.96 and 0.33 to 0.84, respectively.

Species composition and abundance of fishes and shrimp were not the same in the July and September surveys; nevertheless, there were no significant differences when comparing total fish densities, H, and E between the surveys (t-test, $P > 0.05$). In July, starry flounder was by far the most abundant species (Table 10, Appendix Table 5). Other commonly captured fishes were juvenile chinook salmon, peamouth, threespine stickleback, and banded killifish, *Fundulus diaphanus*. In September, peamouth was by far the most numerous species, with American shad, juvenile chinook salmon, banded killifish, threespine stickleback, starry flounder, and the California bay shrimp (*Crangon franciscorum*) also being common (Table 10, Appendix Table 5). Although juvenile chinook salmon was one of the abundant species at Miller Sands in July and September, it usually did not represent more than 10% of the total catch at any station (Figs. 10-11).

Table 9.--Summary of fish and shrimp collections at Miller Sands, Columbia River estuary by beach seine, July and September 1991.

Station	Mean depth (m)	Number of species	Number per hectare	Weight (g) per hectare	Diversity (H)	Equitability (E)
			JULY			
M2	1.0	6	1,638	3,803	0.53	0.20
M3	1.0	6	607	70,327	1.83	0.71
M4	1.0	8	1,772	46,595	0.68	0.23
M5	1.0	6	795	22,647	1.67	0.65
M10	1.0	3	646	2,126	0.26	0.16
M11	1.0	5	1,012	2,304	0.91	0.39
M13	1.0	3	264	819	1.44	0.91
M14	1.0	3	367	2,201	1.10	0.70
			SEPTEMBER			
M2	1.0	8	2,832	7,317	0.98	0.33
M3	1.0	7	611	2,039	1.96	0.70
M4	1.0	5	463	1,783	1.94	0.83
M5	1.0	8	7,546	7,962	1.65	0.55
M10	1.0	5	224	657	1.96	0.84
M11	1.0	2	107	397	0.76	0.76
M13	1.0	7	2,385	14,260	1.95	0.70
M14	1.0	2	51	130	0.39	0.39

Table 10.--Species composition and abundance of fishes and shrimp captured by beach seine at Miller Sands, Columbia River estuary, July and September 1991. All values are mean numbers/hectare.

Species	Jul 91	Sep 91
American shad	0	125
Chinook salmon (subyearling)	68	48
Common carp	5	0
Peamouth	86	649
Largescale sucker	9	4
Banded killifish	27	375
Threespine stickleback	43	330
Prickly sculpin	1	0
Pacific staghorn sculpin	4	1
Unidentified sculpin (juvenile)	1	2
Starry flounder	646	86
California bay shrimp	0	157
Total	890	1,777

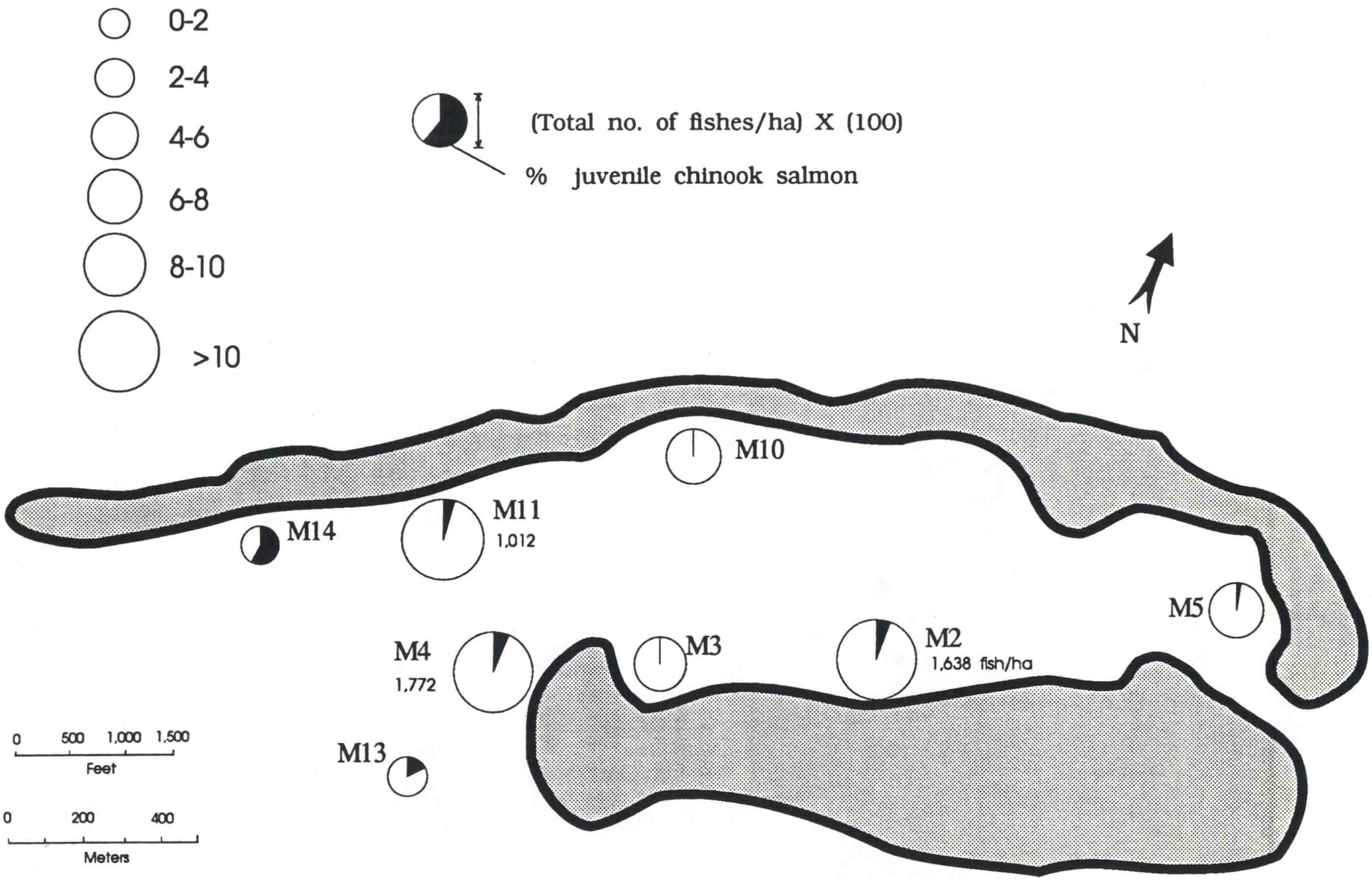

Figure 10.--Fish densities and percent juvenile chinook salmon at beach seine stations at Miller Sands, Columbia River estuary, July 1991.

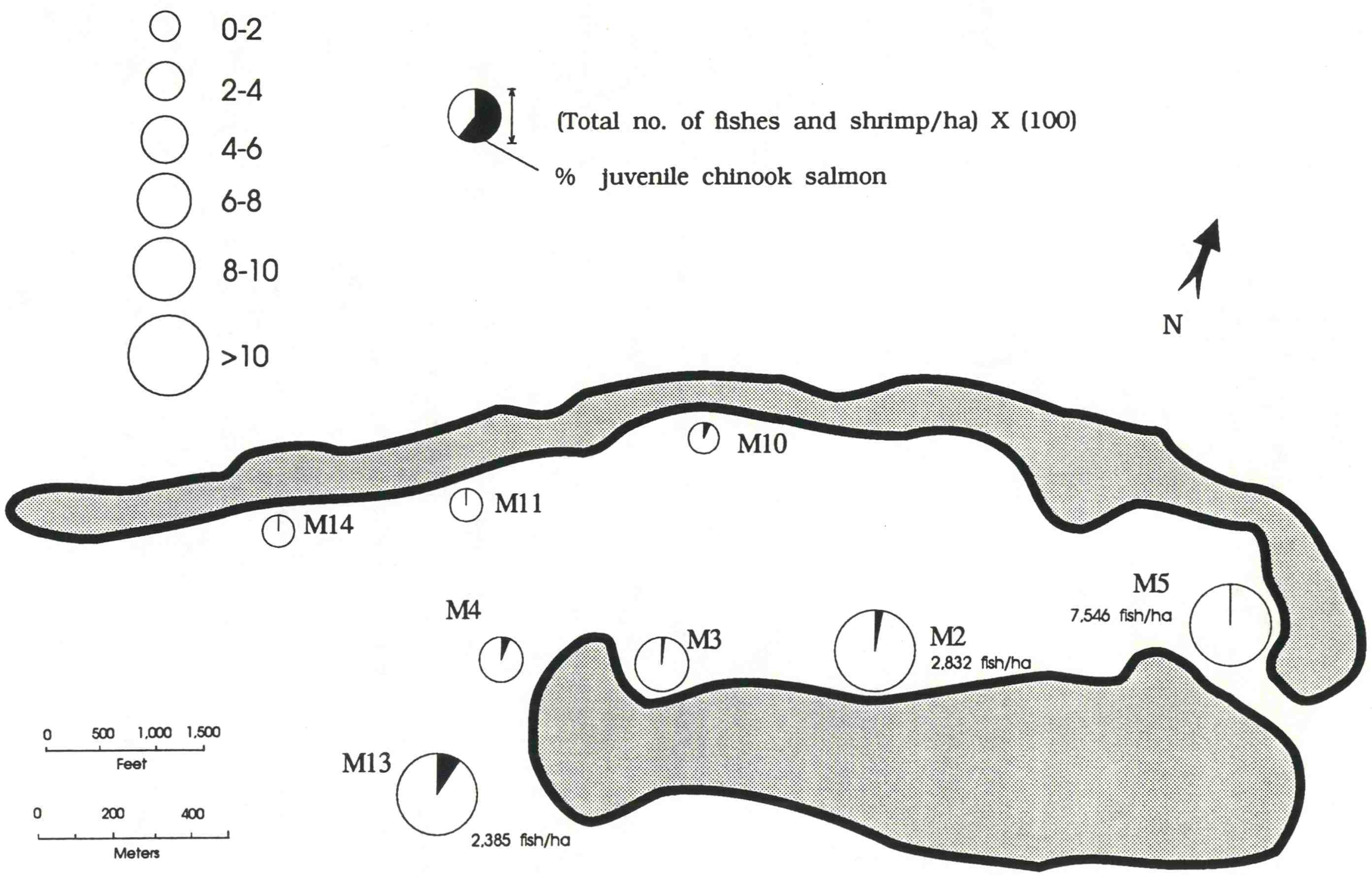

Figure 11.--Fish and shrimp densities and percent juvenile chinook salmon at beach seine stations at Miller Sands, Columbia River estuary, September 1991.

Sediments

The median grain size at most Miller Sands stations in July and September was fine sand (0.125 to <0.25 mm in diameter) (Table 11). Exceptions occurred at Station M6 in July and Stations M6 and M13 in September where the median grain size was very fine sand (0.0625 to <0.125 mm). The amount of silt/clay in July and September was $\leq$6.5% for all stations, except Station M6, where the percentage was 18.1 in July and 19.1 in September. The percent volatile solids per station for both surveys was never greater than 1.4% and usually <1.0%. There were no significant differences for median grain size, percent silt/clay, and percent volatile solids between the July and September surveys at Miller Sands (t-test, $P > 0.05$).

DISCUSSION

Rice Island

For both July and September, benthic invertebrate densities in the Rice Island study area were lowest at the shoreline stations. The lower densities may have resulted from the unstable benthic habitat. These shoreline stations are intertidal and are subjected to considerable wave action caused by strong northwest winds during the summer. Winds also blow sand from the higher non-vegetated elevations of the island onto the intertidal area. In addition, some of the shoreline stations were adversely impacted by dredged-material disposal operations on the island during this study.

Benthic invertebrate densities at the shoreline stations in July and September 1991 averaged 1,237 and 2,388 organisms/m^2, respectively. The July 1991 density was similar to that reported by Hinton et al. (1990) for intertidal sites at Rice Island in July 1989 (mean = 1,121 organisms/m^2). The mean density for September 1991 was less than the mean density in the same

Table 11.--Sediment characteristics at Miller Sands, Columbia River estuary, July and September 1991.

Station	JULY			SEPTEMBER		
	Median grain size (mm)	Silt/ clay (%)	Volatile solids (%)	Median grain size (mm)	Silt/ clay (%)	Volatile solids (%)
M2	0.1436	1.4	0.7	0.1340	1.8	1.0
M3	0.2176	5.4	0.9	0.2333	4.3	0.9
M4	0.1436	3.1	0.9	0.1895	1.3	0.5
M5	0.2031	1.7	0.6	0.2031	1.8	0.9
M6	0.0769	18.1	1.3	0.0769	19.1	1.4
M10	0.1649	3.0	0.8	0.1649	2.4	0.8
M11	0.2031	6.5	1.3	0.2031	4.8	1.1
M13	0.1250	0.3	0.8	0.1166	0.2	0.8
M14	0.1649	0.6	0.9	0.1768	0.5	0.6

area in September 1988 (mean = 5,162 organisms/m^2) and greater than the density in September 1989 (mean = 487 organisms/m^2; Hinton et al. 1990).

The shallow subtidal area north of Rice Island supported large populations of C. salmonis, particularly in September 1991, when densities of C. salmonis at individual stations frequently exceeded 33,000 organisms/m^2 and the mean density for the area was 31,418 organisms/m^2. For comparison, densities of C. salmonis in deeper-water areas near Woody Island, in the upper estuary at RM 28, never exceeded 5,212 organisms/m^2 along individual transects in September 1988 and 1989 (McCabe et al. 1989, McCabe and Hinton 1990). The mean density of C. salmonis at four shallow subtidal sites in Cathlamet Bay (RM 19-24) was 22,688 organisms/m^2 (range, 8,586 to 48,253 organisms/m^2) in September 1984 (Emmett et al. 1986). During the present study, mean densities of C. salmonis in July and September at Rice Island were three to five times greater than densities at Miller Sands.

The large standing crop of C. salmonis in the shallow subtidal area north of Rice Island represents an important food source for local fishes. Corophium salmonis is a primary prey for juvenile chinook and coho salmon, O. kisutch, steelhead, O. mykiss, and starry flounder in the Columbia River estuary (McCabe et al. 1983, 1986). Juvenile white sturgeon <80 cm long (total length) collected in the lower Columbia River also preyed heavily on C. salmonis (Muir et al. 1988, McCabe and Hinton 1990). Corophium spp. are also eaten by larger white sturgeon (≥102 cm total length) in the Columbia River estuary. White sturgeon use the area north of Rice Island--three subadult white sturgeon were captured by hook-and-line during a 1-hour period in August 1991. In addition, sport fishermen occasionally fish for white sturgeon in this area.

Although only a small number of subyearling chinook salmon were sacrificed for stomach analyses during the present study, the results suggested that C. salmonis is important in the diets of subyearling chinook salmon using the area north of Rice Island. We were surprised that C. salmonis was the primary prey during August. McCabe et al. (1986) found that Daphnia spp. were the primary prey of subyearling chinook salmon collected in pelagic and intertidal areas of the upper Columbia River estuary in August 1980. Apparently, C. salmonis were numerous and available enough in the Rice Island area in 1991 for the juvenile chinook salmon to feed successfully. The limited stomach analyses also suggested that the juvenile chinook salmon were feeding well (i.e., IF = 3.45% and no empty stomachs). For comparison, McCabe et al. (1986) reported median IF values of 0.02% and 0.30%, respectively, for subyearling chinook salmon collected in pelagic and intertidal areas of the Columbia River estuary during August 1980. An intensive food habit study of juvenile chinook salmon in the Rice Island area is needed to describe their diets adequately.

In September 1991, two banded killifish were collected in a beach seine at Rice Island (Stations BS2 and BS5). This represents the farthest downstream capture of banded killifish in the Columbia River estuary. Prior to this capture, the farthest downstream capture was the embayment at Miller Sands (Hinton et al. 1990). Additional sampling at the Rice Island intertidal areas in the future would determine if the banded killifish has expanded its range in the Columbia River estuary.

Miller Sands

Prior to the present study, Miller Sands was last sampled for benthic invertebrates and fishes in 1988-1989 (Hinton et al. 1990). Most of the same stations sampled in the earlier study were reoccupied in the present study. Sampling was conducted at 11 stations in 1988-1989, whereas sampling was conducted at only 9 of the 11 stations in 1991. Sampling in 1991 was not conducted at one of the former intertidal stations and one shallow subtidal station, which had high benthic invertebrate densities, including high densities of C. salmonis. Mean densities of benthic invertebrates in July and September 1991 were similar to those observed in July and September 1989. In July and September 1989, mean densities at Miller Sands were 18,109 and 26,275 organisms/m^2, respectively. In July and September 1991, mean benthic invertebrate densities at Miller Sands were 19,919 and 23,479 organisms/m^2, respectively. The mean benthic invertebrate density in September 1988 (36,880 organisms/m^2) was higher than densities observed in September of both 1989 and 1991. In July and September 1991, oligochaetes and C. salmonis were the two most abundant taxa at Miller Sands. Likewise, in September 1988, July 1989, and September 1989, oligochaetes and C. salmonis were the two most numerous taxa.

In July 1989, the mean fish density at Miller Sands was 1,111 fishes/ha (Hinton et al. 1990), which was higher than the density observed in July 1991 (890 fishes/ha). The mean density of fishes in September 1991 was higher than those observed in September 1988 and 1989. In September 1988 and 1989, fish densities averaged 416 and 1,635 fishes/ha, respectively (Hinton et al. 1990); whereas in September 1991, the mean density was 1,777 fishes/ha. Similar species were collected during the present study and the 1988-1989 study; however, the proportional abundances of the various species varied between the two studies.

CONCLUSIONS AND RECOMMENDATIONS

The shallow subtidal area north of Rice Island had high benthic invertebrate densities during July and September 1991, particularly during September. The most abundant benthic invertebrate during each survey was the amphipod C. salmonis, a primary prey item for juvenile salmonids. Densities of C. salmonis at Rice Island were higher than densities at Miller Sands, which is similar in configuration to the proposed island-spit complex at Rice Island.

Construction of a spit north of Rice Island using dredged material would undoubtedly reduce the high standing crop of C. salmonis in this area, which in turn could reduce the use of this area by juvenile salmonids. Spit construction would 1) reduce the total amount of aquatic habitat available for fishes and invertebrates and 2) reduce densities of C. salmonis in intertidal areas adjacent to the spit due to unstable habitat. Because of the high biological value of this area north of Rice Island, it is recommended that a spit not be constructed.

The intertidal stations closest to Rice Island typically had the lowest benthic invertebrate densities of all the sampling stations. Sand blown from Rice Island onto these intertidal areas may be causing the lower densities. If the non-vegetated areas of Rice Island were seeded and secured with vegetation, less sand would be blown onto the intertidal areas, providing a more favorable habitat for benthic invertebrates.

No major changes in the biological community at Miller Sands were identified between 1988-1989 (Hinton et al. 1990) and 1991, although there was some variation in benthic invertebrate and fish densities between the two time periods. Ideally, biological sampling should be continued at Miller Sands to document any major changes in the benthic invertebrate and fish communities.

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

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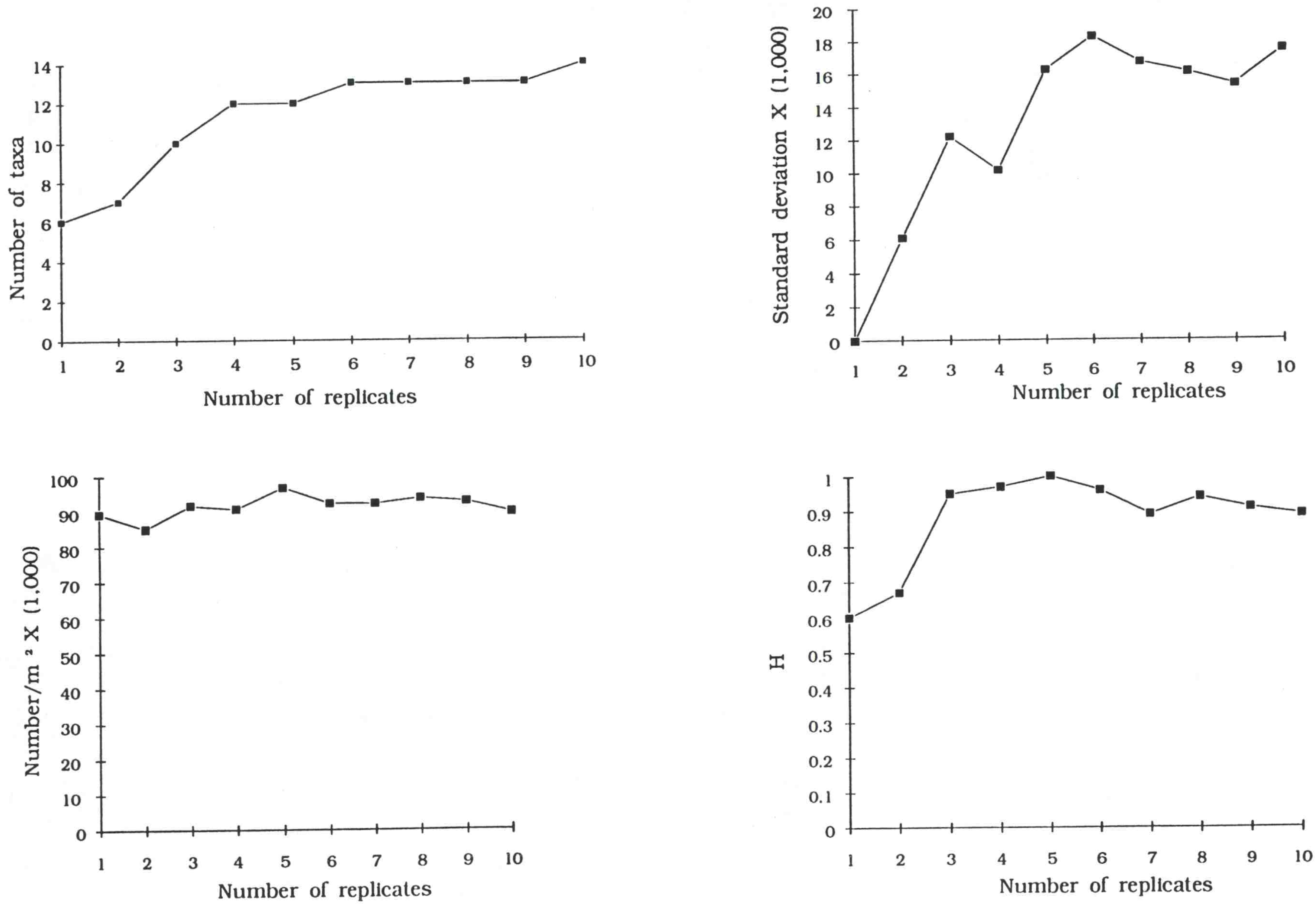
APPENDIX



Appendix Figure 1.--Cumulative analysis of station statistics by increasing replication from Station R25, Rice Island, Columbia River estuary, September 1991.

Appendix Table 1.--Station locations at Rice Island and Miller Sands, Columbia River estuary, July and September 1991. Limited sampling was also done in August 1991 at Rice Island.

RICE ISLAND

Station				
Benthic/ sediment	Beach seine	Purse seine	Latitude	Longitude
R11	BS1		46°15.108	123°42.946
R21		PS1	15.174	42.984
R31		PS2[a]	15.245	43.032
R41		PS3	15.321	43.086
R51		PS4[a]	15.401	43.150
R12	BS2[a]		46°15.187	123°42.429
R22			15.239	42.474
R32			15.316	42.537
R42			15.404	42.593
R52			15.507	42.63
R13	BS3[a]		46°15.285	123°42.011
R23			15.370	42.069
R33			15.442	42.108
R43			15.512	42.152
R53			15.600	42.194
R14	BS4		46°15.268	123°41.641
R24		PS5	15.357	41.704
R34		PS6[a]	15.433	41.758
R44		PS7	15.513	41.809
R54		PS8[a]	15.588	41.849
R15	BS5[a]		46°15.325	123°41.321
R25			15.392	41.393
R35			15.464	41.434
R45			15.524	41.489
R55			15.591	41.550

Appendix Table 1.--Continued.

MILLER SANDS

Station[b]	Latitude	Longitude
M2	46°14.797	123°39.383
M3	14.698	39.844
M4	14.722	39.978
M5	15.09	38.507
M6	14.987	39.713
M10	46°15.061	123°39.869
M11	14.864	40.327
M13	14.475	40.268
M14	14.592	41.056

[a] Stations occupied in August.
[b] Benthic invertebrate, sediment, and beach seine stations were the same; no beach seining was done at Station M6.

Appendix Table 2.--Invertebrate taxa found at Rice Island and Miller Sands, Columbia River estuary, July and September 1991.

Taxon	Rice Island		Miller Sands	
	Jul	Sep	Jul	Sep
Hydra sp.	x			
Turbellaria	x	x	x	
Nemertea	x	x	x	x
Nematomorpha	x	x	x	x
Polychaeta				
Neanthes limnicola	x	x	x	x
Oligochaeta	x	x	x	x
Copepoda				
Calanoida				x
Harpacticoida	x	x	x	x
Cyclopoida		x		x
Gastropoda		x		
Gastropoda egg cases	x			x
Fluminicula virens		x		
Fluminicola sp.	x	x		
Juga plicifera		x		
Bivalvia				
Corbicula fluminea	x	x	x	x
Pisidium spp.			x	x
Ostracoda	x		x	x
Mysidacea		x		
Amphipoda				
Corophium spp.	x	x	x	x
Corophium salmonis	x	x	x	x
Corophium spinicorne	x	x		
Eohaustorius estuaris				x
Pontoporeia hoyi			x	x

Appendix Table 2.--Continued.

Taxon	Rice Island		Miller Sands	
	Jul	Sep	Jul	Sep
Insecta		x		
Collembola		x		
Odonata				x
Coleoptera	x	x	x	
Coleoptera larvae		x		
Trichoptera larvae		x		
Lepidoptera			x	
Diptera larvae			x	
Heleidae larvae	x	x	x	x
Chironomidae larvae	x	x	x	x
Chironomidae pupae	x		x	x
Invertebrate eggs	x	x	x	x
Arachnida	x		x	
Hydracarina	x	x	x	
Total number of taxa	21	25	21	20

Appendix Table 3.--Summaries of benthic invertebrate surveys (by station) conducted in July and September 1991 at Rice Island and Miller Sands, Columbia River estuary (not included in basic report due to size; available upon request to NMFS, Point Adams Biological Field Station, P. O. Box 155, Hammond, OR 97121).

Appendix Table 4.--Fishes and shrimp captured by beach and purse seines at Rice Island, and by beach seine at Miller Sands, Columbia River estuary, July and September 1991. Sampling in August at Rice Island was limited to three beach seines and four purse seines.

Scientific name	Common name	Rice Island			Miller Sands	
		Jul	Aug	Sep	Jul	Sep
Acipenseridae						
Acipenser transmontanus	White sturgeon	x	x			
Clupeidae						
Alosa sapidissima	American shad		x	x		x
Salmonidae						
Oncorhynchus kisutch	Coho salmon			x		
Oncorhynchus tshawytscha	Chinook salmon	x	x	x	x	x
Prosopium williamsoni	Mountain whitefish			x		
Osmeridae						
Hypomesus pretiosus	Surf smelt	x				
Cyprinidae						
Cyprinus carpio	Common carp				x	
Mylocheilus caurinus	Peamouth	x	x	x	x	x
Catostomidae						
Catostomus macrocheilus	Largescale sucker	x	x	x	x	x
Cyprinodontidae						
Fundulus diaphanus	Banded killifish		x	x	x	x
Gasterosteidae						
Gasterosteus aculeatus	Threespine stickleback	x	x	x	x	x
Cottidae						
Cottus asper	Prickly sculpin				x	
Leptocottus armatus	Pacific staghorn sculpin	x		x	x	x
Unidentified sculpin					x	x
Pleuronectidae						
Platichthys stellatus	Starry flounder	x	x	x	x	x
Decapoda						
Crangon franciscorum	California bay shrimp	x				x
	Total number of taxa	9	8	10	10	10

Appendix Table 5.--Summaries of individual beach and purse seine efforts (by station) conducted in July, August, and September 1991 at Rice Island and Miller Sands, Columbia River estuary (not included in basic report due to size; available upon request to NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121.