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Biological Surveys of the Trestle Bay Enhancement Project 1994, 1996-97

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EXECUTIVE SUMMARY

Trestle Bay is 11.3 RKm upstream from the mouth of the Columbia River in Oregon. The 244-ha bay consists of shallow subtidal and intertidal mudflats and intertidal marsh habitats. Trestle Bay formed as a result of the initial construction of the Columbia River south jetty which took place from 1885 to 1895. Sand accumulation around the jetty created the bay, which is surrounded by land on the west, south, and east sides and separated from the mainstem of the Columbia River by a 2,682-m rock jetty along the north side. Although the rock jetty is permeable to water, it has likely discouraged resident and migratory juvenile fishes (e.g., salmonids) from entering the bay.

In August 1995, the jetty was modified by removing a 152-m section of rock, creating an unobstructed passageway between the bay and the lower Columbia River estuary. This allowed better flushing and made Trestle Bay available as foraging habitat for many marine and estuarine fishes and shellfish, and ultimately reestablished the bay as an integral part of the lower Columbia River estuarine ecosystem. In 1994, the U.S. Army Corps of Engineers contracted with the National Marine Fisheries Service to conduct pre- (1994) and post-breach (1996-97) surveys in and adjacent to Trestle Bay, to determine any physical or biological changes caused by the jetty breach.

Resource agencies were particularly interested in the use of the bay by juvenile salmonid species and changes in their benthic and epibenthic invertebrate prey after the breach. This is a concern because the Columbia River is critical habitat for several endangered salmonid species. Biological sampling was conducted to assess benthic and epibenthic invertebrate populations, fish species compositions, and sediment characteristics before and after the jetty was breached. Sampling was also conducted outside and adjacent to Trestle Bay to provide reference information.

Estuaries and associated wetlands provide critical habitat for many marine and estuarine fish and shellfish species. The primary producers (algae and eelgrass) within these areas provide extensive cover and foraging habitat. Prior to the jetty breach, biological surveys within Trestle Bay found very high densities of benthic and epibenthic invertebrate species that are prey for many fishes that rear in the Columbia River estuary, yet few of those fishes were found inside the bay. In particular, no juvenile salmonids were captured in the bay during the pre-breach sampling period.

The effects of jetty modification were most apparent in the benthic invertebrate and fish populations in Trestle Bay, although the effects were difficult to discern because of confounding interactions. For benthic invertebrates, the decline in pre-breach to post-breach density inside the bay was more than twice that of the decline outside the bay, indicating a causal factor other than normal natural variation. Possibilities include either increased foraging activities by fishes after the jetty breach, or there was a physical disruption of the fauna related to a sustained freshwater flood that reduced salinities. For fishes, more species were common between the two sampling

areas (in Trestle Bay and in the reference area) during post-breach surveys than during pre-breach surveys. This indicates that the jetty acted as a barrier, ultimately affecting the ability or willingness of some fish species to enter and utilize the Bay as foraging habitat. Juvenile salmonids, for example, were captured inside Trestle Bay only in surveys conducted after the jetty was breached. Fish densities were also more similar between the two sampling areas after the jetty was breached.

Although epibenthic invertebrate densities declined from 1994 to 1997, the breach did not appear to affect them significantly. Similarly, sediment characteristics remained essentially unchanged between the pre- and post-breach surveys.

The Trestle Bay project provided a rare opportunity to return ecologically functioning estuarine marshes, intertidal, and shallow subtidal habitats back to an estuary. The primary goal of restoring fish access to the bay, particularly for salmonids which could include federally listed endangered and threatened salmonid species, appears to have been met. Resource agencies should continue to look for similar project sites that could be modified at minimum cost, yet have long-term benefits for associated ecosystems.

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INTRODUCTION

Trestle Bay is a 244-ha (603 acre) area consisting of shallow subtidal and intertidal mudflats and intertidal marsh habitats located in the northwest corner of Oregon, near the mouth of the Columbia River, at River Kilometer (RKm) 11.3. The bay is bordered on the south, west, and east by Fort Stevens State Park and to the north by the Columbia River estuary (Fig. 1). Trestle Bay formed after the initial construction of the Columbia River south jetty was completed (1885 to 1895). The placement of the jetty caused sand to accumulate near its base, resulting in the formation of Clatsop Spit and Trestle Bay. The development of Clatsop Spit ultimately shifted the operational portion of the south jetty 3 miles toward the west of the original jetty base. Trestle Bay lies between the Clatsop Spit formation and the original jetty base. Approximately 2,682 m (8,800 ft) of the South Jetty separates Trestle Bay from the Columbia River. Although permeable to water the large rock jetty can hinder the export of detritus from the marshes to the river, and seemed to discourage passage into the bay by juvenile fishes residing in the lower Columbia River estuary.

In the late 1980s, discussions began among local groups and regional and national agency representatives regarding a modification to the south jetty to restore fish access into Trestle Bay. The intent of the modification (breaching the jetty) would be to create a passage between the bay and the lower Columbia River estuary, permitting better water exchange, making foraging habitat available for many marine and estuarine fishes and shellfishes, and ultimately reestablishing Trestle Bay as an integral part of the lower Columbia River estuarine ecosystem. In 1995, the Trestle Bay Enhancement Project, as it had become known, was determined to meet the requirements under Section 1135(b) of the Authority of the Water Resources Development Act (namely, the project entailed the physical modification of a structure operated and maintained by the COE). The act also has streamlined requirements regarding reporting and implementation compared to other processes and requires a local non-federal sponsor to share 25% of the total cost. The Oregon Parks and Recreation Department agreed to take the cost-sharing responsibility.

In 1995, with local, state, and federal agencies in agreement, the COE issued a contract for modification of the jetty structure near the original base to take place in the form of a breach, which occurred in August 1995. The breach consisted of lowering a 152-m portion of the jetty to 1.7 m below mean sea level, and placing the removed stone in three mounds 18-30 m riverward of the existing structure.

In 1994, the COE contracted the National Marine Fisheries Service (NMFS) to conduct biological surveys in and adjacent to Trestle Bay. Because the Columbia River is recognized as critical habitat for salmonids including several listed and endangered species, particular interest was placed on use of the bay by juvenile salmonids and their benthic and epibenthic invertebrate prey. Sampling consisted of assessing benthic and epibenthic invertebrate populations, fish species compositions, and sediment characteristics inside and outside Trestle Bay before and after the jetty was breached.

METHODS

Sampling

Fish, benthic and epibenthic invertebrate, and sediment sampling station locations (latitude and longitude) were established using a Global Positioning System, which allowed stations to be easily reoccupied (Appendix Table 1).

Benthic Invertebrates and Sediment

Thirteen stations inside and three stations outside Trestle Bay were sampled for benthic invertebrates and sediments (Fig. 1). Benthic invertebrate samples were collected in April, June, and August of 1994 and 1997. Sediment samples were collected in August 1993, April and June 1994, and June and August 1997. A polyvinyl chloride (PVC) coring device with an inside diameter of 3.85 cm and a penetrating depth of 15 cm (volume of 174.6-cm^3) was used to collect benthic invertebrate and sediment samples (Hinton et. al 1995). Samples were collected by scuba diving or snorkeling. For benthic invertebrates, ten core samples (replicates) from each station 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, organisms were sorted from the remaining residue, identified to the lowest practical taxon/category (category represents a group of related organisms), counted, and stored in vials with 70% ethanol. One sediment sample from each station was placed in a labeled plastic bag and refrigerated until delivery to COE North Pacific Division Materials Laboratory, Troutdale, Oregon, and AGRA Earth & Environmental, Inc., Portland, Oregon, for grain size and percent organics analyses.

Epibenthic Invertebrates

Thirteen stations inside and three stations outside the bay were sampled for epibenthic invertebrates (Fig. 1). Sampling occurred in April, June, and August of 1994 and 1997. These invertebrates were collected using an epibenthic pump that consisted of a base (15.2-cm diameter by 25.4-cm-high PVC pipe with 10 3.8-cm holes covered with 130-micron nitex screen), a bilge pump, and a 3.05-meter handle made from 3.2-cm PVC pipe with a control switch at the upper end. The epibenthic pump sampled an area of approximately 181.5 cm^2.. The bilge pump was powered by a 12-volt battery, and the outflow was filtered through a 130-micron plankton net. Each sample consisted of placing the pump base vertically on the bottom while pumping water through a plankton net for 1 minute. The plankton net was then washed down and the residue collected in the cup was placed in a labeled jar and preserved with a formaldehyde solution. In the laboratory, organisms were sorted, identified to the lowest practical taxon, counted, and stored in 70% alcohol. Three replicates were taken at each station.

Fishes

In 1994 (pre-breach) and 1997 (post-breach), fishes were sampled monthly, May through September, at seven purse-seine stations inside and three stations outside the bay, as well as three trapnet stations inside the bay (Fig. 2). In 1996 (post-breach), only stations inside the bay were sampled. Because of the shallow and confined nature of the bay prior to the jetty breach, options for sampling fishes were limited. Therefore a small shallow-water purse seine was designed to effectively sample the area. The purse seine was 36.6 by 3.4 m with variable mesh (9.5-, 12.7-, and 19.0-mm stretched) and knotless web in the bunt to reduce descaling. The purse seine sampled an area of approximately a 106.5 m^2. The sampling was conducted using the round-haul technique. One end of the seine was held in place by an anchor and deployed by backing away in a large circle while feeding the net off a platform on the bow of the boat. Once the circle was complete the net was pursed and brought back onboard in a manner that collected the fish in the bunt. Fishes were then quickly transferred to tubs for holding until they could be processed.

Three trapnet stations were established inside Trestle Bay (Fig. 2). The nets were attached to pilings (inside the bay) adjacent to the rock jetty and extended perpendicular to the jetty. Each trapnet consisted of six collapsible frames, constructed as follows: the lead wing was 15.2 m long by 0.9 m high with 19.0-mm stretched mesh; the body was 4.9 m long and consisted of two 1.8- by 0.9-m rectangular metal frames followed by four 0.7-m-diameter circular frames; the frames were covered with 19.0-mm stretched knotless mesh. A 6.8-kg weight attached to the cod end held the net in position. Trapnets were set for approximately 24 hours. At retrieval, fishes were collected into the cod end and transferred to tubs for processing.

All captured fishes were identified to lowest practical taxonomic level, counted, and a maximum of 50 individuals of each species was measured (total length in mm). Juvenile salmonids were anesthetized using benzocaine (ethyl-*p*-aminobenzoate) solution prior to any handling and were allowed to fully recover before being released.

Data Analysis

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 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 from each sampling station.

Mean numbers of species and total benthic invertebrate densities were compared between areas (i.e., inside Trestle Bay and reference stations outside the bay) and years (i.e., pre- and post-jetty breach) using two-way analysis of variance (ANOVA) (Cruze and Hartzell 1991); invertebrate densities were transformed ($\log_{10}$) prior to performing the ANOVA. Statistical tests were performed on the means from the 10 samples collected at each station.

Epibenthic Invertebrates

Epibenthic invertebrate data were analyzed by station to determine species composition and densities (by taxon and total). Diversity (H) was also determined for each station. Means from the three samples collected at each station provided the data for analysis.

Mean numbers of species and total epibenthic invertebrate densities were compared between areas (i.e., inside Trestle Bay and reference stations outside the bay) and years (i.e., pre- and post-jetty breach) using two-way analysis of variance (ANOVA); epibenthic invertebrate densities were transformed ($\log_{10}$) prior to performing the ANOVA. Statistical tests were performed on the means from the three samples collected at each station.

Sediment

For each sediment sample, median grain size, percent silt/clay, and percent volatile solids were determined. No statistical comparisons were performed on the sediment characteristics because of the non-normal distribution of the data and the lack of a satisfactory data transformation.

Fishes

For each purse-seine station, individual species and total fish densities (number/ha) were determined using the catch data and area sampled. The two previously described community structure indices, H and E, were also calculated for each station.

Monthly mean numbers of species and densities (numbers/ha) were compared between areas (i.e., inside Trestle Bay and reference stations outside the bay) and years (i.e., pre- and post-jetty breach) using two-way analysis of variance (ANOVA); fish densities were transformed ($\log_{10}$ (density + 1)) prior to performing the ANOVA. Means were obtained by combining all stations for each area (seven in Trestle Bay, three outside the bay) by month.

RESULTS

Benthic Invertebrates

The total numbers of taxa/categories collected at benthic invertebrate sampling stations in Trestle Bay (three surveys/year) ranged from 12 to 22 in 1994, and 6 to 12 in 1997 (Table 1, Appendix Table 2). At the reference stations outside Trestle Bay, taxa/categories ranged from 8 to 18 in 1994 and 4 to 14 in 1997. Mean benthic invertebrate densities (number organisms/m^2) in Trestle Bay ranged from 58,068 to 356,653 in 1994, and 2,921 to 42,950 in 1997 (Table 2). At the reference stations, mean benthic invertebrate densities ranged from 5,068 to 114,332 in 1994, and 1,976 to 30,752 in 1997.

At sampling locations both inside and outside Trestle Bay, the number of taxa/categories and mean benthic invertebrate density both decreased significantly after the jetty breach (ANOVA, $P < 0.05$). Although areas inside the bay and in the outside reference area both showed a decreasing trend from 1994 to 1997, the decrease in benthic invertebrate densities was greater inside the bay than in the reference area. Some of the steeper decrease can be attributed to habitat changes caused by the breaching of the jetty (Appendix Fig. 1). Subtracting the decrease that could be attributed to natural variation (i.e., the differences between surveys observed in the reference area) indicated that benthic invertebrate densities inside the bay decreased by about one-half as a result of the jetty breach. A similar analysis indicated that there was a loss of three or four taxa from inside Trestle Bay that may be attributed to the breach.

Benthic invertebrate species compositions changed between the pre- and post-breach surveys both inside and outside the bay (Table 3). In Trestle Bay in 1994, the most abundant taxonomic category was Polychaeta, comprising 55% of the overall species composition, followed by Oligochaetes (24%) and Arthropoda (18%). In 1997, the most abundant taxonomic category in the bay was Arthropoda (46%) followed by Polychaeta (29%) and Oligochaeta (17%). Changes in the reference area species composition also occurred between years. In 1994, the most abundant benthic taxon was Oligochaeta (44%) followed by Polychaeta (37%), Arthropoda (8%), and Mollusca (7%). In 1997, dominant benthic taxa included Arthropoda (53%), Polychaeta (38%), and Mollusca (7%). Several dominant species in 1994 virtually disappeared by 1997. In the bay, these included the estuarine anemone *Nematostella vectensis*, the polychaetes *Pygospio elegans* and *Manyunkia aestuarina*, and the amphipod *Eogammarus confervicolus*. At the reference stations there were large changes in the numbers of Turbellaria, spionid polychaetes, and oligochaetes between 1994 and 1997.

Benthic invertebrate diversities (H) were similar between monthly surveys and areas within each year (Table 4). In 1994, station diversity ranged from 0.99 to 3.55 inside the bay, and 2.03 to 3.12 at the reference area. In 1997, H ranged from 1.28 to 2.93 inside the bay, and 1.12 to 3.02 at the reference area. Equitability (E) was also similar among surveys and areas for each year (Table 5). The mean E values for each survey and area indicated there were no dominant benthic invertebrate species. Mean equitability values in 1994 for each survey ranged from 0.52

Table 1. Numbers of taxa/categories of benthic invertebrate at sampling stations located in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	1994 Taxa/categories			1997 Taxa/categories		
Station	April	June	August	April	June	August
1	15	19	20	12	9	10
2	14	19	22	6	9	6
3	17	20	22	8	6	8
4	18	17	19	9	8	9
5	16	19	20	6	10	8
6	13	17	21	11	12	10
7	14	15	20	10	9	9
8	17	22	17	9	7	8
9	19	17	18	7	9	7
10	17	16	19	8	10	8
14	14	15	17	8	10	11
15	16	12	16	10	8	8
Mean	16	17	19	9	9	9
11c	13	18	18	6	14	11
12c	8	10	15	4	7	7
13c	11	12	16	6	8	9
Mean	11	13	16	5	10	9

Table 2. Mean densities (number/m^2) of benthic invertebrates at sampling stations in and djacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	1994			1997		
Station	April	June	August	April	June	August
1	226,344	250,310	128,075	21,045	18,468	42,950
2	138,383	109,435	152,728	6,185	17,867	24,395
3	88,304	198,942	278,742	15,634	11,596	12,627
4	132,199	153,759	91,912	9,707	7,645	17,008
5	87,188	191,898	209,078	2,921	11,425	41,403
6	58,240	142,506	146,458	9,019	28,604	23,966
7	101,704	151,698	140,789	10,480	12,885	23,107
8	70,867	192,414	58,068	9,191	5,498	8,934
9	87,016	163,208	63,565	7,130	11,081	14,345
10	65,455	165,270	103,251	2,577	12,971	6,614
14	137,267	201,691	84,525	8,075	11,511	15,204
15	356,653	256,065	200,832	7,817	21,647	32,040
Mean	129,135	181,433	138,169	9,148	14,267	21,883
11c	22,047	114,332	51,024	1,976	7,731	14,603
12c	7,387	16,235	36,507	3,780	8,160	30,752
13c	5,068	28,261	46,471	3,951	5,154	23,966
Mean	11,501	52,942	44,667	3,236	7,015	23,107

Table 3. Summary of densities (mean number/m^2) for major benthic invertebrate taxa found in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Monthly surveys (April, June, and August) were combined for each year and area. Stations 1-10, 14, and 15 were located inside the bay; and Reference Stations (Ref.) 11c-13c were located outside and adjacent to the bay.

Taxon	1994 Inside	1997 Inside	1994 Ref.	1997 Ref.
Nemertea	55	12	917	105
Turbellaria	644	346	820	0
Cnidaria				
Edwardsiidae				
Nematostella vectensis	2,725	0	0	0
Polychaeta				
Spionidae unidentified juveniles	549	0	7,422	0
Polydora cornuta	1,432	14	1,419	10
Pygospio elegans	8,199	0	183	10
Hobsonia florida	25,483	2,420	212	10
Neanthes limnicola	4,030	1,489	1,535	3,923
Pseudopolydora kempi	165	2	1,815	153
Sabellidae				
Manayunkia aestuarina	41,728	439	0	0
Miscellaneous Polychaeta (11 categories)	140	2	869	95
Oligochaeta	35,703	2,627	16,137	153
Mollusca				
Bivalvia	258	267	1,506	258
Macoma balthica	1,370	453	801	496
Miscellaneous Mollusca (3 categories)	0	2	116	20
Arthropoda				
Copepoda				
Coullana canadensis	4,765	2	328	0
Cumacea				
Nippoleucon hinumensis	4,367	2,952	116	277
Amphipoda Gammaridae				
Eogammarus confervicolus	4,818	158	154	10
Eohaustorius estuaris	0	12	2,037	1,966
Corophium spp.	3,052	181	0	181
Corophium salmonis	1,501	2,076	19	3,407
Corophium spinicorne	7,244	1,627	10	19
Miscellaneous Arthropoda (8 categories)	1,345	7	116	29
Insecta (5 categories)	31	9	0	0
Mean total	149,604	15,097	36,532	11,122

Table 4. Diversities (H) of benthic invertebrates at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	1994			1997		
Station	April	June	August	April	June	August
1	0.99	2.61	2.79	2.77	2.25	2.50
2	2.45	2.81	3.41	1.89	1.42	1.28
3	2.35	2.31	2.65	1.49	1.40	1.58
4	1.73	2.18	3.23	2.49	2.41	2.46
5	2.44	2.78	2.58	1.70	2.48	1.85
6	2.28	2.98	3.23	2.93	2.77	2.51
7	2.09	2.72	3.55	2.42	2.09	2.34
8	2.46	2.64	2.83	2.83	2.34	2.50
9	2.27	2.49	2.72	1.81	2.46	2.02
10	2.56	2.55	2.87	2.76	2.67	2.33
14	1.46	2.58	2.51	2.55	1.96	2.63
15	1.64	2.13	2.84	2.69	2.11	1.83
Mean	2.06	2.57	2.93	2.36	2.20	2.15
11c	2.59	2.09	2.95	2.19	3.02	1.84
12c	2.34	2.03	2.26	1.14	2.24	1.63
13c	2.96	2.28	3.12	1.12	1.59	1.85
Mean	2.63	2.13	2.78	1.48	2.28	1.77

Table 5. Equitabilities (E) of benthic invertebrates at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

Station	1994			1997		
	April	June	August	April	June	August
1	0.25	0.61	0.65	0.77	0.71	0.75
2	0.64	0.66	0.76	0.73	0.45	0.49
3	0.58	0.53	0.59	0.50	0.54	0.53
4	0.42	0.53	0.76	0.79	0.80	0.78
5	0.61	0.65	0.60	0.66	0.75	0.62
6	0.62	0.73	0.73	0.85	0.77	0.76
7	0.55	0.70	0.82	0.73	0.66	0.74
8	0.60	0.59	0.69	0.89	0.83	0.83
9	0.53	0.61	0.65	0.65	0.78	0.72
10	0.63	0.64	0.67	0.92	0.80	0.78
14	0.38	0.66	0.60	0.85	0.59	0.76
15	0.41	0.59	0.71	0.81	0.70	0.61
Mean	0.52	0.63	0.69	0.76	0.70	0.70
11c	0.70	0.50	0.75	0.85	0.79	0.53
12c	0.78	0.61	0.56	0.57	0.80	0.58
13c	0.86	0.63	0.76	0.43	0.53	0.58
Mean	0.78	0.58	0.69	0.62	0.71	0.56

to 0.69 in the bay and 0.58 to 0.78 in the reference area. Mean values in 1997 for each survey ranged from 0.70 to 0.76 in the bay and 0.56 to 0.71 in the reference area.

Summaries by station for benthic invertebrate surveys are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR, 97121-0155.

Epibenthic Invertebrates

The mean numbers of epibenthic invertebrate taxa/categories (by monthly survey) were slightly lower in 1997 than in 1994 for both Trestle Bay and the reference areas (Table 6, Appendix Table 3). In 1994, mean numbers of taxa ranged from 24 to 31 per station, whereas in 1997 mean numbers ranged from 20 to 27 per station. Mean epibenthic densities were higher in 1994 than in 1997 in both the bay and the reference area. Mean epibenthic densities in 1994 ranged from 51,876 to 119,894 organisms/m^2, and in 1997 from 19,591 to 36,056 organisms/m^2 (Table 7).

There were no significant differences in taxa/categories or densities when comparing results from the pre- and post-breach surveys for areas inside and outside Trestle Bay (ANOVA $P > 0.05$) (Appendix Fig. 2). Therefore, changes in epibenthic species and densities were within the natural variation of these communities, and the jetty breach had no significant effect.

Although taxa/categories were similar in Trestle Bay and the reference area, there were differences in mean epibenthic densities when comparing the same areas and the two surveys (1994 and 1997) (Table 8). Nearly every taxon/category showed a reduction in densities between 1994 and 1997, with the exception of a few harpacticoid and cyclopoid copepod species. Crustaceans, primarily unidentified juvenile copepod nauplii and harpacticoids, remained the dominant taxonomic categories each year, comprising 56-84% of the overall epibenthic densities for both areas.

Epibenthic diversity (H) values were generally higher in 1994 than in 1997 for stations in Trestle Bay and in the reference area (Table 9). In the bay, mean H values ranged from 3.08 to 3.35 in 1994, and 2.19 to 2.61 in 1997. At the reference area, mean H values were 2.33 to 3.05 in 1994, and 1.90 to 2.50 in 1997.

Summaries by station for epibenthic invertebrate surveys are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR, 97121-0155.

Table 6. Numbers of taxa/categories of epibenthic invertebrates at sampling stations in and adjacent to trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

Station	1994			1997		
	April	June	August	April	June	August
1	26	26	24	17	26	20
2	24	24	29	21	20	20
3	24	24	23	15	19	25
4	23	28	24	14	30	28
5	29	27	27	19	32	15
6	36	32	19	21	23	19
7	25	28	27	16	26	19
8	32	27	19	20	34	20
9	24	25	26	27	25	22
10	28	23	25	22	28	24
14	26	27	28	19	24	18
15	20	27	21	23	32	25
Mean	26	27	24	20	27	21
11c	29	35	29	25	26	22
12c	28	24	26	21	27	32
13c	22	33	21	27	27	27
Mean	26	31	25	24	27	27

Table 7. Mean densities (number/m^2) of epibenthic invertebrates at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). the jetty was breached in August 1995. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	1994			1997		
Station	April	June	August	April	June	August
1	33,593	56,667	76,481	17,333	46,463	31,593
2	24,074	68,093	134,852	18,444	39,111	29,648
3	66,315	88,611	95,519	21,000	23,167	35,296
4	107,574	104,370	69,333	17,019	26,685	17,278
5	25,741	62,519	19,593	4,278	13,333	4,241
6	70,130	62,259	102,704	15,667	3,111	10,481
7	22,722	34,093	152,074	21,185	31,926	17,852
8	60,444	61,593	162,833	16,333	82,407	6,704
9	96,148	58,593	307,630	30,574	32,593	20,963
10	17,204	154,907	92,389	19,704	55,852	12,370
14	138,852	46,296	94,556	67,722	54,833	11,870
15	38,759	13,389	130,759	148,019	23,185	36,796
Mean	58,463	67,616	119,894	33,107	36,056	19,591
11c	125,945	41,907	50,870	34,944	37,278	20,537
12c	64,889	64,907	86,611	19,759	35,074	34,185
13c	144,741	48,815	55,296	27,352	21,407	22,889
Mean	111,858	51,876	64,259	27,352	31,253	25,870

Table 8. Summary of densities (mean number/m^2) for major epibenthic invertebrate taxa/categories found in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Monthly surveys (April, June, and August) were combined for each year and area. Stations 1-10, 14, and 15 were located inside the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	Mean number/m^2			
Taxa/categories	1994 Inside	1997 Inside	1994 Control	1997 Control
Rotifera	1,647	437	4,025	654
Platyhelminthes				
Turbellaria	3,672	83	722	167
Nematoda	17,088	982	5,025	807
Annelida				
Oligochaeta	1,785	497	1,173	632
Polychaeta				
Spionidae	2,887	67	5,809	74
Hobsonia florida	3,214	362	62	0
Manayunkia aestuarina	1,362	197	4	0
Misc. Polychaeta (3 categories)	536	37	319	208
Crustacea				
Branchiopoda				
Cladocera (11 categories)	27	198	9,702	293
Copepoda				
Unidentified nauplii	5,308	3,494	13,595	6,321
Calanoida	48	1,779	78	6,418
Eurytemora affinis	673	368	1,706	2,749
Misc. Calanoida (4 categories)	48	51	0	15
Harpacticoida				
Unidentified nauplii	11,081	3,756	6,543	899
Coullana canadensis	1,663	488	1,570	638
Pseudobradya sp.	1,935	5,050	2,850	3,685
Microarthridion littorale	1,521	7,129	253	247
Tachidius triangularis	8,674	984	9,988	681
Paronychocamptus cf. *huntsmani*	8,420	419	148	2
Mesochra sp.	1,118	9	74	2
Limnocletodes behningi	823	314	47	6
Misc. Hapacticoida (13 categories)	938	429	9,613	353

Table 8. Continued.

Taxa/categories	1994 Inside	1997 Inside	1994 Control	1997 Control
	Mean number/m^2			
Cyclopoida				
Cyclopoida unidentified nauplii	18	43	60	105
Halicyclops sp.	3,753	3	12	0
Diacyclops thomasi	20	79	49	130
Misc. Cyclopoida (5 categories)	14	176	1,422	74
Cirripedia				
Balanomorpha nauplii	1,380	406	239	2,774
Balanomorpha cyprids	11	0	41	2
Malacostraca				
Cumacea				
Nippoleucon hinumensis	376	149	68	15
Cumella vulgaris	1	0	2	0
Amphipoda				
Eogammarus confervicolus	668	27	17	0
Corophium spinicorne	511	8	0	12
Misc. Amphipoda (3 categories)	12	64	4	16
Miscellaneous (17 categories)	760	1,543	776	179
Mean total	81,991	29,588	75,998	28,158

Table 9. Diversities (H) of epibenthic invertebrates at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). The jetty was breached in August 1995. Stations 1-10, 14, and 15 were located in side the bay, and Stations 11c-13c were located outside and adjacent to the bay.

	1994			1997		
Station	April	June	August	April	June	August
1	3.10	3.53	3.21	1.93	1.61	2.10
2	3.60	3.73	3.59	1.76	2.04	3.21
3	3.20	2.81	2.80	2.03	1.25	3.35
4	3.06	2.40	2.64	2.55	2.36	1.55
5	3.20	3.77	3.23	2.81	3.52	2.48
6	2.76	3.41	2.74	1.54	2.96	1.47
7	2.86	3.54	3.47	1.80	2.04	1.94
8	3.31	3.61	3.29	2.13	2.49	2.25
9	3.03	3.64	2.80	3.04	3.61	2.28
10	3.47	2.35	3.15	2.89	3.82	2.29
14	2.94	3.56	3.03	2.02	2.07	1.76
15	2.38	3.84	3.09	2.42	3.53	1.62
Mean	3.08	3.35	3.09	2.24	2.61	2.19
11c	2.48	2.64	2.68	2.20	1.72	2.71
12c	2.96	3.17	2.18	2.10	2.07	2.27
13c	2.93	3.34	2.14	2.62	1.91	2.52
Mean	2.79	3.05	2.33	2.31	1.90	2.50

Sediment

With few exceptions, sediment characteristics (median grain size, percent silt/clay, and percent volatile solids) remained fairly constant at each station during the pre- and post-breach studies (Fig. 3). Even though median grain size varied at each station for each survey, the sediment type usually remained the same (Appendix Tables 4-6). Percentages of silt/clay and volatile solids were higher in sediment from inside Trestle Bay than in the reference area because of the reduced currents and water circulation in the bay. There were no apparent effects of the jetty breach on sediment characteristics in the bay or reference area.

Fishes

In 1994 (pre-breach), monthly mean numbers of fish and shellfish species collected at each purse-seine sampling station ranged from two to three in Trestle Bay and one to three at the reference stations (Table 10, Appendix Table 7). Monthly mean fish species numbers during the two post-breach studies in the bay ranged from two to three, and from three to four at the reference stations (1997 only). There was no significant difference in the number of species between pre- and post-breach surveys for either of the two areas (Appendix Fig. 3).

Monthly mean fish and shellfish densities (number/hectare) in Trestle Bay varied most during the pre-breach study (1,698 to 25,606) (Table 11). During the two post-breach studies (1996-97), mean fish and shellfish densities were less variable between months and years (876 to 2,655). Variation in mean monthly fish and shellfish densities during the pre-breach survey was primarily a result of the large number of threespine sticklebacks (*Gasterosteus aculeatus*) that were captured in September 1994 (Table 12).

In Trestle Bay, Dungeness crab (*Cancer magister*) was the only species captured by purse seine in 1994 that was not found in 1996 or 1997. However the following eight species were captured during one or both of the post-breach studies and not in 1994: American shad (*Alosa sapidissima*), Pacific herring (*Clupea pallasi*), chinook salmon (*Oncorhynchus tshawytscha*), juvenile smelt (Osmeridae), banded killifish (*Fundulus diaphanus*), largemouth bass (*Micropterus salmoides*), larval flatfish (Pleuronectidae), and yellow shore crab (*Hemigrapsus oregonensis*)(Table 12). Densities of Pacific herring and surf smelt (*Hypomesus pretiosus*) were underestimated, in the post-breach surveys, particularly in 1997, because nearly all the individuals of these two species were approximately 2-3 months old (postlarval stage) and readily swam through the 9.5- to 19.0-mm mesh of the purse seine. Length-frequency histograms for Pacific herring showed that most were 30-65 mm long (Appendix Fig. 4).

At the reference stations, mean monthly fish and shellfish densities were usually lower than in Trestle Bay, ranging from 220 to 3,900 in 1994 and 817 to 1,509 in 1997 (Table 11). Although similar species were caught between the pre- and post-breach studies, the proportional abundances of those species changed (Table 13). In 1994, shiner perch (*Cymatogaster*

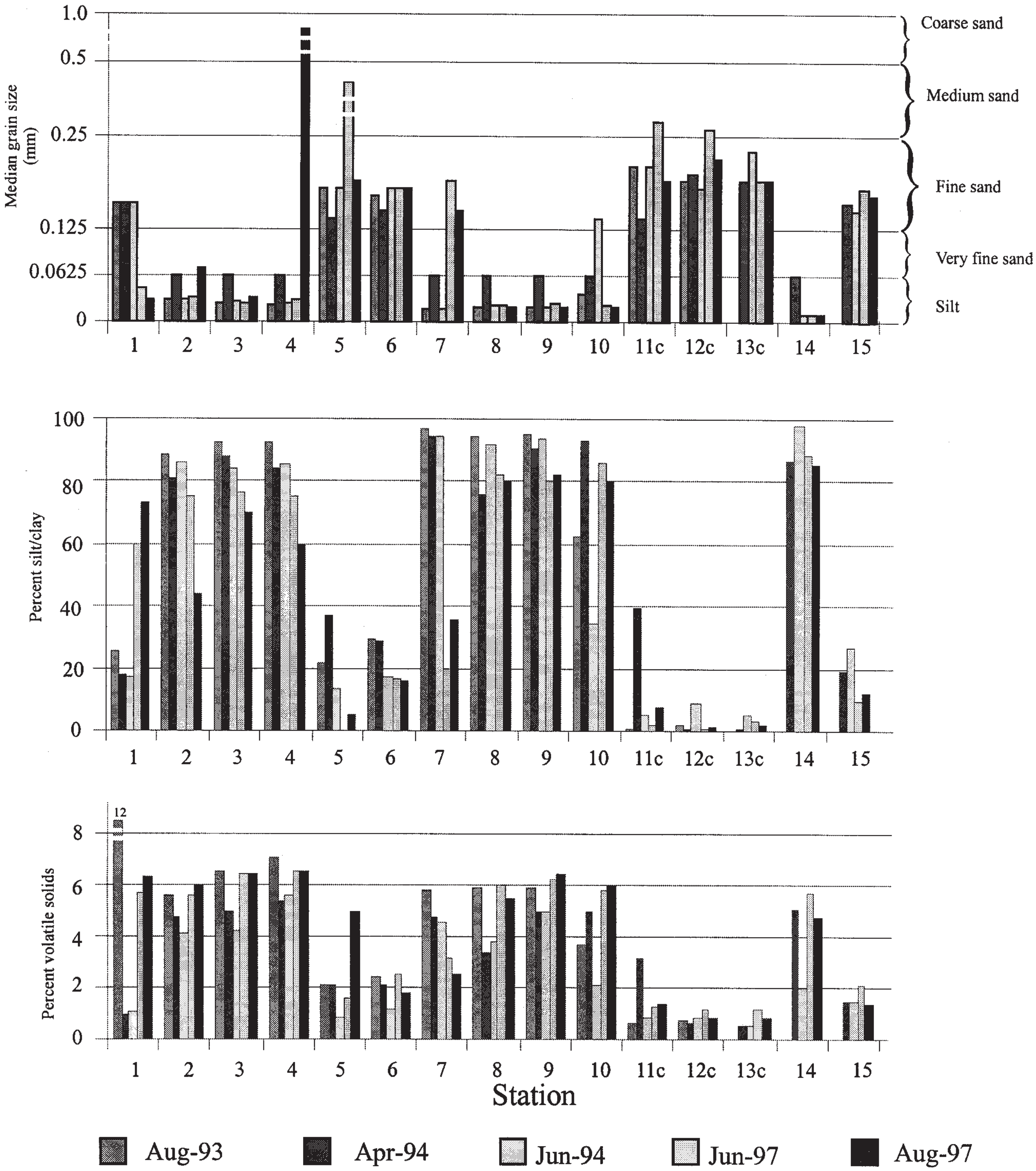

Figure 3. Median grain size, percent silt/clay, and percent volatile solids at sediment sampling stations located in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted August 1993, April and June 1994 (pre-breach), and June and August 1997 (post-breach). Stations 1-10, 14, and 15 were located inside the bay, and Stations 11C-13C were located outside and adjacent to the bay. The jetty was breached in August 1995.

Table 10. Numbers of fish and shellfish species collected by purse seine at sampling stations in and adjacent to Trestle Bay(RKm 11.3), Columbia River estuary. Sampling was conducted May-September 1994 (pre-breach), 1996, and 1997 (post-breach). The jetty was breached in August 1995. Stations P1-P7 were located inside the bay, and Stations PE, PM and PW were located outside and adjacent to the bay.

Station	May			June			July			August			September		
	94	96	97	94	96	97	94	96	97	94	96	97	94	96	97
							Inside								
P1	4	4	3	3	3	3	2	2	5	3	1	2	3	4	1
P2	4	2	3	2	4	4	2	1	4	3	3	6	3	2	4
P3	3	3	3	2	3	3	3	2	1	2	2	0	1	1	3
P4	2	2	4	2	2	5	3	3	5	3	6	4	3	5	5
P5	4	3	5	3	1	6	*	2	3	6	2	6	3	2	5
P6	3	2	2	1	2	3	1	3	3	3	2	2	2	1	1
P7	4	2	4	2	1	2	2	1	4	2	3	0	2	3	3
Mean	3	3	3	2	2	4	2	2	4	3	3	3	2	3	3
							Control								
PE	0	*	4	4	*	3	6	*	5	5	*	3	1	*	5
PM	1	*	4	2	*	3	2	*	3	0	*	4	1	*	2
PW	2	*	4	2	*	3	0	*	3	1	*	4	2	*	2
Mean	1	*	4	3	*	3	3	*	4	2	*	4	1	*	3

* station not sampled.

Table 11. Densities (numbers/hectare) of fish and shellfish species collected by purse seine at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted May-September, 1994 (pre-breach), 1996, and 1997 (post-breach). The jetty was breached in August 1995. Stations P1-P7 were located inside the bay, and Stations PE, PM and PW were located outside and adjacent to the bay.

Station	May			June			July			August			September		
	94	96	97	94	96	97	94	96	97	94	96	97	94	96	97
Inside															
P1	1,320	5,565	3,302	660	2,642	3,207	1,415	566	1,981	1,414	755	1,132	1,603	1,791	189
P2	1,603	2,925	661	4,057	3,113	1,226	2,264	1,321	660	1,981	1,131	13,395	17,170	283	1,792
P3	565	471	2,169	566	1,698	660	565	754	283	1,698	188	94	7,736	94	2,735
P4	944	1,132	1,792	8,962	1,226	2,264	5,943	848	1,887	23,396	5,754	660	124,622	3,207	755
P5	1,132	943	5,849	2,642	755	4,056	*	1,698	377	16,698	1,132	303	13,679	1,038	4,810
P6	849	943	472	660	566	943	283	472	2,075	8,491	1,981	660	9,434	94	755
P7	5,471	1,132	1,415	283	189	1,698	2,547	472	943	1,981	7,641	94	5,000	2,264	565
Mean	1,698	1,873	2,237	2,547	1,456	2,008	2,170	876	1,172	7,947	2,655	2,334	25,606	1,253	1,657
Control															
PE	0	*	1,415	5,566	*	1,792	1,886	*	1,415	5,943	*	1,697	94	*	1,320
PM	283	*	1,887	755	*	472	660	*	377	0	*	1,132	283	*	188
PW	378	*	1,226	5,378	*	1,132	0	*	660	283	*	1,132	377	*	1,509
Mean	220	*	1,509	3,900	*	1,132	849	*	817	2,075	*	1,320	251	*	1,006

* Station not sampled.

Table 12. Densities (number/hectare) by year of fish and shellfish captured by purse seine in Trestle Bay (RKm 11.3), Columbia River estuary. Totals are the average for each year (five months, May-September, seven stations/month). Sampling was conducted in 1994, 1996, and 1997. The jetty was breached in August 1995.

Scientific name	Common name	Mean number/hectare		
		1994	1996	1997
Alosa sapidissima	American shad**	0	11	3
Clupea pallasi	Pacific herring**	0	334	49
Oncorhynchus tshawytscha	Chinook salmon (<1yr)**	0	22	172
Hypomesus pretiosus	Surf smelt	8	78	210
Osmeridae	Unid. juv. smelt**	0	5	0
Fundulus diaphanus	Banded killifish**	0	0	3
Gasterosteus aculeatus	Threespine stickleback	7,489	787	375
Syngnathus leptorhynchus	Bay pipefish	33	3	0
Micropterus salmoides	Largemouth bass**	0	0	3
Cymatogaster aggregata	Shiner perch	75	13	439
Pholis ornata	Saddleback gunnel	50	19	8
Cottus asper	Prickly sculpin	8	3	3
Leptocottus armatus	Pacific staghorn sculpin	308	323	318
Pleuronectidae	Larval flatfish**	0	0	11
Platichthys stellatus	Starry flounder	30	8	275
Cancer magister	Dungeness crab*	164	0	0
Hemigrapsus oregonensis	Yellow shore crab**	0	16	43

* Only found in 1994 (pre-breach).
**Only found in 1996 and/or 1997 (post-breach).

Table 13. Densities (number/hectare) by year of fishes captured by purse seine at the reference area outside Trestle Bay (RKm 11.3) Columbia River estuary. Totals are the average for each year (five months, May-September, three stations/month). Sampling was conducted in 1994 and 1997. No purse seine sampling was conducted in the reference area in 1996. The jetty was breached in August 1995.

Scientific name	Common name	Mean number/hectare		
		1994	1996	1997
Alosa sapidissima	American shad**	0	-	6
Oncorhynchus tshawytscha	Chinook salmon (<1 year)	6	-	377
Oncorhynchus kisutch	Coho salmon**	0	-	19
Oncorhynchus mykiss	Steelhead	<1		6
Hypomesus pretiosus	Surf smelt**	0	-	283
Cymatogaster aggregata	Shiner perch	673	-	126
Pholis ornata	Saddleback gunnel	50	-	6
Gasterosteus aculeatus	Threespine stickleback	31	-	38
Ammodytes hexapterus	Pacific sandlance*	19	-	0
Scorpaenichthys marmoratus	Cabezon*	13	-	0
Leptocottus armatus	Staghorn sculpin	138	-	75
Parophrys vetulus	English sole*	346		0
Platichthys stellatus	Starry flounder**	0	-	188
Cancer magister	Dungeness crab	182	-	6
Hemigrapsus oregonensis	Yellow shore crab**	0	-	25

* Only found in 1994 (pre-breach).
**Only found in 1997 (post-breach).

aggregata) and English sole (*Parophrys vetulus*) were the dominant species, while in 1997 subyearling chinook salmon and surf smelt were the most abundant species. Three species were captured by purse seine at the reference stations only in 1994: Pacific sandlance (*Ammodytes hexapterus*), cabezon (*Scorpaenichthys marmoratus*), and English sole. Five species were captured only in 1997: American shad, coho salmon (*Oncorhynchus kisutch*), surf smelt, starry flounder (*Platichthys stellatus*), and yellow shore crab.

Fish densities (numbers/hectare) were significantly different ($P < 0.05$) between the pre- and post-breach surveys for both areas. This was primarily a result of the decline in fish densities inside the bay and indicates that the breach affected fish. Although fish densities in Trestle Bay decreased between surveys, fish densities in the outside reference area increased (Appendix Fig. 3). The significant decline in density in Trestle Bay was most likely influenced by the large number of threespine sticklebacks captured in 1994 that were not observed in 1997. As such, it is difficult to determine the degree of impact that the jetty breach had on fish densities inside Trestle Bay because they naturally are highly variable and are influenced by many biotic and abiotic factors (i.e., species schooling tendencies, recruitment success, sampling gear efficiency, etc.). However, some effect is seen in the commonality of fish species observed between the two areas before and after the breach occurred. During the 1994 sampling period, 55% of the fish species observed in the bay were also found outside the bay, whereas in 1997, 80% of the fish species were common between the two areas.

Diversity (H) was low for both sampling areas and for all surveys, ranging from 0.27 to 1.58 (Table 14). The low values are a result of few fish species captured at each station, and the occasional sampling efforts when no fish were captured. Mean monthly values for Equitability (E) in Trestle Bay for all surveys ranged from 0.24 to 0.81, with most values less than 0.60. The lower values indicate that the number of individuals captured were not equally distributed between species (Table 15). E values were also influenced by sampling efforts that produced no fish.

Total numbers of fishes captured by trapnets (three stations combined for five sampling months) were similar between the pre- (1994) and post-breach (1997) studies (Table 16, Appendix Table 8). Even though six of the 18 fish and shellfish species found in trapnets were found throughout all three studies, the overall numbers of those species varied between surveys. There were large declines between the pre- and post breach studies in numbers of threespine stickleback, Pacific staghorn sculpin, and Dungeness crab. Shiner perch was the only fish species that had a major increase in abundance from 1994 to 1997. Monthly length-frequency histograms of shiner perch revealed a similar growth pattern for each year, suggesting that they consistently used Trestle Bay as rearing habitat (Appendix Figs. 5-7)

Summaries by station for fish surveys are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR, 97121-0155.

Table 14. Diversities (H) of fish and shellfish captured by purse seine at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted May-September, 1994, 1996, and 1997. The jetty was breached in August 1995. Stations P1-P7 were located inside the bay, and Stations PE, PM, and PW were located outside and adjacent to the bay.

Station	May			June			July			August			September		
	94	96	97	94	96	97	94	96	97	94	96	97	94	96	97
Inside															
P1	1.09	1.34	0.96	1.38	1.09	1.05	0.92	0.65	1.70	0.70	0.00	0.41	0.98	0.88	0.00
P2	1.14	0.99	1.56	0.74	1.32	1.78	0.41	0.00	1.84	0.86	0.82	0.74	0.95	0.92	1.46
P3	1.25	1.37	0.51	0.65	0.80	1.45	1.25	0.54	0.00	0.31	1.00	0.00	0.00	0.00	0.43
P4	0.72	0.92	1.57	0.34	0.39	1.90	0.39	0.99	2.04	0.13	1.22	1.84	0.02	0.89	2.25
P5	1.73	1.30	1.19	0.73	0.00	2.30	*	0.65	1.50	0.42	0.41	1.80	0.33	0.99	0.55
P6	1.22	0.97	0.97	0.00	0.65	1.30	0.00	1.52	1.22	0.24	0.28	0.99	0.08	0.00	0.00
P7	0.67	0.41	1.43	0.92	0.00	0.50	0.76	0.00	1.69	0.28	0.38	0.00	0.14	1.14	1.25
Mean	1.12	1.04	1.17	0.68	0.61	1.47	0.62	0.62	1.43	0.42	0.59	0.83	0.36	0.69	0.85
Control															
PE	**	*	1.24	0.78	*	0.59	1.83	*	1.86	0.88	*	0.61	0.00	*	1.99
PM	0.00	*	1.69	0.81	*	1.52	0.59	*	1.50	**	*	1.42	0.00	*	1.00
PW	1.00	*	1.35	0.88	*	1.04	**	*	1.38	0.00	*	1.61	0.81	*	0.95
Mean	0.33	*	1.43	0.82	*	1.05	0.81	*	1.58	0.29	*	1.21	0.27	*	1.31

* Station not sampled.
** No fish captured.

Table 15. Equitabilities (E) of fish and shellfish captured by purse seine at sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted May-September, 1994, 1996, and 1997. The jetty was breached in August 1995. Stations P1-P7 were located inside the bay, and Stations PE, PM, and PW were located outside and adjacent to the bay.

Station	May			June			July			August			September		
	94	96	97	94	96	97	94	96	97	94	96	97	94	96	97
Inside															
P1	0.54	0.67	0.61	0.87	0.69	0.66	0.92	0.65	0.73	0.44	0.00	0.41	0.62	0.44	0.00
P2	0.57	0.99	0.98	0.74	0.66	0.89	0.41	0.00	0.92	0.54	0.52	0.29	0.60	0.92	0.73
P3	0.79	0.86	0.32	0.65	0.51	0.91	0.79	0.54	0.00	0.31	1.00	0.00	0.00	0.00	0.27
P4	0.72	0.92	0.79	0.34	0.39	0.82	0.25	0.62	0.88	0.08	0.47	0.92	0.01	0.38	0.97
P5	0.86	0.82	0.51	0.46	0.00	0.89	*	0.65	0.95	0.16	0.41	0.70	0.21	0.99	0.24
P6	0.77	0.97	0.97	0.00	0.65	0.82	0.00	0.96	0.77	0.15	0.28	0.99	0.08	0.00	0.00
P7	0.33	0.41	0.71	0.92	0.00	0.50	0.76	0.00	0.84	0.28	0.24	0.00	0.14	0.72	0.79
Mean	0.65	0.81	0.70	0.57	0.41	0.78	0.52	0.49	0.73	0.28	0.42	0.47	0.24	0.49	0.43
Control															
PE	**	*	0.62	0.39	*	0.37	0.71	*	0.80	0.38	*	0.39	0.00	*	0.85
PM	0.00	*	0.84	0.81	*	0.96	0.59	*	0.95	**	*	0.71	0.00	*	1.00
PW	1.00	*	0.68	0.88	*	0.66	**	*	0.87	0.00	*	0.81	0.81	*	0.95
Mean	0.33		0.71	0.69		0.66	0.43		0.87	0.13		0.64	0.27		0.93

* Station not sampled.
** No fish captured.

Table 16. Yearly total numbers of fish and shellfish captured by trapnet stations in Trestle Bay (RKm 11.3), Columbia River estuary. Values are totals derived from three trapnet sampling stations/month for five months (May-September). Sampling was conducted in 1994, 1996, and 1997. The jetty was breached in August 1995.

Species	1994	1996	1997
American shad	0	0	3
Chinook salmon (<1yr)	0	0	4
Common carp	1	2	3
Peamouth	0	0	1
Threespine stickleback	555	138	33
Longfin smelt	0	2	5
Surf smelt	0	5	0
Shiner perch	353	462	1,129
Pacific herring	0	1	0
Pacific tomcod	0	4	0
Unid. perch	1	0	0
Saddleback gunnel	5	0	1
Snake prickleback	1	0	0
Prickly sculpin	204	112	151
Pacific staghorn sculpin	205	59	53
Starry flounder	4	0	2
Dungeness crab	452	2	0
Yellow shore crab	12	80	64
Totals	1,793	867	1,449

DISCUSSION

Removing a section of the Trestle Bay jetty created an unobstructed passageway between the bay and the lower Columbia River estuary, essentially returning 244 ha of marsh and intertidal habitat to the estuarine system. The effects of the modification on Trestle Bay were apparent for benthic invertebrate and fish populations; however, epibenthic invertebrate populations were not influenced significantly, and sediment characteristics were virtually unchanged. Benthic invertebrate populations showed a significant decline in density and changes in species compositions both inside the bay and in the reference area from 1994 to 1997, yet the decline was twice as great inside the bay. Something other than normal natural variation also reduced invertebrate densities in Trestle Bay after the breach. Two likely explanations for the declines are 1) an increase in predation by fishes, and/or 2) a physical disruption of the local fauna related to the sustained high Columbia River flows beginning in February 1996. The permeability of the jetty allows the interior of Trestle Bay to experience the same tidal influence and salinities as the shallow subtidal estuarine habitat outside the bay. In February 1996, major and minor tributaries to the Columbia River experienced some of the highest flows recorded since the introduction of flood-control dams in the 1940-50s (Oregon Climate Service 1997). High river flows continued for much of 1996 and into 1997 (Fig. 4) (U.S. Geological Survey 1992). These high freshwater flows lowered salinity levels inside Trestle Bay long enough to eliminate or reduce invertebrate species that were less tolerant of sustained low salinity conditions. Even though invertebrate densities inside Trestle Bay were less in 1997 than in 1994, they were still similar to densities in other intertidal and subtidal benthic invertebrate surveys conducted in the lower Columbia River estuary (Hinton et al. 1990).

Although epibenthic invertebrate populations experienced declines in species numbers and densities similar to the benthic invertebrates, an impact attributed to breaching the jetty was not observed. In addition, no change was indicated from sediment analysis. Circulation patterns within the bay did not appear to change between the pre- and post-breach studies, because most stations maintained their original sediment classification after the breach.

Changes in overall fish densities in Trestle Bay were primarily influenced by the capture of a large number of threespine sticklebacks in 1994. Therefore, the degree to which the jetty breach influenced changes in fish densities is uncertain. However, a possible effect of the breach was revealed by increased similarity in composition and densities of fishes inside and outside the bay after the jetty was breached.

The 1994 surveys revealed that the habitat inside Trestle Bay contained many of the positive biological attributes of estuaries and wetlands. By furnishing important prey, foraging habitat, and cover, estuaries and wetlands provide critical habitat for migrating juvenile salmonids (Healey 1982, Simenstad et al. 1982, Fisher and Pearcy 1989, Miller and Simenstad 1997) and various other anadromous and marine fishes, such as American shad, surf smelt, English sole, Pacific herring (Bottom et al. 1984, Schiewe et al. 1989), and shellfish (Armstrong and Gunderson 1985, Emmett and Durkin 1985). Shallow-water estuarine habitats have high

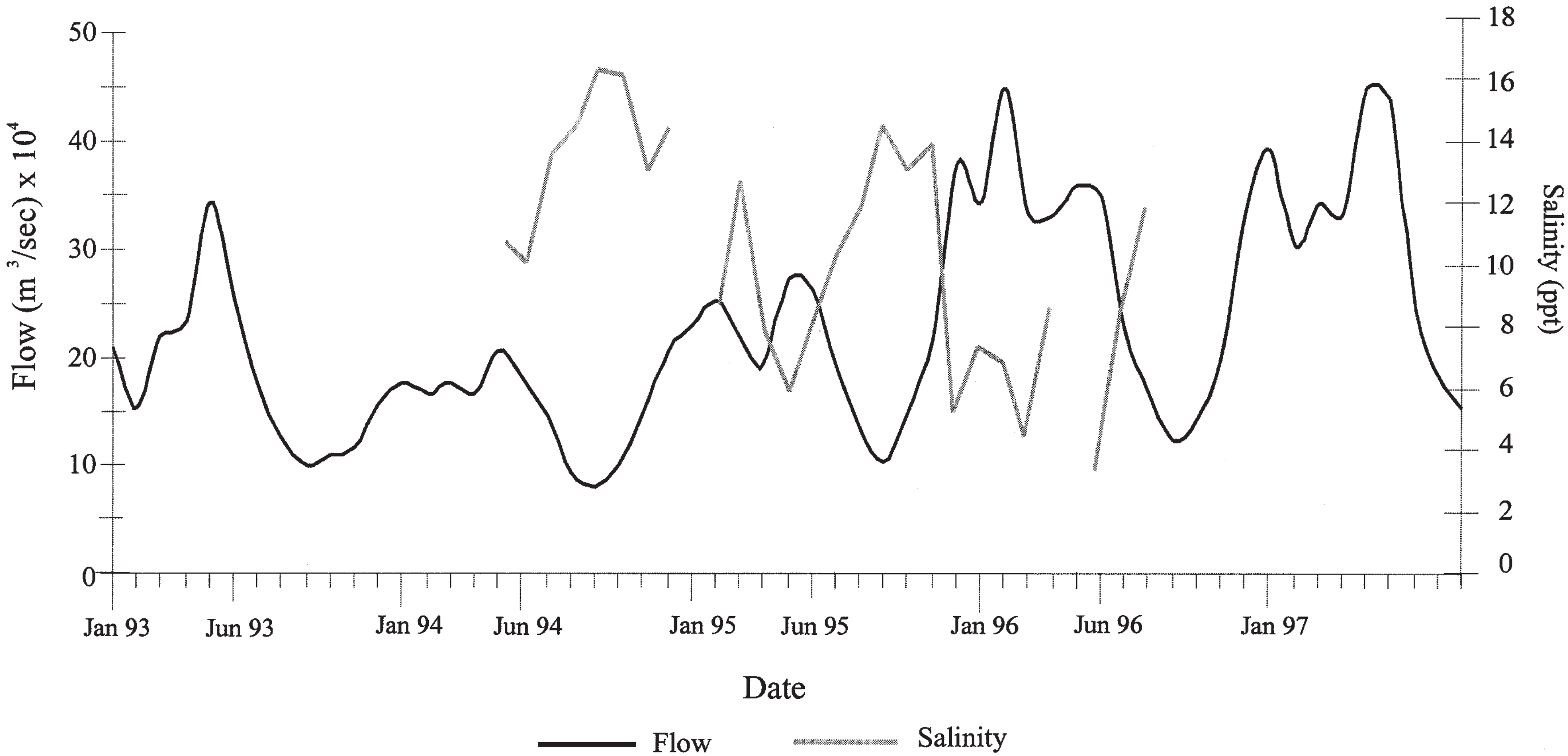

Figure 4. Average monthly river discharges for the Columbia River during 1993-1997 at Beaver Army Terminal near Quincy, Oregon (RKm 86.1; 46°10'54", 123°10'05"), and average monthly salinities in Trestle Bay (RKm 11.3), Columbia River estuary, during May 1994-August 1996 (with some periods of no salinity data).

primary productivity rates, which in turn support high densities of secondary consumers. Detrital food webs also add to this secondary production.

During this study Trestle Bay contained extensive marshes, several large eelgrass beds (*Zostera* spp.), and high benthic and epibenthic invertebrate populations. The benthic invertebrate densities inside Trestle Bay in 1994 were some of the highest observed in the lower Columbia River estuary (Holton 1984; Emmett et al. 1986; Hinton et al. 1990; Hinton et al. 1992; McCabe and Hinton 1993; McCabe et al. 1993a, 1993b; McCabe and Hinton 1996; McCabe et al. 1996). Benthic and epibenthic populations in Trestle Bay during both surveys consisted of many prey organisms juvenile fishes are known to consume during their resident times in an estuary. Most of the copepods, amphipods, and several polychaete species found in Trestle Bay are important prey for many estuarine fish species, including post-larval and juvenile stages of Pacific herring, surf smelt, starry flounder, and salmonids (Hart 1973, Meyer et al. 1981, Durkin 1982, Pearce et al. 1982, Kirn et al. 1986, McCabe et al. 1982, Nicholas and Lorz 1984, Emmett et al. 1991).

Despite the positive attributes within Trestle Bay, results from the 1994 fish sampling suggested that many juvenile fishes of the Columbia River estuary were not taking advantage of the cover and foraging habitat available inside the bay because of the barrier created by the rock jetty. Passage into Trestle Bay by some fish species (e.g., schooling fishes and juvenile salmonids) appeared to be inhibited by the rock jetty, perhaps because of the low light levels within the rock jetty itself. Research at hydropower dams suggests that light affects the willingness of salmonids to pass into or through orifices and gatewells of fish bypass systems (Marquette et al. 1970, Ebel et al. 1971). Salmonid passage was increased when orifices were lighted. Even though the rock jetty was extremely permeable, the thickness of the structure (up to 5 m at the base) created a dark tunnel effect that probably discouraged juvenile salmonids and possibly other estuarine fish species from passing through. Results from the pre- and post-breach fish sampling support this hypothesis. Pacific herring, chinook salmon, surf smelt, and starry flounder took advantage of the new opening. These species were either absent or had low numbers inside the bay prior to the breach. Therefore, the removal of the rock jetty positively affected the ability of estuarine fishes to utilize Trestle Bay.

CONCLUSIONS

Trestle Bay provided a rare opportunity to observe the biological impact of returning valuable wetland and intertidal and shallow subtidal habitats to an estuary that has seen a decline in similar habitats as a result of urban and industrial development and pollution. Breaching the jetty created an unobstructed passageway allowing access of fishes to the highly productive habitats within Trestle Bay. The main goal of this project was to restore fish access to the bay primarily for juveniles salmonids which potentially includes federally listed endangered and threatened species. This goal appears to have been met, as evidenced by the observed increase in use of the bay by juvenile salmonids. In addition, the breach improved forage conditions for other important recreational and commercial fishes of the lower Columbia River estuary. No apparent adverse effects on environmental conditions within Trestle Bay were observed as a result of the jetty breach. Resource agencies should continue to look for similar project sites which could be modified and returned to the ecosystem (with minimum cost) and that would provide long-term benefits for natural resources.

ACKNOWLEDGMENTS

Thank you to all those involved with this project since the voluntary beginning study of 1993. Without your vision and persistence such a positive project would not have been possible. Thank you to Paul Bentley, George T. McCabe, Jr., and Dennis Umphfres for their valuable assistance in the field. Thanks also to Pat Oxley and Fort Stevens Park Service for sponsoring and gaining the public obligation to secure project funding, and to Geoff Dorsey of the COE for successfully implementing and seeing the project through the federal process.

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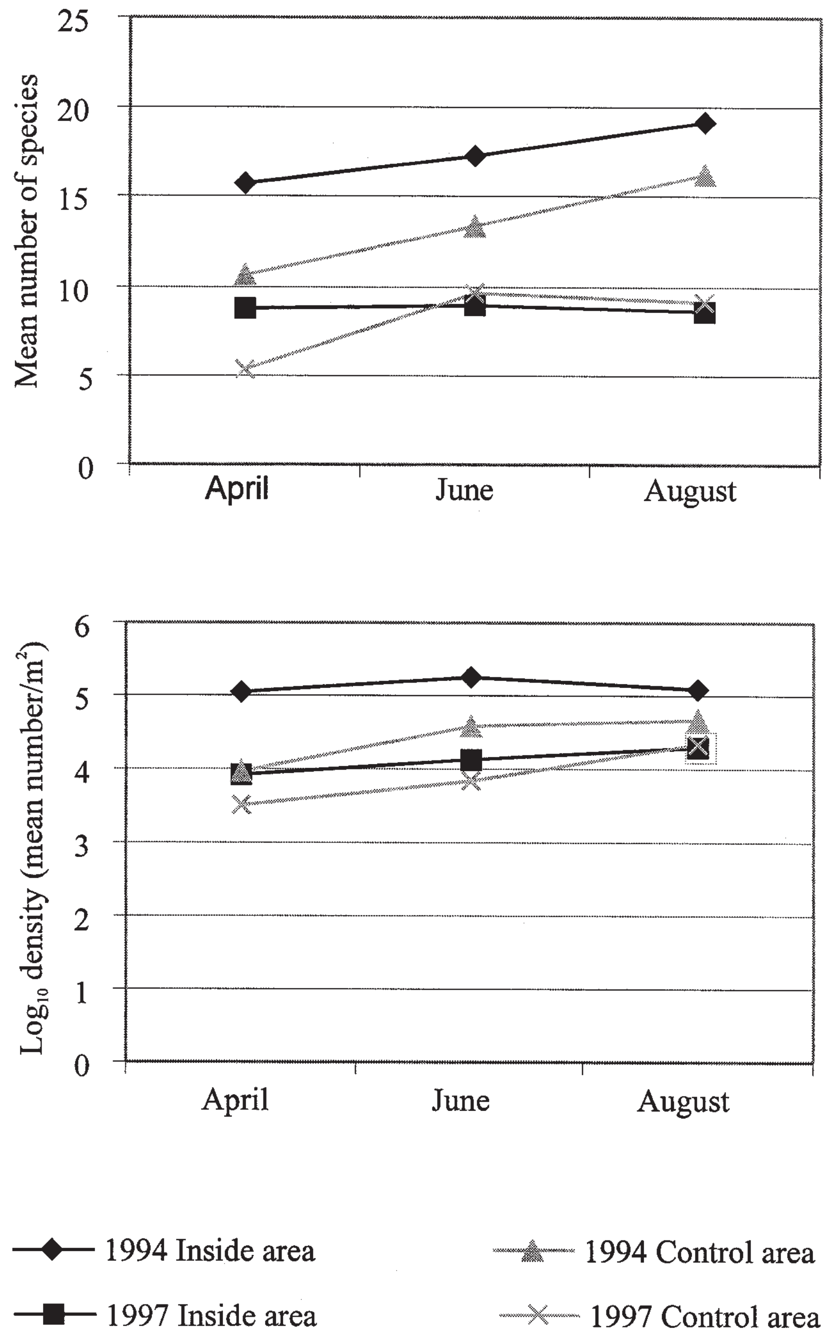
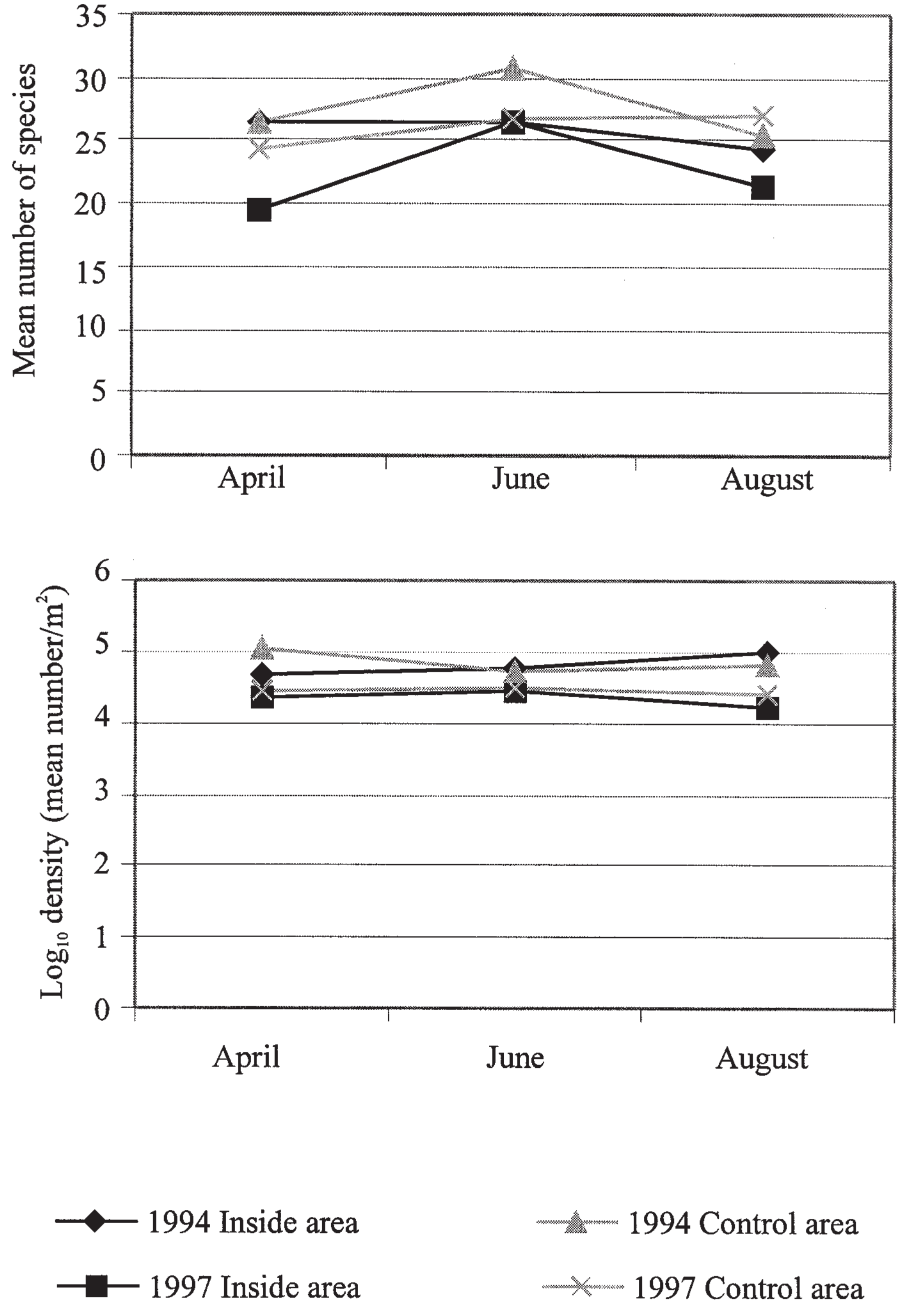
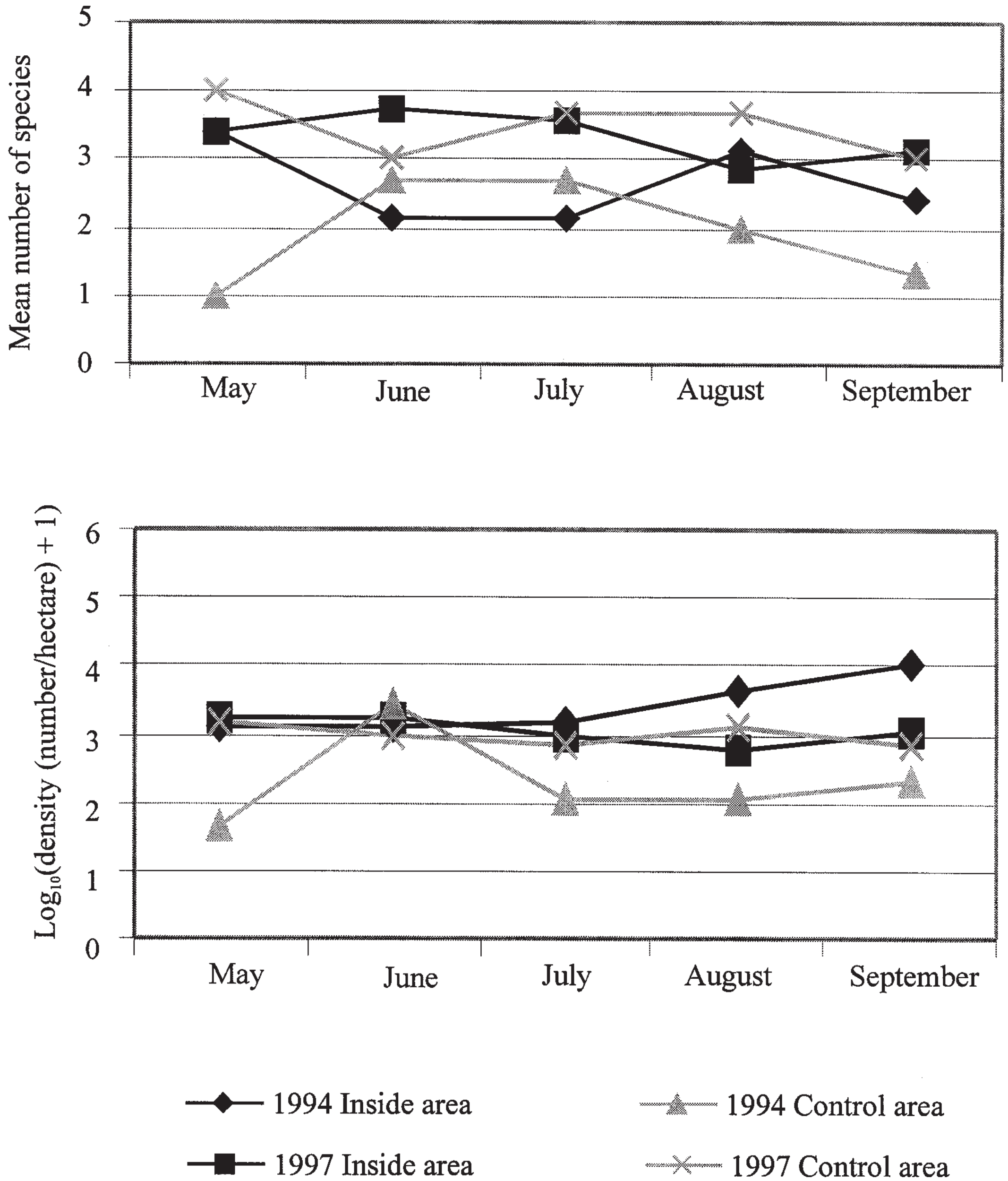
APPENDIX A: FIGURES



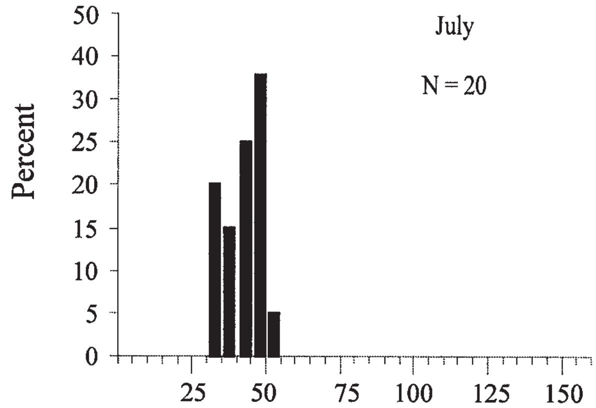
Appendix Figure 1. Differences in monthly means of benthic invertebrates for numbers of species and densities ($\log_{10}$ (mean number/m^2)) from stations located in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). Stations 1-10, 14, and 15 were located inside the bay and Stations 11C-13C were located outside and adjacent to the bay. The jetty was breached in August 1995.

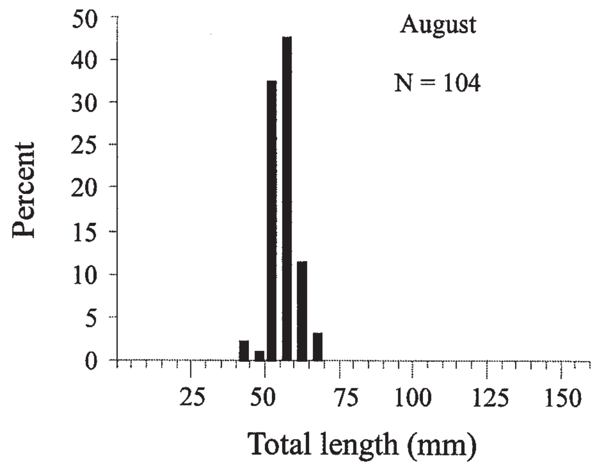


Appendix Figure 2. Differences in monthly means of epibenthic invertebrates for numbers of species and densities ($\log_{10}$ (mean number/m^2)) from stations located in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). Stations 1-10, 14, and 15 were located inside the bay and Stations 11C-13C were located outside and adjacent to the bay. The jetty was breached in August 1995.

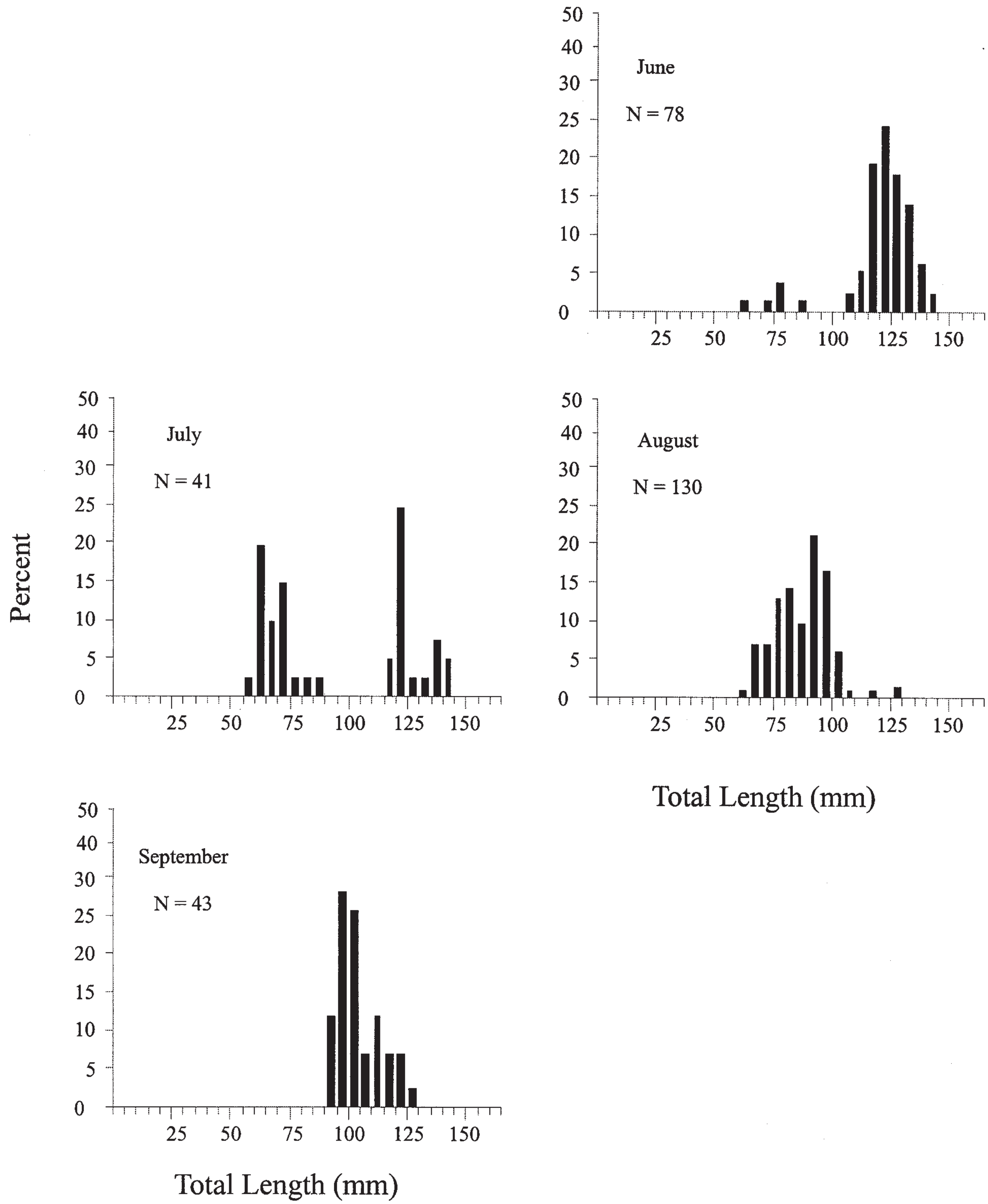


Appendix Figure 3. Differences in monthly means of fish and shellfish for numbers of species and densities ($\log_{10}$ (mean number/m^2)) from stations located in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in April, June, and August of 1994 (pre-breach) and 1997 (post-breach). Stations 1-7 were located inside the bay and Stations PE, PM, nd PW were located outside and adjacent to the bay. The jetty was breached in August 1995.

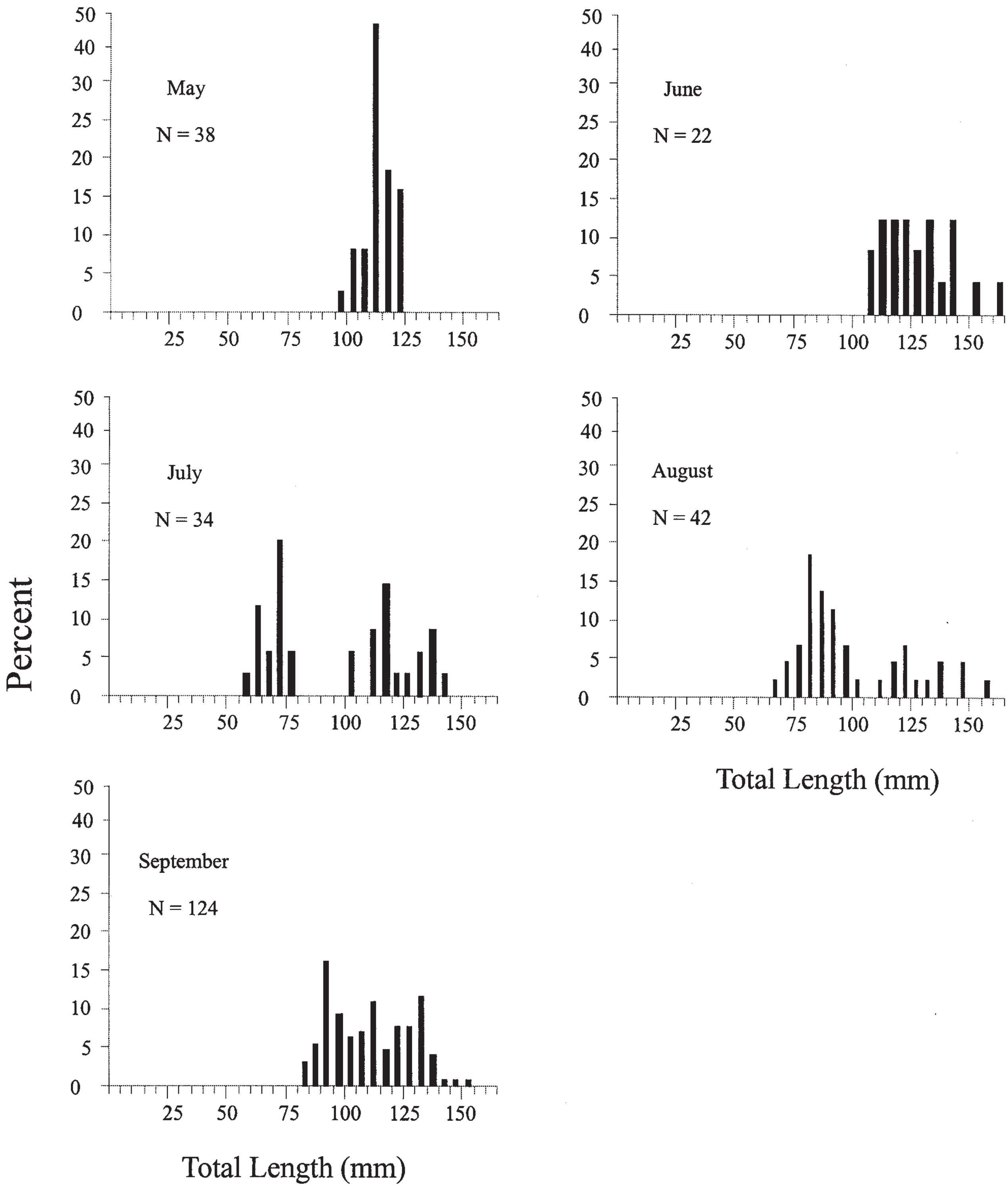




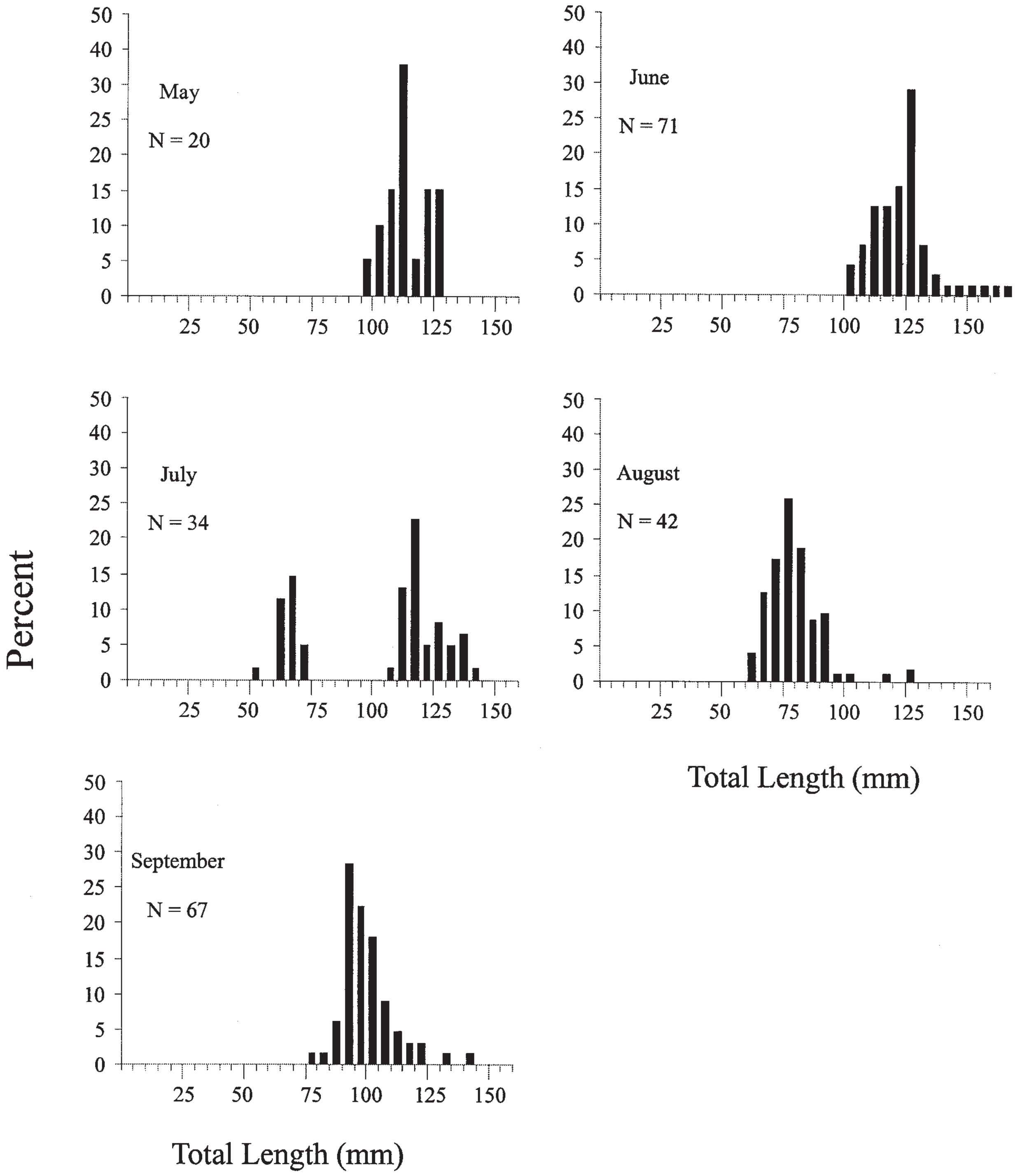
Appendix Figure 4. Length-frequency histograms for Pacific herring (*Clupea pallasi*), collected by purse seine in Trestle Bay, Columbia River estuary, in July and August 1996.



Appendix Figure 5. Length-frequency histograms for shiner perch (*Cymatogaster aggregata*) collected by trapnet in Trestle Bay, Columbia River estuary, in May-September 1994. Data were combined for three trapnet stations for each month.



Appendix Figure 6. Length-frequency histograms for shiner perch (Cymatogaster aggregata) collected by trapnet in Trestle Bay, Columbia River estuary, in May-September 1996. Data were combined for three trapnet stations for each month.



Appendix Figure 7. Length-frequency histograms for shiner perch (Cymatogaster aggregata) collected by trapnet in Trestle Bay, Columbia River estuary, in May-September 1997. Data were combined for three trapnet staitons for each month.

APPENDIX B: TABLES

Appendix Table 1. Geographic locations of benthic invertebrate, sediment, purse seine, and trapnet sampling stations for Trestle Bay surveys 1994 and 1997.

Station	Latitude	Longitude
	Benthic Invertebrate and Sediment Stations	
1	46° 13.173' N	123° 59.705' W
2	13.122	59.734
3	12.932	59.288
4	12.867	59.064
5	12.841	58.851
6	12.733	59.631
7	12.578	58.760
8	12.651	59.012
9	12.709	59.261
10	12.808	59.484
11c		
12c	13.189	59.347
13c	13.077	59.110
14	12.582	58.690
15	12.615	59.260
	Purse Seine Stations	
PS1	46° 13.053' N	123° 59.637' W
PS2	12.913	59.090
PS3	12.787	58.873
PS4	12.890	59.567
PS5	12.813	59.177
PS6	12.582	58.690
PS7	12.615	59.260
PS11c		
PS12c	13.189	59.347
PS13c	13.077	59.110
	Trapnet Stations	
TNE	46° 12.832' N	123° 58.725' W
TNmid	12.985	59.115
TNW	13.138	59.505

Appendix Table 2. Summary of benthic invertebrate taxa/categories at sampling statinos in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Stations 1-10 were located in the bay and reference Stations 11c-13c were located outside and adjacent to the bay. Sampling occurred in April, June, and August of 1994 and 1997. The jetty was breached in August 1995.

Taxa/categories	1994						1997					
	Apr		Jun		Aug		Apr		Jun		Aug	
	in	ref	in	ref	in	ref	in	ref	in	ref	in	ref
Nemertea	x	x	x	x	x	x	x	x	x	x	x	x
Cnidaria												
Edwardsiidae												
Nematostella vectensis	x		x		x							
Turbellaria	x	x	x	x	x	x	x		x		x	
Annelida-Polychaeta	x											
Phyllodocidae												
Eteone spp.	x	x	x	x	x	x				x		x
Nereidae	x											
Neanthes limnicola	x	x	x	x	x	x	x	x	x	x	x	x
Spionidae	x		x	x	x	x						
Polydora spp.												x
Polydora cornuta	x	x	x	x	x	x	x	x			x	
Pygospio elegans	x	x	x	x	x					x		
Scolelepis squamata		x										
Pseudopolydora kempi	x	x	x	x	x	x	x	x		x		x
Capitelledae					x							
Mediomastus spp.											x	
Barantolla americana	x											
Sabellidae												
Manayunkia aestuarina	x		x		x		x		x		x	
Ampharetidae												
Hobsonia florida	x	x	x	x	x	x	x		x	x	x	
Opheliidae												
Euzonus williamsi						x						
Annelida - Oligochaeta	x	x	x	x	x	x	x		x	x	x	x

Appendix Table 2. Continued.

Taxa/categories	1994						1997					
	Apr		Jun		Aug		Apr		Jun		Aug	
	in	ref	in	ref	in	ref	in	ref	in	ref	in	ref
Mollusca - Unid. Gastropoda											x	
Mollusca - Unid. Bivalvia	x	x	x	x	x	x	x	x	x	x	x	x
Mactridae												
Tresus capax						x				x		
Myidae												
Mya arenaria		x		x								x
Tellinidae												
Macoma balthica	x	x	x	x	x	x	x	x	x	x	x	x
Arthropoda - Cumacea												
Leuconidae												
Nippoleucon hinumensis	x		x	x	x	x	x		x	x	x	x
Nannastacidae												
Cummella vulgaris		x	x	x		x						
Arthropoda - Amphipoda												
Gammaridae			x			x						
Eogammarus spp.			x		x							
Eogammarus confervicolus	x	x	x	x	x	x	x		x	x	x	
Haustoriidae												
Eohaustorius spp.										x		
Eohaustorius estuaris		x		x		x		x	x	x		x
Corophiidae												
Corophium spp.	x		x		x		x		x	x	x	x
Corophium salmonis	x		x		x	x	x		x	x	x	x
Corophium spinicorne	x		x		x	x	x		x	x	x	
Arthropoda - Isopoda												
Idoteidae												
Saduria entomon							x	x			x	
Sphaeromatidae												
Gnorimosphaeroma spp.					x							
Gnorimosphaeroma oregonensis			x		x	x						
Arthropoda - Copepoda												
Harpacticoida												
Coullana canadensis	x	x	x	x	x	x					x	

Appendix Table 2. Continued.

Taxa/categories	1994 Apr in	1994 Apr ref	1994 Jun in	1994 Jun ref	1994 Aug in	1994 Aug ref	1997 Apr in	1997 Apr ref	1997 Jun in	1997 Jun ref	1997 Aug in	1997 Aug ref
Miscellaneous Insecta												
Diptera larvae											x	
Chironomidae larvae	x		x		x						x	
Ceratopogonidae larvae							x		x			
Collembola adult	x				x							
Hydracarina					x							
Total taxa/categories	25	17	25	18	27	22	17	8	15	17	20	13

Appendix Table 3. Summary of epibenthic invertebrate taxa/categories at sampling statinos in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Stations 1-10 were located in the bay and reference Stations 11c-13c were located outside and adjacent to the bay. Sampling occurred in April, June, and August of 1994 and 1997. The jetty was breached in August 1995.

Taxa/categories	1994						1997					
	Apr		Jun		Aug		Apr		Jun		Aug	
	in	ref	in	ref	in	ref	in	ref	in	ref	in	ref
Protozoa - Foraminifera												
Rhizopodea	x		x		x		x	x	x	x	x	x
Rotifera	x	x	x	x	x	x	x	x	x	x	x	x
Cnidaria												
Hydrozoa	x	x	x	x	x	x	x	x	x			
Anthozoa	x		x		x		x	x	x			
Platyhelminthes												
Turbellaria	x	x	x	x	x	x	x	x	x	x	x	x
Nematoda	x	x	x	x	x	x	x	x	x	x	x	x
Annelida - Polychaeta - larvae	x	x	x	x			x	x				
Nereidae	x		x	x	x				x	x	x	x
Spionidae - unid. juv.	x		x	x	x	x					x	x
Spionidae - larvae		x	x	x	x	x				x	x	x
Ampharetidae												
Hobsonia florida	x		x	x	x	x			x		x	
Sabellidae												
Manayunkia aestuarina	x	x	x	x	x		x		x		x	
Annelidae - Oligochaeta	x	x	x	x	x	x	x	x	x	x	x	x
Mollusca - Gastropoda - larvae	x		x			x					x	
Mollusca - Bivalvia	x	x	x	x	x	x	x	x	x		x	x
Arthropoda - Arachnida												
Acarina	x	x	x	x	x	x	x	x	x	x	x	x

Appedix Table 3. Continued.

Taxa/categories	1994 Apr in	1994 Apr ref	1994 Jun in	1994 Jun ref	1994 Aug in	1994 Aug ref	1997 Apr in	1997 Apr ref	1997 Jun in	1997 Jun ref	1997 Aug in	1997 Aug ref
Arthropoda - Crustacea												
Cladocera												x
Podocopida	x	x		x		x	x	x	x	x		x
Podocopida - unid.		x										
Daphniidae												
Ceriodaphnia sp.			x						x	x		
Daphnia sp.		x	x	x	x	x	x		x	x		x
Sididae									x			
Bosminidae												
Bosmina longirostris	x	x	x	x			x	x	x	x	x	x
Chydoridae												
Chydorus sp.							x	x	x	x		
Eurycercus sp.			x									
Podonidae												
Evadne nordmanni												x
Pleopis polyphaemoides											x	x
Arthropoda - Crustacea												
Copepoda - unid. nauplii	x	x	x	x	x	x	x	x			x	x
Calanoida - copepodids	x	x	x	x	x	x			x	x	x	
Paracalanus sp. - copepodids					x	x						
Pseudodiaptomidae								x	x	x		x
Pseudodiaptomus inopinus	x		x		x							
Temoridae												
Eurytemora affinis	x	x	x	x	x	x	x	x	x	x	x	x
Acartiidae									x			
Acartiella sinensis												x
Hapacticoida - unid. nauplii	x	x	x	x	x	x	x	x	x	x	x	x
Hapacticoida - unid. copepodids	x		x	x	x			x	x		x	
Canuellidae												
Coullana canadensis	x	x	x	x	x	x	x	x	x	x	x	x
Ectinosomatidae								x	x	x	x	
Pseudobradya sp.	x	x	x	x	x	x	x	x	x	x	x	x
Microsetella sp.				x				x				

Appendix Table 3. Continued.

Taxa/categories	1994						1997					
	Apr		Jun		Aug		Apr		Jun		Aug	
	in	ref	in	ref	in	ref	in	ref	in	ref	in	ref
Tachidiidae												
Microarthridion littorale	x	x	x	x			x	x	x	x	x	x
Tachidius triangularis	x	x	x	x	x	x	x		x	x	x	x
Tachidius discipes							x		x	x	x	
Laophontidae									x			
Paronychocamptus cf. *huntsmani*	x		x	x	x	x	x	x	x		x	
Cylindropsyllidae												
Paraleptastacus sp.	x	x	x	x	x	x	x	x	x			x
Ameiridae												
Nitocra sp.	x		x		x		x		x	x	x	x
Huntemanniidae												
Huntemannia jadensis	x	x	x	x		x	x	x	x	x	x	x
Canthocamptidae												
Leimia vaga	x	x	x	x			x	x				
Mesochra sp.	x		x	x	x	x					x	x
Mesochra alaskana							x	x	x	x		
Cletodidae					x							
Limnocletodes behningi	x		x	x	x	x	x		x		x	x
Diosaccidae												
Schizopera sp.			x				x	x	x		x	
Schizopera knabeni	x				x							
Cyclopidae - copepodids	x	x	x	x	x	x	x	x	x		x	x
Halicyclops sp.	x		x	x	x	x	x		x			
Acanthocyclops vernalis								x	x	x	x	x
Diacyclops thomasi	x	x	x	x	x		x	x	x	x	x	x
Cyclops vernalis	x	x	x	x								
Oithonidae - copepodids					x	x						x
Oithona sp.		x										
Cirripedia												
Balanomorpha - unid. nauplii	x	x	x	x	x	x			x	x	x	x
Balanomorpha - unid. cyprids	x	x		x	x	x				x		
Arthropoda - Isopoda												
Sphaeromatidae												
Gnorimosphaeroma sp.			x									
Idoteidae												
Saduria entomon							x					x

Appendix Table 3. Continued.

Taxa/categories	1994						1997					
	Apr		Jun		Aug		Apr		Jun		Aug	
	in	ref	in	ref	in	ref	in	ref	in	ref	in	ref
Arthropoda - Malacostraca												
Mysidacea									x			
Archaeomysis grebnitzkii		x										
Cumacea												
Leuconidae												
Nippoleucon hinumensis	x	x	x	x	x	x	x	x	x	x	x	
Nannastacidae												
Cumella vulgaris	x	x										
Amphipoda												
Anisogammaridae												
Eogammarus confervicolus	x	x	x	x	x	x	x		x		x	
Corophiidae												
Corophium spp.	x		x						x		x	x
Corophium salmonis									x	x		
Corophium spinicorne	x		x		x				x	x		
Haustoriidae												
Eohaustorius sp.		x										
Arthropoda - Caridae												
Crangoniidae												
Crangon sp.		x		x			x	x				
Miscellaneous												
Collembola	x						x		x			
Chironomidae							x		x	x	x	x
Ceratopogonidae								x	x			
Tardigrada									x	x		
Epicaridea											x	
Total taxa/categories	47	37	48	41	42	32	40	35	53	35	41	38

Appendix Table 4. Median grain sizes at sediment sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in August 1993, April and June 1994 (pre-breach), and June and August 1997 (post-breach). Stations 1-10, 14, and 15 were located in the bay, and Stations 11c-13c were located outside and adjacent to the bay. The jetty was breached in August 1995.

Station	Aug 93	Apr 94	Jun 94	Jun 97	Aug 97
		Median grain size			
1	0.160	0.160	0.160	0.046	0.031
2	0.031	**	0.031	0.033	0.073
3	0.026	**	0.028	0.024	0.033
4	0.022	**	0.026	0.031	0.540
5	0.180	0.140	0.180	0.490	0.190
6	0.170	0.150	0.180	0.180	0.180
7	0.018	**	0.018	0.190	0.150
8	0.021	**	0.022	0.022	0.019
9	0.019	**	0.019	0.026	0.020
10	0.038	**	0.140	0.022	0.021
14	*	**	0.010	0.010	0.010
15	*	0.160	0.150	0.180	0.170
11c	0.210	0.140	0.210	0.270	0.190
12c	0.190	0.200	0.180	0.260	0.220
13c	*	0.190	0.230	0.190	0.190

* Station was not sampled in 1993.
**No analysis was performed to determine median grain size. All material was classified as silt (<0.0625 mm).

Appendix Table 5. Percent silt/clay at sediment sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in August 1993, April and June 1994 (pre-breach), and June and August 1997 (post-breach). Stations 1-10, 14, and 15 were located in the bay, and Stations 11c-13c were located outside and adjacent to the bay. The jetty was breached in August 1995.

Station	Aug 93	Apr 94	Jun 94	Jun 97	Aug 97
		Percent silt/clay			
1	25.2	18.0	17.4	60.0	73.0
2	88.4	80.5	85.7	75.0	43.5
3	91.8	87.6	83.8	76.0	70.0
4	92.0	84.1	85.1	75.0	60.0
5	21.5	36.7	13.5	0.2	4.9
6	29.5	28.5	17.0	16.4	16.0
7	96.7	94.1	94.2	19.7	35.4
8	94.1	75.3	91.4	82.0	80.0
9	94.9	89.9	93.3	80.0	82.0
10	62.4	92.4	34.5	86.0	80.0
14	*	86.5	97.5	88.0	85.0
15	*	18.9	26.5	9.6	12.2
11C	0.4	39.5	5.3	1.8	7.9
12C	1.9	0.6	8.7	0.4	1.3
13C	*	0.7	5.0	3.0	2.1

* Station was not sampled in 1993.

Appendix Table 6. Percent volatile solids at sediment sampling stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted in August 1993, April and June 1994 (pre-breach), and June and August 1997 (post-breach). Stations 1-10, 14, and 15 were located in the bay, and Stations 11c-13c were located outside and adjacent to the bay. The jetty was breached in August 1995.

Station	Aug 93	Apr 94	Jun 94	Jun 97	Aug 97
		Percent volatile solids			
1	12.0	1.0	1.1	5.7	6.3
2	5.6	4.7	4.1	5.6	6.0
3	6.5	4.9	4.2	6.4	6.4
4	7.1	5.4	5.6	6.5	6.5
5	2.1	2.1	0.8	1.6	4.9
6	2.4	2.1	1.2	2.5	1.8
7	5.8	4.7	4.5	3.2	2.5
8	5.9	3.4	3.8	6.0	5.5
9	5.9	4.9	4.9	6.2	6.4
10	3.7	5.0	2.1	5.8	6.0
14	*	5.1	2.0	5.7	4.7
15	*	1.5	1.5	2.1	1.4
11C	0.6	3.2	0.8	1.3	1.4
12C	0.7	0.6	0.8	1.2	0.8
13C	*	0.5	0.5	1.2	0.8

* Station was not sampled in 1993.

Appendix Table 7. Summary of fish and shellfish captured by purse seine at stations in and adjacent to Trestle Bay (RKm 11.3), Columbia River estuary. Sampling was conducted May-September, 1994, 1996, and 1997. No sampling was conducted in the reference area in 1996. The jetty was breached in August 1995.

		Purse Seine Sampling - Inside								
		May			Jun			Jul		
Scientific Name	Common Name	94	96	97	94	96	97	94	96	97
Clupeidae										
Alosa sapidissima	American shad	-	-	-	-	-	-	-	-	-
Clupea pallasi	Pacific herring	-	-	-	-	-	-	-	x	x
Salmonidae										
Oncorhynchus tshawytscha	Chinook salmon (<1 yr)	-	x	x	-	x	x	-	-	x
Osmeridae										
Unidentified juv. smelt		-	-	-	-	-	-	-	-	-
Hypomesus pretiosus	Surf smelt	x	x	x	-	-	x	-	x	-
Cyprinodontidae										
Fundulus diaphanus	Banded killifish	-	-	-	-	-	-	-	-	-
Gasterosteidae										
Gasterosteus aculeatus	Threespine stickleback	x	x	x	x	x	x	x	x	x
Syngnathidae										
Syngnathus leptorhynchus	Bay pipefish	x	-	-	-	-	-	-	-	-
Centrarchidae										
Micropterus salmoides	Largemouth bass	-	-	-	-	-	-	-	-	-
Embiotocidae										
Cymatogaster aggregata	Shiner perch	-	-	-	x	-	x	x	x	x
Pholidae										
Pholis ornata	Saddleback gunnel	x	-	-	x	x	x	x	x	-
Cottidae										
Cottus asper	Prickly sculpin	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	x	x	x	x	x	x	x	x	x
Pleuronectidae	Larval flatfish	-	-	x	-	-	x	-	-	-
Platichthys stellatus	Starry flounder	-	-	x	x	x	x	x	-	x
Canceridae										
Cancer magister	Dungeness crab	-	-	-	-	-	-	-	-	-
Hemigrapsus oregonensis	Yellow shore crab	-	-	x	-	x	-	-	x	x
Total		5	4	7	5	6	8	5	7	7

Appendix Table 7. Continued.

Scientific Name	Common Name	Purse Seine Sampling - Inside: Aug 94	Aug 96	Aug 97	Sep 94	Sep 96	Sep 97
Clupeidae							
Alosa sapidissima	American shad	-	x	-	-	-	x
Clupea pallasi	Pacific herring	-	x	x	-	-	-
Salmonidae							
Oncorhynchus tshawytscha	Chinook salmon (<1yr)	-	x	-	-	x	x
Osmeridae							
Unidentified juv. smelt		-	x	-	-	-	-
Hypomesus pretiosus	Surf smelt	-	x	-	-	x	-
Cyprinodontidae							
Fundulus diaphanus	Banded killifish	-	-	x	-	-	-
Gasterosteidae							
Gasterosteus aculeatus	Threespine stickleback	x	x	x	x	x	x
Syngnathidae							
Syngnathus leptorhynchus	Bay pipefish	x	-	-	x	x	-
Centrarchidae							
Micropterus salmoides	Largemouth bass	-	-	x	-	-	-
Embiotocidae							
Cymatogaster aggregata	Shiner perch	x	x	x	x	x	x
Pholidae							
Pholis ornata	Saddleback gunnel	x	x	x	-	x	x
Cottidae							
Cottus asper	Prickly sculpin	x	-	x	x	x	-
Leptocottus armatus	Pacific staghorn sculpin	x	x	x	x	x	x
Pleuronectidae	Larval flatfish	-	-	-	-	-	-
Platichthys stellatus	Starry flounder	x	x	x	-	-	x
Canceridae							
Cancer magister	Dungeness crab	-	-	-	x	-	-
Hemigrapsus oregonensis	Yellow shore crab	-	x	-	-	x	x
Total		7	11	9	6	9	8

Appendix Table 7. Continued.

		Purse Seine Sampling - Reference Area								
		May			Jun			Jul		
Scientific Name	Common Name	94	96	97	94	96	97	94	96	97
Clupeidae										
Alosa sapidissima	American shad	-		-	-		x	-		-
Salmonidae										
Oncorhynchus tshawytscha	Chinook salmon (<1yr)	-		x	-		-	-		x
Oncorhynchus kisutch	Coho salmon	-		x	-		-	-		-
Oncorhynchus mykiss	Steelhead	-		x	-		-	-		-
Osmeridae										
Hypomesus pretiosus	Surf smelt	-		x	-		x	-		-
Embiotocidae										
Cymatogaster aggregata	Shiner perch	-		-	x		x	x		x
Pholidae										
Pholis ornata	Saddleback gunnel	-		-	-		-	x		-
Gasterosteidae										
Gasterosteus aculeatus	Threespine stickleback	-		x	x		x	x		x
Ammodytidae										
Ammodytes hexapterus	Pacific sandlance	-		-	-		-	-		-
Cottidae										
Scorpaenichthys marmoratus	Cabezon	-		-	-		-	x		-
Leptocottus armatus	Staghorn sculpin	x		x	x		x	x		x
Pleuronectidae										
Platichthys stellatus	Starry flounder	-		-	-		x	-		x
Parophrys vetulus	English sole	x		-	x		-	x		-
Canceridae										
Cancer magister	Dungeness crab	-		-	x		-	x		-
Hemigrapsus oregonensis	Yellow shorecrab	-		-	-		x	-		x
Total		2		6	5		7	7		6

Appendix Table 7. Continued.

		Purse Seine Sampling - Reference Area					
		Aug			Sep		
Scientific Name	Common Name	94	96	97	94	96	97
Clupeidae							
Alosa sapidissima	American shad	-		-	-		-
Salmonidae							
Oncorhynchus tshawytscha	Chinook salmon (<1yr)	x		x	-		x
Oncorhynchus kisutch	Coho salmon						
Oncorhynchus mykiss	Steelhead	-		-	-		-
Osmeridae							
Hypomesus pretiosus	Surf smelt	-		-	-		-
Embiotocidae							
Cymatogaster aggregata	Shiner perch	x		x	-		x
Pholidae							
Pholis ornata	Saddleback gunnel	x		-	x		x
Gasterosteidae							
Gasterosteus aculeatus	Threespine stickleback	-		x	-		-
Ammodytidae							
Ammodytes hexapterus	Pacific sandlance	x		-	-		-
Cottidae							
Scorpaenichthys marmoratus	Cabezon	x		-	-		-
Leptocottus armatus	Pacific staghorn sculpin	-		x	x		-
Pleuronectidae							
Platichthys stellatus	Starry flounder	-		x	-		x
Parophrys vetulus	English sole	-		-	-		-
Canceridae							
Cancer magister	Dungeness crab	x		-	x		x
Hemigrapsus oregonensis	Yellow shorecrab	-		-	-		-
Total		6		5	3		5

Appendix Table 8. Total numbers of fish and shellfish captured at trapnet sampling stations in Trestle Bay (RKm 11.3), Columbia River estuary. Values are for three trapnet stations combined by month. Sampling was conducted May-September 1994, 1996, and 1997. The jetty was breached in August 1995.

Species	Common name	May			Jun		
		94	96	97	94	96	97
Clupeidae							
Alosa sapidissima	American Shad	0	0	0	0	0	3
Clupea pallasi	Pacific herring	0	0	0	0	0	0
Salmonidae							
Oncorhynchus tshawytshcha	Chinook salmon (<1yr)	0	0	2	0	0	1
Osmeridae							
Hypomesus pretiosus	Surf smelt	0	1	0	0	1	0
Spirinchus thaleichthys	Longfin smelt	0	2	3	0	0	2
Cyprinidae							
Cyprinus carpio	Common carp	0	0	0	0	2	1
Mylocheilus caurinus	Peamouth	0	0	0	0	0	1
Gadidae							
Microgadus proximus	Pacific tomcod	0	0	0	0	0	0
Gasterosteidae							
Gasterosteus aculeatus	Threespine stickleback	0	11	7	73	77	8
Embiotocidae	Unid. perch	0	0	0	0	0	0
Cymatogaster aggregatta	Shiner perch	0	38	31	86	22	60
Stichaeidae							
Lumpenus sagitta	Snake prickleback	0	0	0	0	0	0
Pholidae							
Pholis ornata	Saddleback gunnel	0	0	0	0	0	0
Cottidae							
Cottus asper	Prickly sculpin	22	13	29	36	36	23
Leptocottus armatus	Pacific staghorn sculpin	8	32	19	102	7	6
Pleuronectidae							
Platichthys stellatus	Starry flounder	4	0	0	0	0	0
Canceridae							
Cancer magister	Dungeness crab	0	0	0	1	0	0
Hemigrapsus oregonensis	Yellow shore crab	0	5	9	0	23	4
Total		34	102	100	298	168	109

Appendix Table 8. Continued.

Species	Common name	Jul 94	Jul 96	Jul 97	Aug 94	Aug 96	Aug 97
Clupeidae							
Alosa sapidissima	American Shad	0	0	0	0	0	0
Clupea pallasi	Pacific herring	0	1	0	0	0	0
Salmonidae							
Oncorhynchus tshawytshcha	Chinook salmon (<1yr)	0	0	1	0	0	0
Osmeridae							
Hypomesus pretiosus	Surf smelt	0	1	0	0	2	0
Spirinchus thaleichthys	Longfin smelt	0	0	0	0	0	0
Cyprinidae							
Cyprinus carpio	Common carp	1	0	1	0	0	1
Mylocheilus caurinus	Peamouth	0	0	0	0	0	0
Gadidae							
Microgadus proximus	Pacific tomcod	0	0	0	0	0	0
Gasterosteidae							
Gasterosteus aculeatus	Threespine stickleback	79	40	6	278	5	9
Embiotocidae	Unid. perch	0	0	0	1	0	0
Cymatogaster aggregatta	Shiner perch	41	34	59	183	42	872
Stichaeidae							
Lumpenus sagitta	Snake prickleback	0	0	0	0	0	0
Pholidae							
Pholis ornata	Saddleback gunnel	0	0	0	3	0	1
Cottidae							
Cottus asper	Prickly sculpin	23	21	44	56	25	31
Leptocottus armatus	Pacific staghorn sculpin	51	2	4	10	14	11
Pleuronectidae							
Platichthys stellatus	Starry flounder	0	0	2	0	0	0
Canceridae							
Cancer magister	Dungeness crab	0	0	0	53	0	0
Hemigrapsus oregonensis	Yellow shore crab	1	17	10	7	6	8
Total		196	116	127	591	94	933

Appendix Table 8. Continued.

Species	Common name	Sep 94	Sep 96	Sep 97	Total 94	Total 96	Total 97
Clupeidae							
Alosa sapidissima	American Shad	0	0	0	0	0	3
Clupea pallasi	Pacific herring	0	0	0	0	1	0
Salmonidae							
Oncorhynchus tshawytshcha	Chinook salmon (<1yr)	0	0	0	0	0	4
Osmeridae							
Hypomesus pretiosus	Surf smelt	0	0	0	0	5	0
Spirinchus thaleichthys	Longfin smelt	0	0	0	0	2	5
Cyprinidae							
Cyprinus carpio	Common carp	0	0	0	1	2	3
Mylocheilus caurinus	Peamouth	0	0	0	0	0	1
Gadidae							
Microgadus proximus	Pacific tomcod	0	4	0	0	4	0
Gasterosteidae							
Gasterosteus aculeatus	Threespine stickleback	125	5	3	555	138	33
Embiotocidae	Unid. perch	0	0	0	1	0	0
Cymatogaster aggregatta	Shiner perch	43	326	107	353	462	1,129
Stichaeidae							
Lumpenus sagitta	Snake prickleback	1	0	0	1	0	0
Pholidae							
Pholis ornata	Saddleback gunnel	2	0	0	5	0	1
Cottidae							
Cottus asper	Prickly sculpin	67	17	24	204	112	151
Leptocottus armatus	Pacific staghorn sculpin	34	4	13	205	59	53
Pleuronectidae							
Platichthys stellatus	Starry flounder	0	0	0	4	0	2
Canceridae							
Cancer magister	Dungeness crab	398	2	0	452	2	0
Hemigrapsus oregonensis	Yellow shore crab	4	29	33	12	80	64
Total		647	387	180	1,793	867	1,449