ENVIRONMENTAL STUDIES OF THREE

COLUMBIA RIVER ESTUARINE BEACHES

by

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FRONTISPIECE

Seaside, Oregon, artist, Ron Pittard, portrays a common subtidal fish, fall chinook salmon *(Oncorhynchus tshawytscha)* and a common estuarine invertebrate, the amphipod, *Corophium salmonis.*

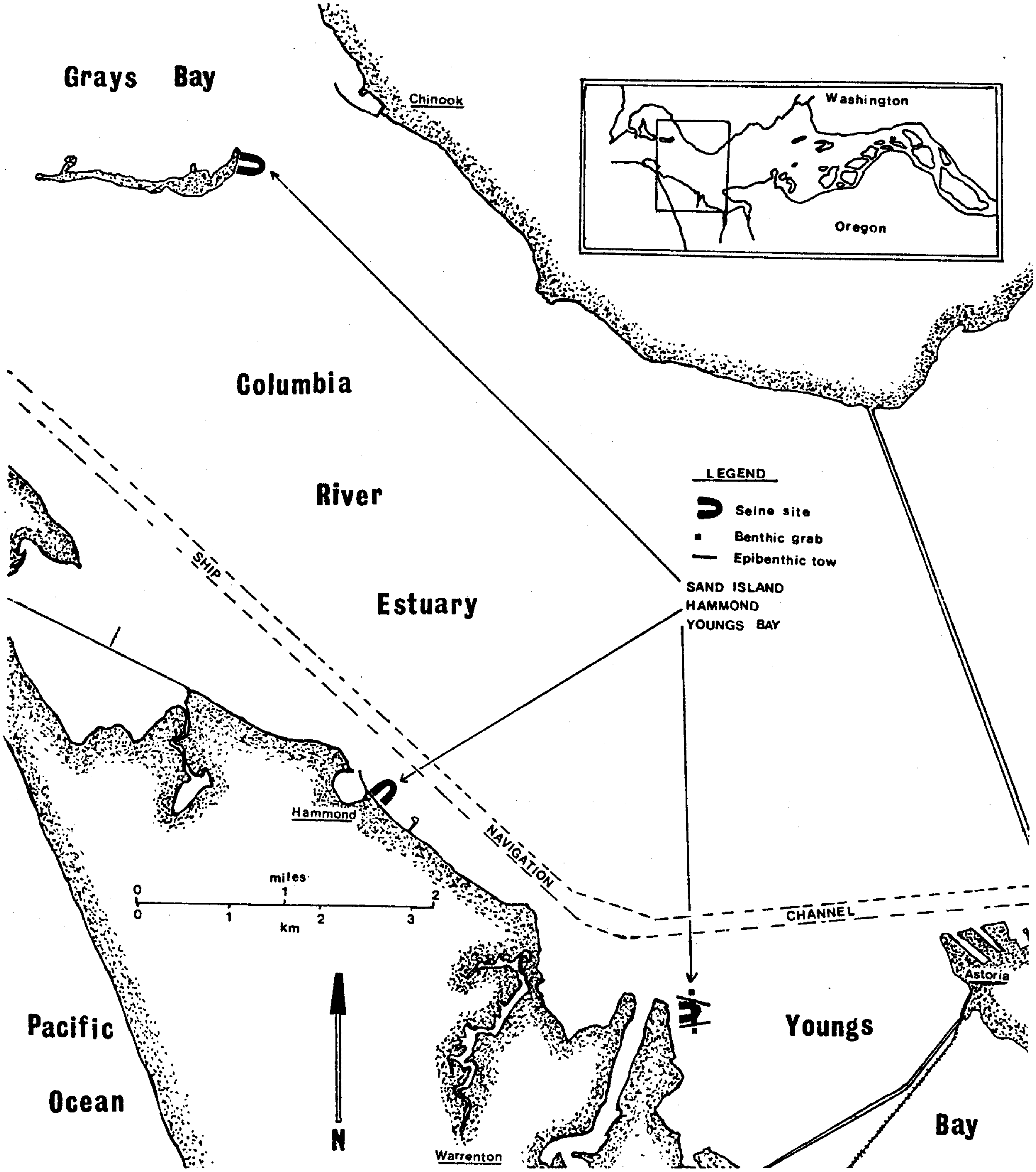

Figure 1. Estuarine sampling sites within the Columbia River estuary studied May to September 1976. Inset shows the area involved. The sampling effort is out of scale and some benthic grab sites are obscured since they were taken within the seine site

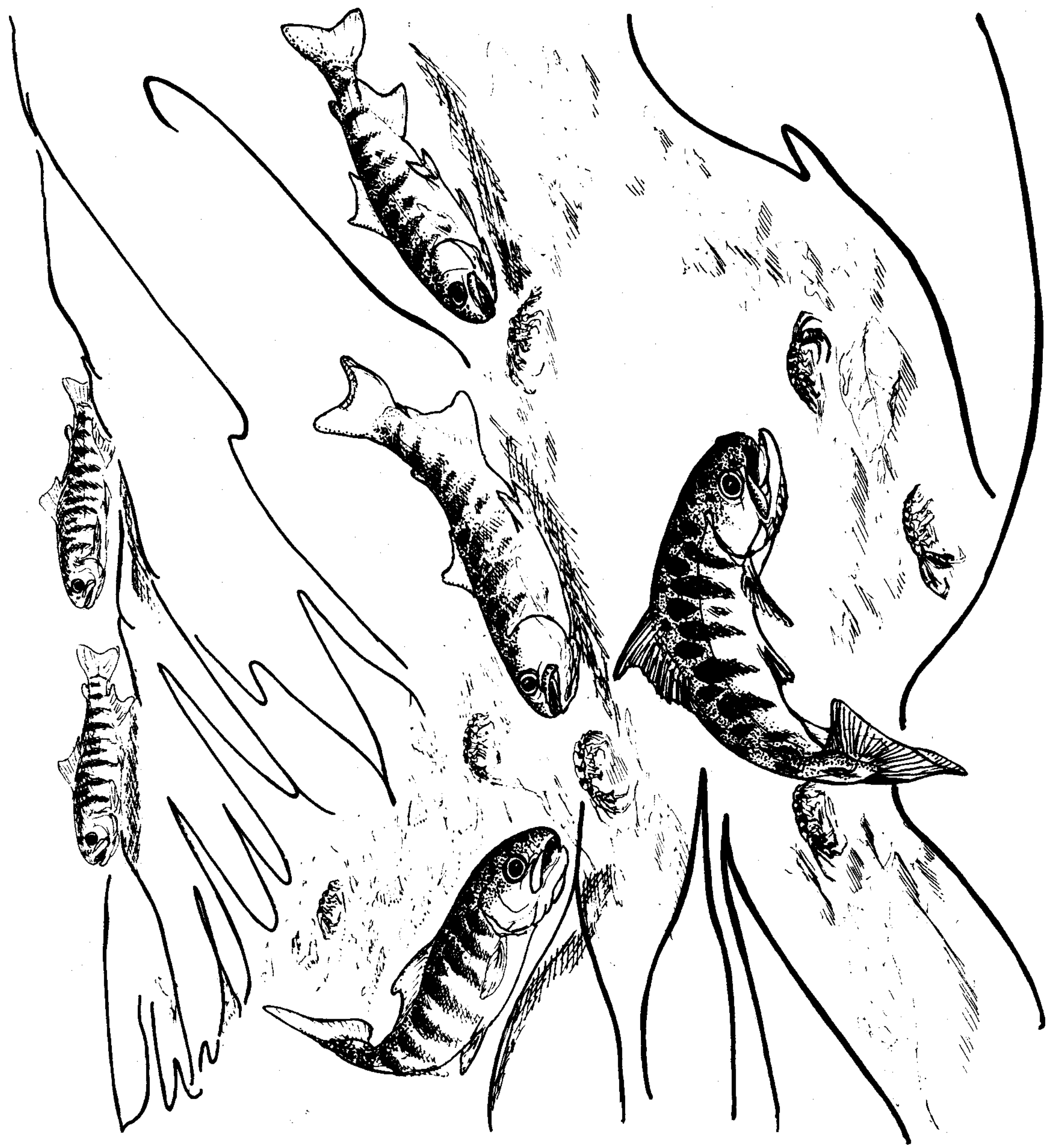

TABLE OF CONTENTS

INTRODUCTION

Increasing interest and attention is being focused on commercial and industrial development of estuarine sites. Preferred areas are shore development or shoreline associated with and often involving intertidal zones. Agencies responsible for protecting the nation's aquatic fisheries resources are alarmed over loss of these shallow estuarine areas since evidence reveals their importance to commercially and recreationally valuable species of fish and wildlife. Estuaries are important as spawning areas, nursery areas for juvenile fish, sanctuaries for migrating and indigenous wildlife, feeding areas, and as osmotic transition zones for anadromous and catadromous species of fish. Further, estuaries are used by commercial fishermen and as recreational areas by hunters, fishermen, and boaters. The National Marine Fisheries Service (NMFS), in cooperation with other state and federal agencies, carries an obligation to the public to ensure that any necessary proposed estuarine development causes the least possible adverse effects to the aquatic resources.

General information on estuarine resources has some value, but site-specific data is essential for informed and supportable decisions. A number of shallow sites within the Columbia River estuary have been suggested for future development; however, vital data concerning aquatic life in those areas is generally limited. One location at the northwest portion of Youngs Bay mouth has been proposed as a site to fabricate oil platforms. Several plans have been submitted to the Portland District, U.S. Army Corps of Engineers indicating that substantial acreage would be dredged, filled, or cofferdammed, although the precise acreage involved in each category has not been specified. A second potential development site is the waterfront from Hammond east to Tansy Point. Here, a quay-side dock facility has been proposed as a future project by the Port of Astoria. The site's desirability is based on its location in a self-scouring area indicating minor maintenance dredgig would be needed. A third site is Sand Island in Baker Bay because it has potential as a future sediment deposition site for pipeline dredging of the navigation channels to Chinook.

Sampling at the Youngs Bay, Hammond, and Sand Island sites was initiated in May 1976, to provide additional biological knowledge of these beaches to NMFS resource managers. Funding support for the study was provided in part by the NMFS Environmental and Technical Services Division in Portland, Oregon. The results of the study are contained in this report.

METHODS, EQUIPMENT, AND PROCEDURES

Two seine hauls were made at each beach site monthly for five consecutive months. Sets were made the same day or if large numbers of live specimens required additional processing time, again the following day. The seine's total length was 86.5 m at the floatline with a 22-mm, stretched mesh size at the outer one-third wing, 18-mm mesh in the interior, and a 13-mm mesh knotless bag. Sampling procedure consisted of making an approximate 180 degree sweep with the seine towed by a 7-m dory powered by a 55-hp outboard engine. The maximum sample area would be approximately 0.6 hectare if tides, currents, and bottom permitted a full sweep.

Conditions were not suited for a full seine sweep at the Youngs Bay site. Shallow water through substantial portions of the Youngs Bay site required manual retrieval of the seine one-half to two-thirds through the sweep.

At all three sites seine captured fish except carp (*Cyprinus carpio*), and largescale sucker (*Catostomus macrocheilus*), were eased into the bag, transferred to tubs, and taken to the boathouse at the NMFS Hammond facility for examination. At the facility, all species were held in live cages containing flowing water pumped from the river. Individuals were examined, and up to 50 of each species were randomly selected, measured, weighed, and released. Within the subsample, up to 10 fish were selected for food consumption studies. All juvenile salmonids were closely examined for tags, brands, tattoos, or fin clips. Fish not measured were counted and returned to the estuary. Fish retained for food studies were opened and the stomachs removed between the lower esophagus and the junction of the pyloric caecae. Stomachs were preserved with 10% buffered Formalin[1/] and stored in individual vials for subsequent analysis. In addition to the fish seining and food utilization study, benthic and epibenthic sampling was conducted at the Youngs Bay site which faced the most immediate development pressure.

Samples of the benthic invertebrate community were collected with a .05 m^2 Wildco Ekman Model 197 dredge in water usually of less than 2-m depth. Each of the five monthly samples taken in Youngs Bay was placed in a marked container and returned to Hammond. There the sediments were washed through a 0.75 mm sieve. All remaining material was transferred to a specimen bottle with organisms preserved with a buffered Formalin solution, and stained with rose bengal dye. The invertebrates were identified to the

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[1/]Reference to trade names does not imply endorsement by the United States Department of Commerce to the exclusion of others that may be suitable.

species level when possible or to the lowest possible taxonomic grouping using selected references listed in Table 1. Invertebrate organisms were counted and each group weighed on an Ohaus Model 310 scale to the nearest 0.01 g.

Samples of epibenthic invertebrates were taken with a net having a 21 by 45 cm mouth and mounted on two 10-cm sled skids. Mesh size was 1 mm within the net and also in the detachable cod-end cup where organisms were collected. The method of sampling with the epibenthic sled was to slowly tow it with the dory for approximately 200 m, and in the process, sample approximately 30 m^3 of water. Upon completion of each tow, the sled was brought aboard the dory and organisms were carefuly washed to the cod-end cup. Organisms were removed from the cup, placed in a plastic bag and preserved with buffered Formalin. The epibenthic forms were taken to the laboratory and, as with the benthic specimens, identified to the lowest possible taxonomic order. All specimens were also counted and weighed.

Salinity, temperature and depths were recorded for each survey effort at each site. Depths were invariably less than 3 m and were taken by direct measurement. A Beckman Model RS5-3 salinometer and probe were used to determine temperature to the nearest 0.1°C and salinity concentration to the nearest $0.1\ ^{o}/_{oo}$. Sampling was usually conducted during late ebb, slack ebb, or early flood tidal situations.

Table 1.--References used in the identification of epibenthic and benthic invertebrates captured at the Youngs Bay, Hammond Beach, and Sand Island sites and those found in the fish stomachs.

Organisms	References
Oligochaeta	Pennak (1953)
Polychaeta	Banse and Hobson (1974) Smith and Carlton (1975)
Cladocera	Pennak (1953) Ward and Whipple (1918) Mizuno (1975)
Copepoda	Pennak (1953) Ward and Whipple (1918) Mizuno (1975) Brodskii (1950)
Ostracoda	Pennak (1953) Ward and Whipple (1918)
Mysidacea	Tattersall (1951)
Isopoda	Ward and Whipple (1918) Schultz (1969) Van Name (1936)
Amphipoda	Smith and Carlton (1975) Bradley (1908) Barnard (1969)
Decapoda	Schmitt (1921)
Insecta	Usinger (1956) Pennak (1953) Ward and Whipple (1918) Chu (1949) Jaques (1947)

SAMPLING LOCATION

Seining sites were at the northwest part of Youngs Bay, Hammond Beach, and northeast corner of Sand Island (Figure 1). The Youngs Bay site was intertidal to subtidal, with all sampling conducted within the boundaries of a proposed offshore oil drill platform fabrication facility. Seine hauls began at lat. 46°10'45"N-long. 123°45'00"W with a 100-m variation in any direction to compensate for the tide. The Hammond seine site is situated at lat. 46°14'15"N-long. 123°56'45"W with less than a 50 m site deviation. Sporadic seining had taken place at the site since 1971. The Baker Bay seine site is at lat. 46°15'45"N-long. 123°57'50"W on the northeast end of Sand Island.

Epibenthic sled tows and benthic grabs were an additional segment of the study taken at the shallow subtidal Youngs Bay site. The epibenthic tows were made in an ESE heading with the first tow beginning at lat. 46°10'55"N-long. 123°54'05"W in a direction of 120° true north. The second tow began at lat. 46°10'45"N-long. 123°54'00"W and followed a heading of 100° true north. The first benthic grab was made at lat. 46°10'56"N-long. 123°56'00"W at a heading of 170° true north. The subsequent four benthic dredge grabs were made on that heading at 50 m intervals.

ANALYSIS

Fish species at each site were first compared for numerical importance, for their proportional contribution to the total, and their seasonal availability. Particularly important was the comparison of food organisms utilized by similar species at different sites. In this respect, comparisons were made of numbers of a particular group of organisms eaten, weight of the items consumed, and their frequency of occurrence in the diet of the predator. Lengths and weights of dominant species found at the beach seine sites were also compared.

Species diversity between sites was examined and included Shannon-Weaver, equitability, and species richness tests. Comparative food consumption was made using an index of relative importance (IRI). The tests are described in Appendix I and source references are provided.

SAMPLING RESULTS

FINFISH CHARACTERISTICS

The number of finfish and decapod shellfish captured at the three sites during the study is listed in Table 2. At Youngs Bay and Hammond Beach 10 seine hauls each were carried out in the 5-mo study period, while at Sand Island only 3 seine sets were made in 2 mo. Nearly half of all the

Table 2.--Species" captured with a beach seine at two sites in the Columbia River estuary-1976

Common Name	Scientific Name	Youngs Bay Beach	Hammond Beach	Sand Island Beach	TOTALS
American shad	Alosa sapidissima	13	2	98	113
Pacific herring	Clupea harengus pallasi	21	569	3327	3917
Northern anchovy	Engraulis mordax	49	1004	106	1159
Chum salmon	Oncorhynchus keta	4	33	0	37
Coho salmon	Oncorhynchus kisutch	157	7	104	268
Chinook salmon	Oncorhynchus tshawytscha				
(Spring yearlings)		6	4	7	17
(Fall yearlings)		0	2	0	2
(Fall sub-yearlings)		5462	1383	552	7397
Steelhead trout	Salmo gairdneri	1	0	0	1
Surf smelt	Hypomesus pretiosus	1108	5340	1411	7859
Longfin smelt	Spirinchus thaleichthys	1	0	0	1
Carp	Cyprinus carpio	71	2	0	73
Peamouth	Mylocheilus caurinus	76	361	27	464
Largescale sucker	Catostomus macrocheilus	16	9	0	25
Pacific tomcod	Microgadus proximus	0	0	74	74
Threespine stickleback	Gasterosteus aculeatus	173	658	0	831
Shiner perch	Cymatogaster aggregata	7243	1402	234	8879
Snake prickleback	Lumpenus sagitta	0	0	5	5

Prickly sculpin	Cottus asper	0	3	0	3
Pacific staghorn sculpin	Leptocottus armatus	130	77	24	231
Starry flounder	Platichthys stellatus	117	71	40	228
English sole	Parophrys vetulus	0	0	6	6
Sand shrimp	Crangon franciscorum	52	5	0	57
Total catch		14700	**10932**	6015	31647
Total seine hauls		10	10	3	23
Average catch per seine haul		**1470.0**	1093.2	2005.0	1375.9

1/ Bailey et. al. (1970)

fish (46.1%) were captured at Youngs Bay indicating a high standing crop of fish in that area. Eleven of the twenty-one species were common to all three sites (Table 2). The 23 seine hauls captured 31,846 finfish and shrimp. Dominant species in order of their percentage composition of the total catch were shiner perch, Cymatogaster aggregata (29%); surf smelt, Hypomesus pretiosus (25%); juvenile fall chinook salmon, Oncorhynchus tshawytscha (23%); Pacific herring, Clupea harengus pallasi (12%); northern anchovy, Engraulis mordax (4%); threespine stickleback, Gasterosteus aculeatus (3%) and peamouth, Mylocheilus caurinus (1%) (Figure 2).

Seven species represented **96.4%** of the total yet some were numerically important at only one or two sites. For example, shiner perch, fall chinook salmon, and surf smelt dominated the Youngs Bay catches. Surf smelt, shiner perch, fall chinook salmon, and anchovy were important at Hammond, while herring, surf smelt, and fall chinook salmon were important at Sand Island. There are specific site preferences that are not completely understood or explainable. Specific counts of finfish in relation to individual seine hauls is listed with associated physical conditions in Table 3.

Juvenile fall chinook salmon are the most important economic species and constitute 23.2% of the entire seine catch. They were 37.2% of the Youngs Bay total but were only 12.4% of the Hammond catch and 7.2% of those taken at

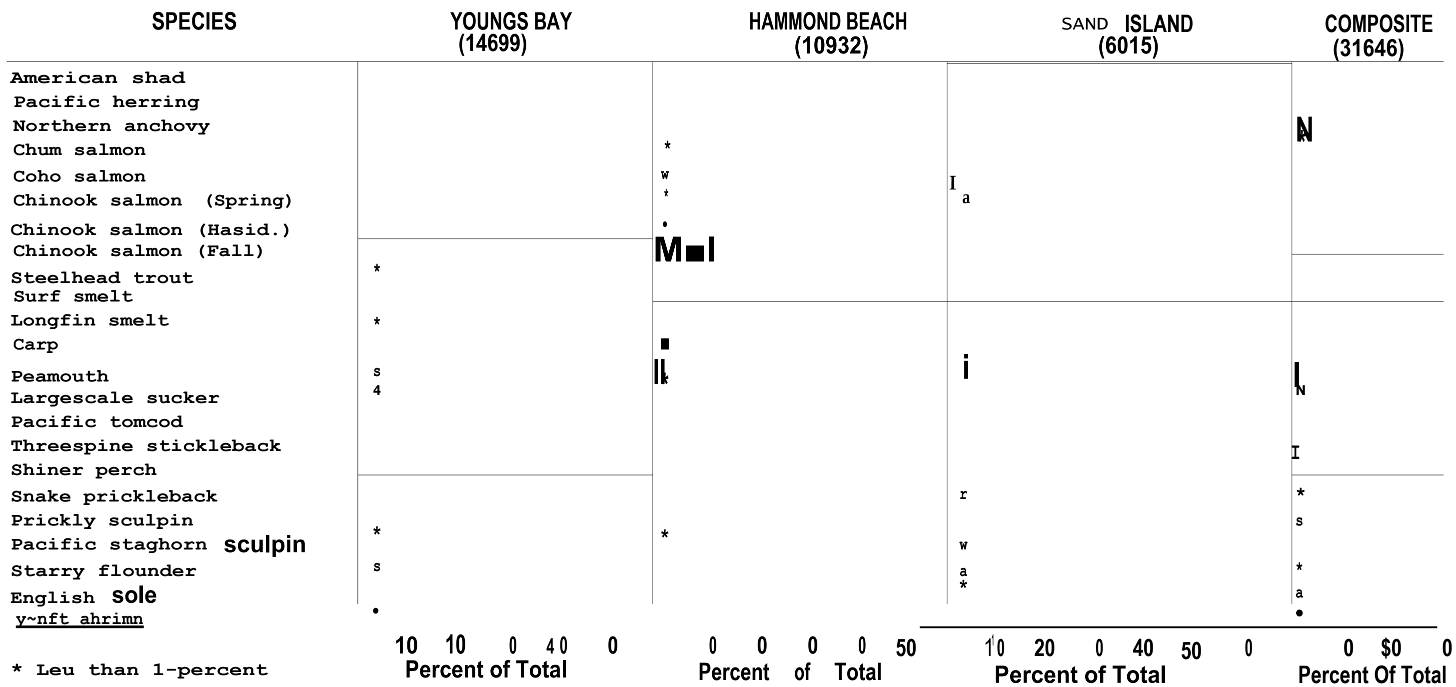

Figure 2. The proportion caught of each fish species at individual seine sites and as part of the total.

Table 3.--Oceanographic conditions and number of fish captured during each seine haul at Hammond (H), Youngs Bay (YB), and Sand Island (SI); May through June 1976.

	May 18	May 18	May 21	May 21	May 21	June 8	June 8.	June 8	June 9	June 14	June 14
Tow number	YB-1	YB-2	H-1	H-2	SI-1	H-2	H-4	YB-3	YB-4	SI-2	SI-3
Depth-feet	2	0.5	9	9	7	8	8	5	6	7	8
Salinity-bottom (°/oo)	0.2	0.2				1.8	3.3	1.1	0.6		
Temperature°-bottom (°C)	14.0	14.6				13.1	12.9	13.5	13.5		
Time	12:10	12:47	09:55	10:40	13:40	09:25	09:40	14:55	15:15	10:30	11:45
Tide	Low Slack	Early Flood	Late Ebb	Late Ebb	Low Slack	Mid Flood	Mid Flood	Mid Ebb	Mid Ebb	Low Slack	Early Flood
	. . . . .Number of fish										
American shad		12			52	2		1			46
Pacific herring					713	105	35	12	---	6	2608
Northern anchovy							4				106
Chum salmon				1		16	16	---	2		
Coho salmon	116	41	4	1	104			1			
Chinook salmon											
Spring yearling	3		2		7			1			
Fall yearling			1			1					
Fall subyearling	1045	173	299	114	375	483	225	2291	1323	109	68
Steelhead trout		1									
Surf smelt	22	16	81	4	630	437	2956	70	2	201	580
Longfin smelt	---	1									
Carp	3	11				1		5			
Peamouth	34	8			27	21		4	1		
Largescale sucker		1		2		2		6	3		
Pacific tomcod											74
Threespine stickleback	52	97	8	2		11	7	2			
Shiner perch		1	182	14	78	97	38	64	9	54	102
Snake prickleback											5
Prickly sculpin							1				
Pacific staghorn sculpin	2	7		2			5	8	27	8	10
Starry flounder	4						9	14	5	10	25
English sole											6
Sand shrimp											
w Totals	1282	370	587	140	1997	1189	3303	2479	1372	388	3630

Table 1.--(concluded) Physical measurements and fish captured during each seine haul at Hammond (H), Youngs Bay (YB), and Sand Island (SI).

	July 1	July 1	July 1	July 2	Aug. 3	Aug. 3	Aug. 4	Aug. 4	Sept. 8	Sept. 8	Sept. 10	Sept. 10
Tow number	H-5	H-6	YB-5	YB-6	YB-7	YB-8	H-7	H-8	H-9	H-10	YB-9	YB-10
Depth-feet	7	9	2	1.5	1.5	1.5	8	8	7	7	3	3.5
Salinity-bottom (°/oo)		6.9	4.0	1.0	2.2	2.2	3.4	2.4	3.1	4.7	3.5	1.1
Temperature-bottom (°C)		15.9	17.6	16.4	18.7	19.2	17.9	18.4	17.0	17.6	17.5	18.7
Time	13:10	15:15	11:35	10:55	13:03	14:27	12:20	13:10	09:21	11:05	09:32	11:06
Tide	Mid Flood	Mid Flood	Low Slack	Late Ebb	Late Ebb	Late Ebb	Mid Ebb	Mid Ebb	Low Slack	Early Flood	Early Flood	Early Flood
American shad	---											
Pacific herring	51	166	6	1		1	24		7	18.1		1
Northern anchovy		14			1		3		710	273	1	47
Chum salmon					1							
Coho salmon										1		
Chinook salmon												
Spring yearling		2	1									
Fall'yearling	---											
Fall subyearling	73	100	247	311	25	40	42	17	8	22		
Steelh d trout	---	---										
Surf S It	215	251	722	268	3	3	1117	190	33	56	---	2
Longfi smelt												
Carp	1		31	13	5	1						2
Peamou	191	57	8	6	11	1	10	16	53	6		3
Largos e sucker	---		2	2	2							
Paci "" a . od												
Three tickleback	2		4	5	1	---	207	12	122	287	1	11
Shia_ K. S ack	153	133	1879	88	510	2241	144	45	223	373	1091	1360
P re in		1								1	---	
Paa horn scuipin	19	19	16	33	5	18	7	8	4	7	14	
Starry lounder	9	3	17	32	8	20	3	3	6	26	17	
English sole												
Sand shrimp			1	24		18			1		3	
Totals	714	746	2934	783	578	2343	1561	291	1167	1233	1131	1429

Sand Island. Considering the poor seining condition existing at the Youngs Bay site, the data indicates presence of a dense population of juvenile chinook salmon particularly during the months of May, June, and July.

The average number of species and average catch for each monthly seine effort declined after June (Figure 3a and 3b). The trends reflect a seasonal shift from anadromous species to marine or brackish tolerant species. There was essentially little difference in the species found at the Youngs Bay and Hammond sites through the study period. Sand Island did have fewer species but these were numerically important. Overall, the catches at Hammond were lowest in July and August in comparison with the Youngs Bay site. June's large catches reflected surf smelt at Hammond, fall chinook at Youngs Bay, and herring at Sand Island.

Other population trends, in particular diversity indices, were examined. Indices have some value determining population changes resulting from environmental stress. None of the sites was subjected to a specific man induced stress during the sampling period; therefore, the test results would generally reflect normal population conditions occurring at those particular shallow estuarine areas. One possible exception was the Sand Island site where a recently completed agitation dredging project within the adjacent Chinook navigation channel may have had a slight impact. Except for that qualification these diversity indices would

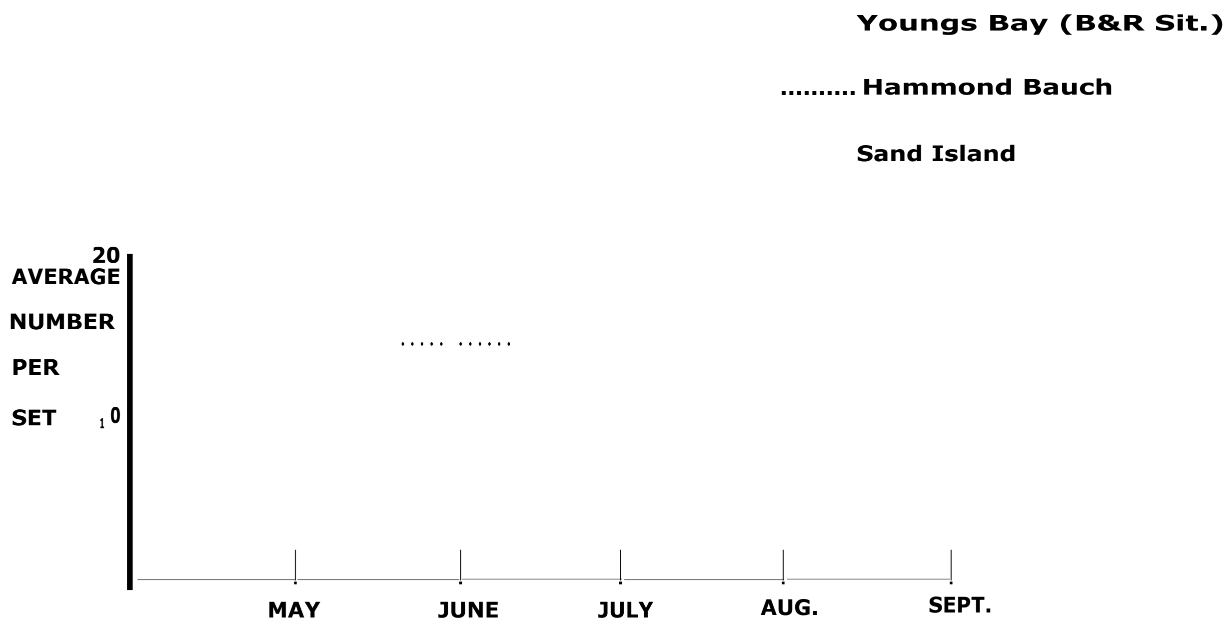

Figure 3a. Ave r age species caught with a beach seine at 3 estuarine sites in 1976.

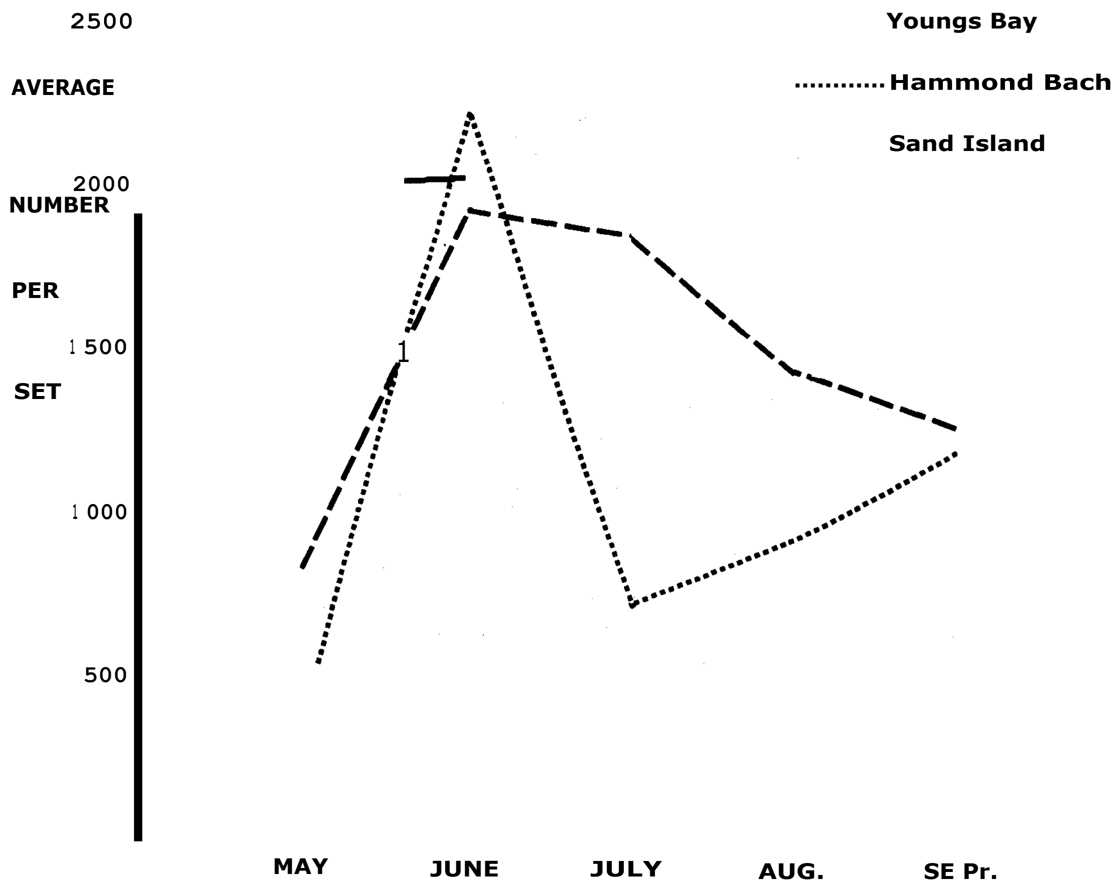

Figure 3b. **Average** number of fish and decapod shellfish taken by beach seine at three estuarine sites in 1976.

be expected to serve as a means for comparison between the sites during undisturbed conditions and form a base for future surveys at the same time of the year when using similar gear and methods.

Shannon-Weaver (1963) diversity tests for each of the 23 seine hauls are indicated in Figure 4. A decline in index readings during June samples reflect the single species dominance by chinook salmon, surf smelt, and herring at the sites. July readings increased with a more equitable balance of species; however, a second strong decline occurred in index values at the Youngs Bay site during August and September. Shiner perch dominated the catch during this period. Catch fluctuations at the Hammond site were obviously not as dramatic as those in Youngs Bay. The indices suggest the Hammond site is perhaps less dominated by single species and may be more stable than the Youngs Bay site. It should be noted that 25% more fish were found at the Youngs Bay site under very poor sampling conditions and the indices more correctly reveal the heavy utilization or numerical dominance of that site by two species.

Equitability indices were determined for each of the seine hauls and are shown in Figure 5. Dominance of the catch by one or two species during some months has been previously discussed and is reflected by the results. Equitability tests tended to parallel the Shannon-Weaver results. Sand Island catches produced higher readings than

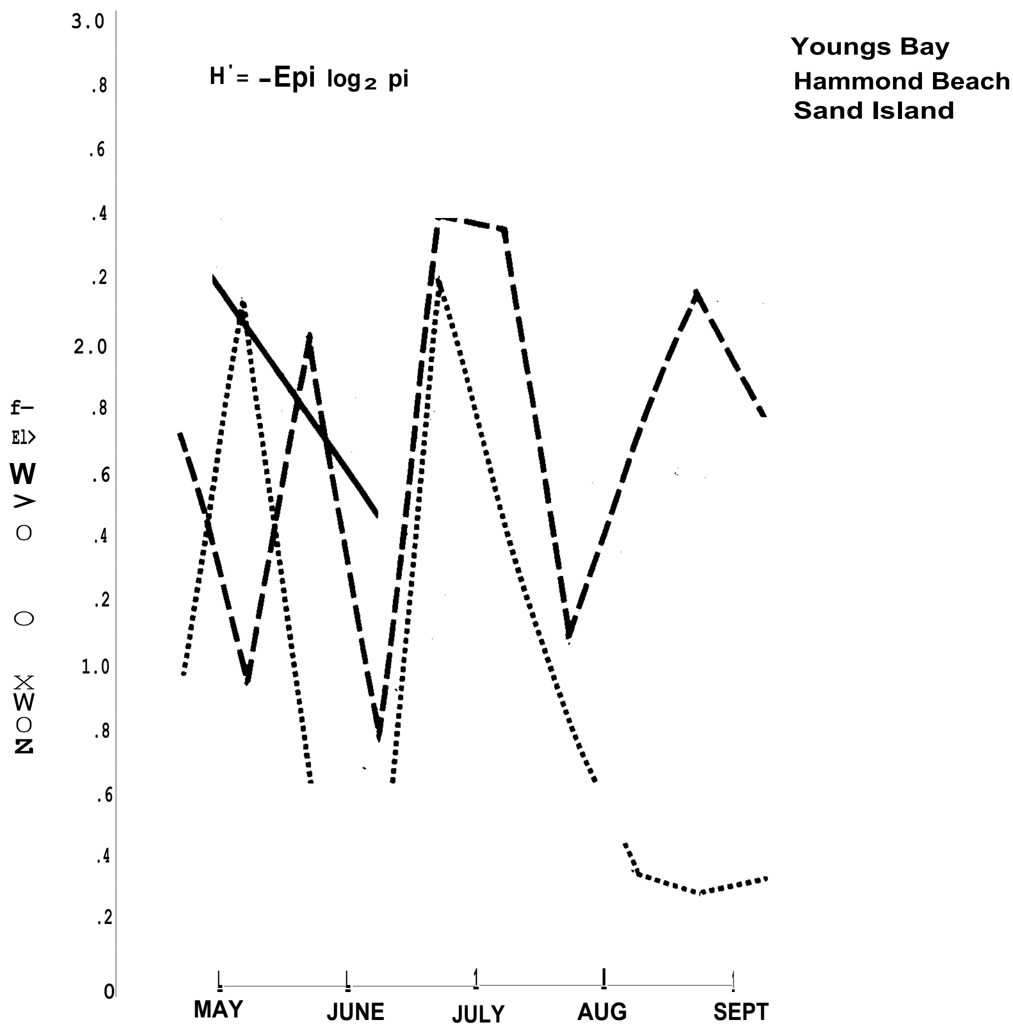

Figure 4. Shannon-Weaver diversity test results of **seine** catches at three estuarine beaches in 1976.

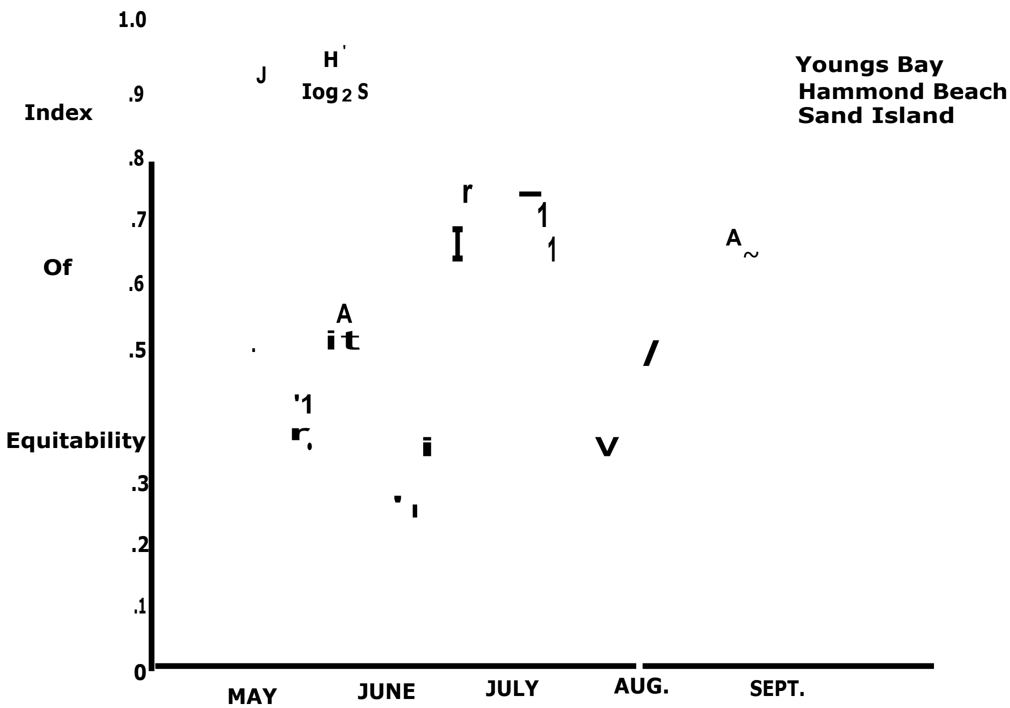

Figure 5. Indices of equitability determined from beach seine catches in the Columbia River estuary in 1976.

the Hammond and Youngs Bay catches during the first several months but differences were not great.

Species richness test indices are shown in Figure 6. Wide fluctuations are apparent and while the Youngs Bay site has lowest test values, it also has the highest. There was a general overall trend toward lower test results through the study period.

Length frequencies were examined and compared for several dominant species at both Hammond and Youngs Bay. Shiner perch measurements are illustrated in Figure 7 and provide size group characteristics. The small shiner perch are rare in May but migrate into the estuary and are common in June. These live bearers apparently deliver their young in June and July since the juveniles first appear in July. The young perch are numerically more abundant and appear earlier at the Youngs Bay site indicating it is one of the areas where young are released from the female. The length-frequency histogram reveals 3 groups at both sites. The age-group 0 fish grow rapdily from July through September. The age-group 1 fish also grow but at a slower rate while there was no evident growth for older fish. This information suggests the Youngs Bay site serves as spawning area, nursery, and also as feeding area for these fish.

Surf smelt lengths are shown in Figure 8. Larval surf smelt were caught but not included in the charts, therefore the small fish which dominate the size groups are of age-

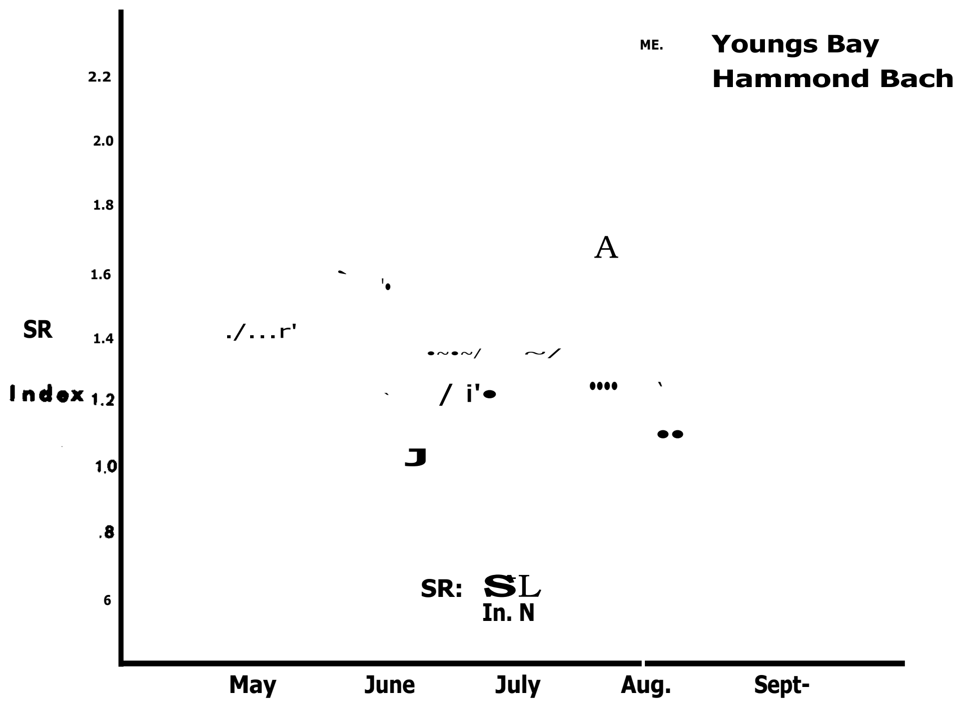

Figure 6. Species Richness index levels indicated by seine catches at two estuarine beach sites in 1976.

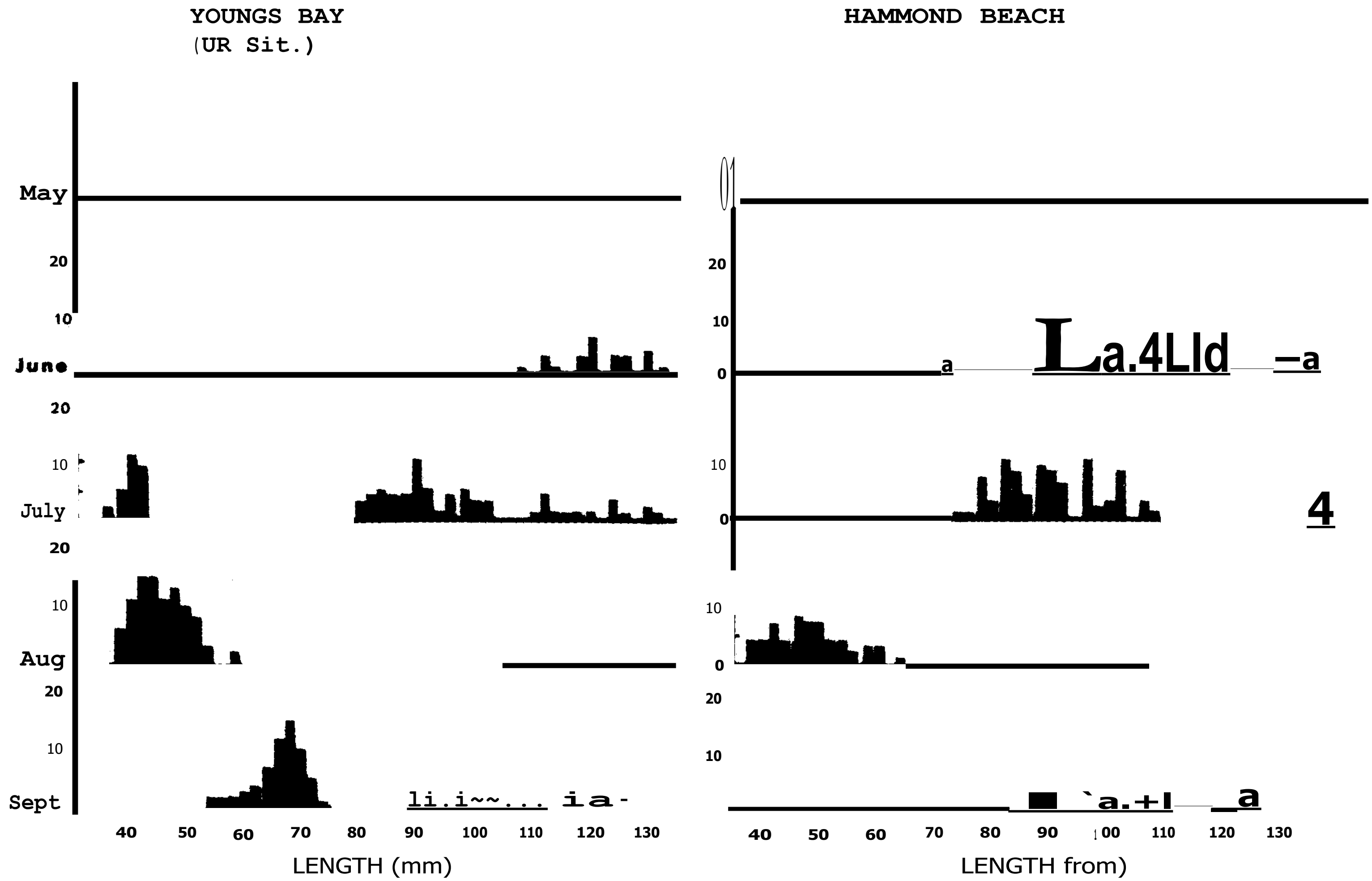

Figure 7. **Length-frequency** histograms of shiner perch captured at two beach seine sites in 1976.

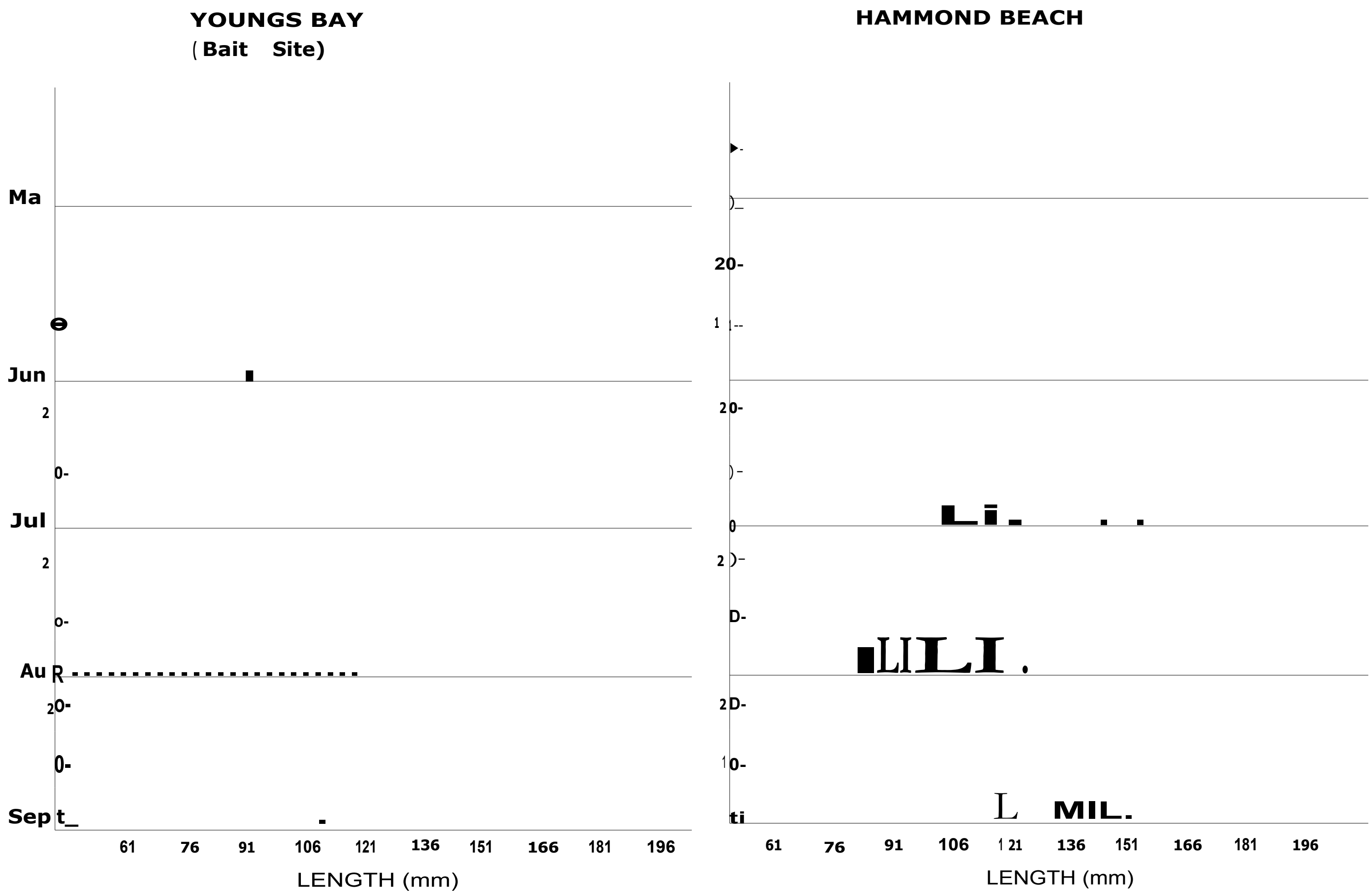

Figure 8. **Length-frequency** of surf smelt captured in seining at two estuarine beach sites in 1976.

group 1. This group is found every month at both sites and gives evidence of rapid growth through August. Older surf smelt were taken in May but were less evident thereafter. Few surf smelt were captured at the Youngs Bay site after July. This suggests both areas function as nurseries, and feeding zones.

Pacific herring were common at the Hammond site from June through September (Figure 9), but were not important components of the Youngs Bay catch. Two size groups were evident, larger fish in June and July, and smaller fish in August and September. Growth was evident for both size groups.

Chinook salmon length-frequency charts for Youngs Bay and Hammond are shown in Figure 10. Most individuals are the fall chinook race, however, a few yearling spring chinook and yearling fall chinook are included. Size groups at each site, while apparently similar, when analyzed revealed the mean size of Youngs Bay fish was 2 to 7 mm larger than Hammond chinook in 4 of the 5 mos. The reverse was true in August. Chinook mean size did not vary greatly from May through July which is similar to results found by Reimer (1973) at the Sixes River. The number of fall chinook subyearlings diminished at both sites after June but historically the quantity entering the estuary from nursery sites is greatest in July and August. If fall chinook had continued to utilize beach sites through their normal

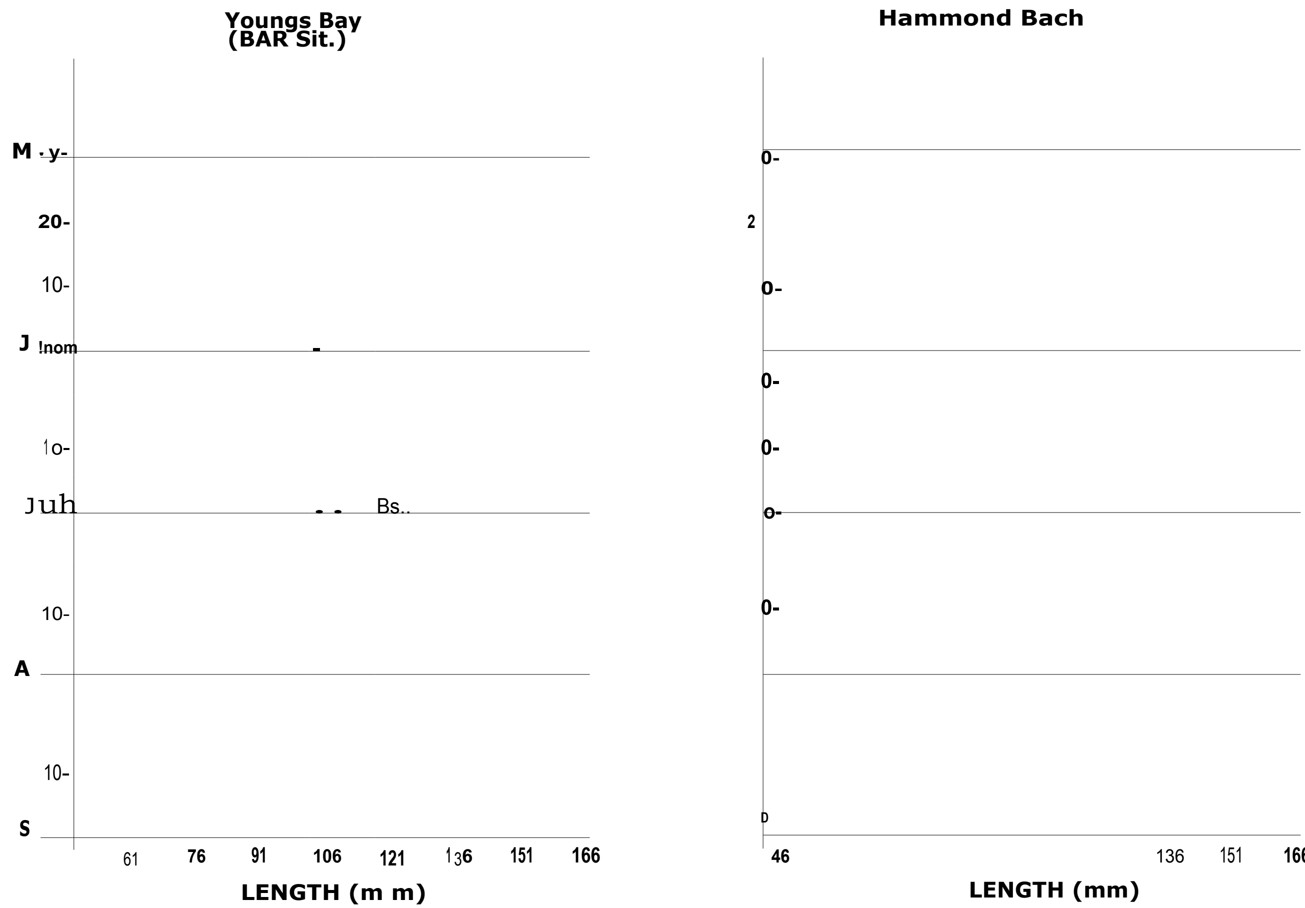

Figure 9. Lengths of Pacific herring captured at two estuarine beach sites in 1916.

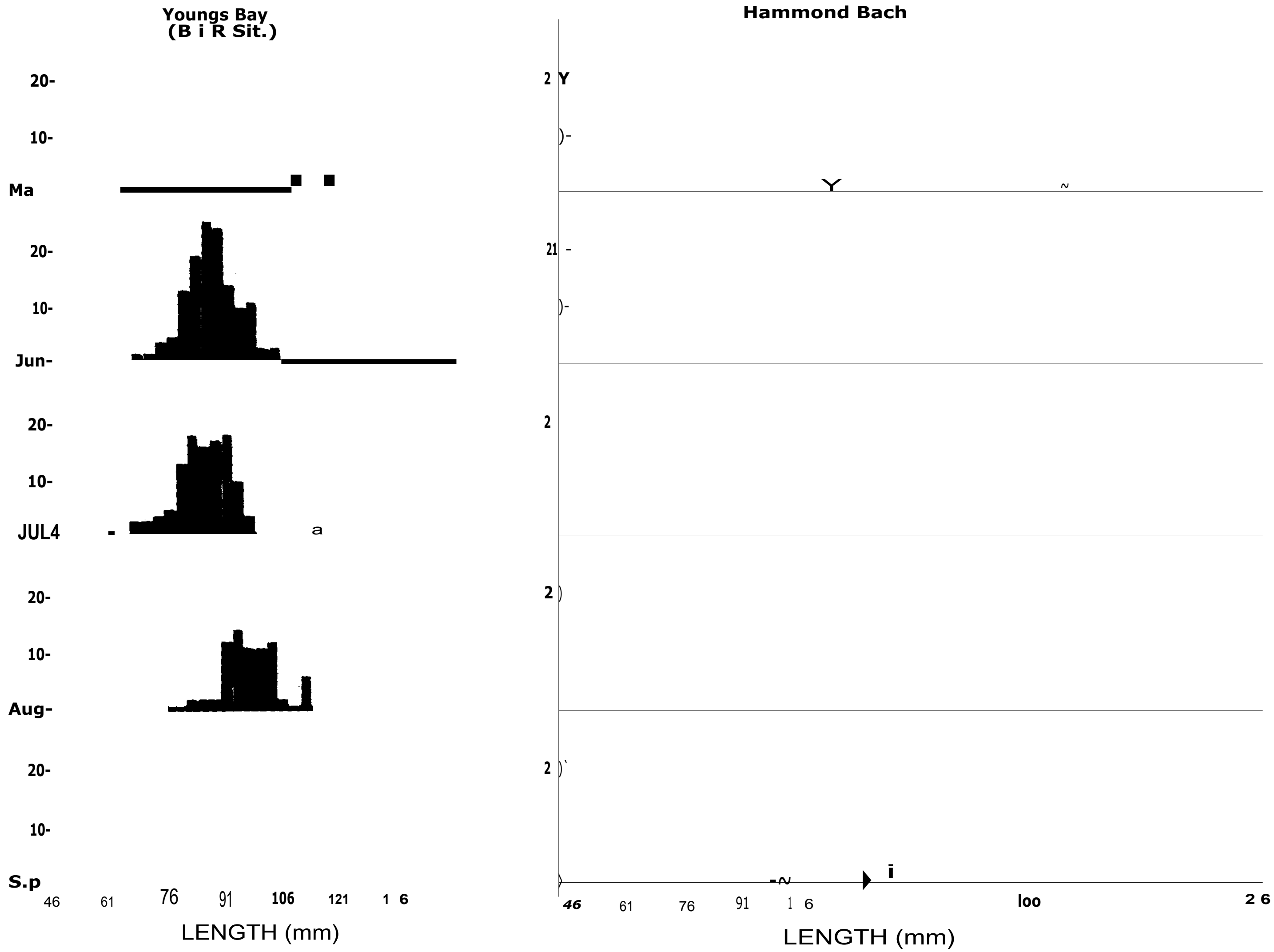

Figure 10. Length—frequency histogram of **juvenile** chinook salmon captured with a beach **seine** at three estuarine sites in 1976.

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migrational peak it would have occurred during nocturnal or near nocturnal conditions when we did not sample.

Some fall chinook salmon with fin clips were observed. Over the study period, seven were captured: six with adipose (Ad) clips and one with a left ventral-right ventral (LV-RV) clip. Four of the fin-clipped chinook were in Youngs Bay and three at Hammond. The Pacific Marine Fisheries Commission's mark list indicates the adipose fin-clipped fish had coded wire tags and were part of 1,500,000 fall chinook released from state (Washington and Oregon) and federal hatcheries in 1976.

The comparative yield of chinook salmon for each seine set is shown in Figure 11. The larger catch at the Youngs Bay site was particularly noticeable in June. Seine set yields at both sites were small but similar in August and September.

Coho salmon, Oncorhynchus kisutch, were also captured at both sites in May, but they were only common at the Youngs Bay site. Size comparisons are somewhat questionable because of numbers but the computed mean length indicated coho were about 133 mm at both sites. Fin-clipped coho were also taken in the Youngs Bay catches with 14 of the 158 fish having identifiable marks. The fin-clipped fish, (Ad, LV-RV, or RV-LM) were released from Oregon's Sandy River Hatchery, Big Creek Hatchery, Willamette River, and also Washington hatcheries.

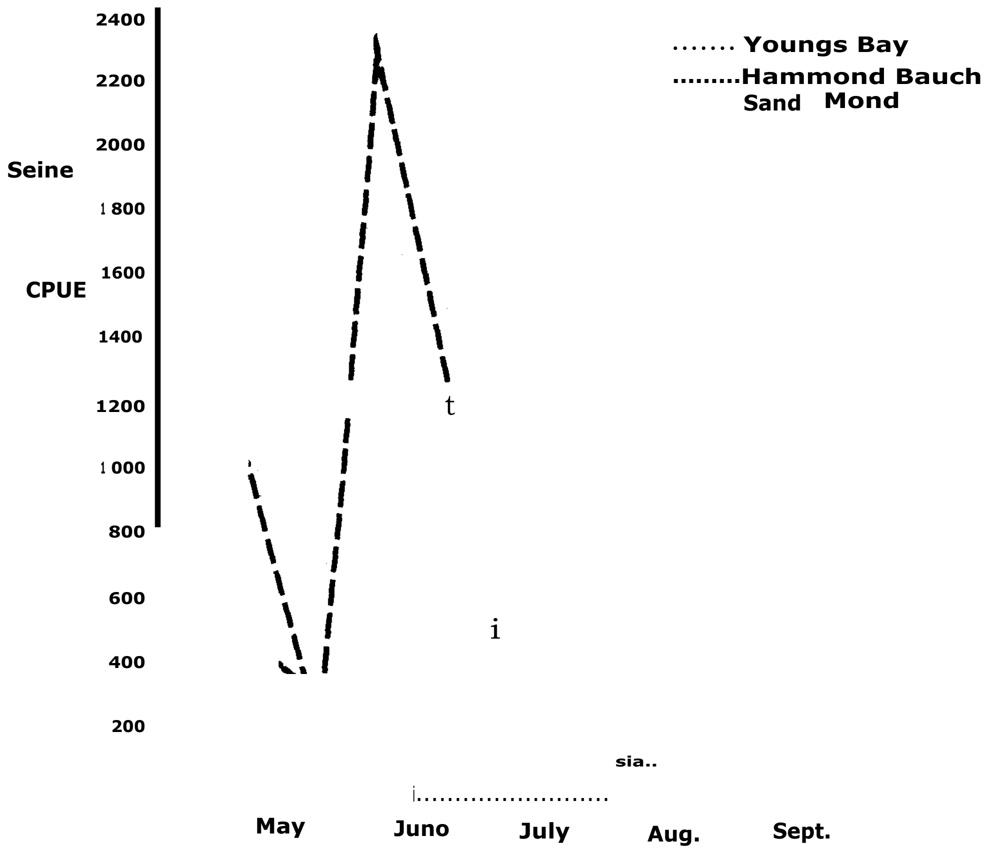

Figure 11. Fall chinook subyearling catches per seine effort at .3 estuarine beaches in 1976.

EPIBENTHUS

Ten epibenthic tows (two each month) were made in Youngs Bay. Eight species of organisms were captured as well as unidentified eggs and the molts of the amphipods, Corophium sp. and Eohaustorius sp. The tows were taken in less than 2 m of water and in water temperatures of 14° to 18° C.

Table 4 lists the numbers of each item collected. The mysid, Neomysis mercedis, was the most abundant organism and was captured both in the juvenile (smaller than 12 mm) and adult (larger than 12 mm) stages. Age differentiation was based on Banner (1948). Juveniles were caught in larger numbers than were the adults during all months; in September no adults were present in the tows. The benthic amphipod, Corophium salmonis, was found in all tows (except the second tow in September) and in numbers ranging from 2 to 42. From 400 to 1200 molts, or cast-off shells, of both C. salmonis and another amphipod genus, Eohaustorius sp., were found from July through September. Since these were not live organisms, the numbers were estimated. Juvenile shrimp, Crangon sp., occurred in the catch during all months sampled with counts ranging up to 17 individuals.

The wet weights of the items captured are listed in Table 5. The mysid juveniles, N. mercedis contributed the most weight to the sample, followed by mysid adults, then C. salmonis, the amphipod. Shrimp, Crangon sp., adults were

Table 4.--Oceanographic conditions and number of organisms captured in epibenthic sled tows at the Youngs Bay site, May through September 1976.

	May 20		June 7		July 2		Aug. 5		Sept. 8		
Tow number	T-1	T-2	T-1	T-2	T-1	T-2	T-1	T-2	T-1	T-2	
Depth-feet	3'8"	2'8"	4'	4'6"	2'6"	2'6"	5'	3'	4'		
Time	09:13	09:25	14:30	14:43	14:02	14:15	15:27	16:12	10:34	10:50	
Conductivity		---	0.8	0.8	0.3	0.0	3.5	3.2	1.1		
Salinity (°/oo)		---	0.6	0.6	0.1	0.0	2.3	2.1	4.8		
Temperature (°C)	---	---	14.0	14.1	18.4	16.8	18.3	18.4	18.4		Total
	. . . . Number of organisms										
Polychaete											
Neanthes sp.			1	---	1	--					2
Cladocera											
Bosmina longirostris							1	---		---	1
Mysid											
Neomysis mercedis adults	194	305	64	111	94	215	556	113		---	1652
Neomysis mercedis juveniles	261	429	739	686	193	392	781	1199	35	59	4774
Amphipod											
Corophium salmonis	4	4	2	2	10	42	7	3	3	---	77
Eohaustorius & Corophium molts			1		400	1200	400	750	700	500	(3951)
Decapod Crustacean											
Crangon sp. juveniles	8	17	7	16	11		11	17		4	96
Crangon sp. adults			7		5		2				14
Crangon franciscorum									1		1
Teleost											
Cottus asper larvae	1	2									3
Clupea harengus **pallasi larvae**							1				1
Other											
Unidentified eggs					9		11	17			37
Totals (excluding molts)	468	757	820	815	323	654	1370	1349	39	63	6658

Table 5.--Oceanographic conditions and weight of organisms captured in epibenthic sled tows at the Youngs Bay site, May through September 1976.

	May		June		July		Aug.		Sept.		
Tow number	T-1	T-2	T-1	T-2	T-1	T-2	T-1	T-2	T-1	T-2	
Depth-feet	3'8"	2'8"	4'	4'6"	2'6"	2'6"	5'	3'	4'	—	
Time	09:13	09:25	14:30	14:43	14:02	14:15	15:27	16:12	10:34	10:50	
Conductivity		---	0.8	0.8	0.3	0."	3.5	3.2	1.1	---	
Salinity (°/oo)		---	0.6	0.6	0.1	0.0	2.3	2.1	4.8		
Temperature (°C)	---	---	14.0	14.1	18.4	16.8	18.3	18.4	18.4	---	Totals
	.Grams.										
Polychaete											
Neanthes sp.			0.02		*	---	---	---	---	---	0.02
Cladocera											
Bosmina longirostris							*				
Mysid											
Neomysis mercedis adults	9.96	13.76	1.69	4.00	1.34	4.67	8.38	4.30			48.10
Neomysis mercedis juveniles	1.41	2.30	6.27	12.44	0.99	3.42	6.19	5.17	0.09	0.13	38.41
Amphipod											
Corophium salmonis	0.15	0.16	0.04	0.92	0.01	1.04	0.01	0.20	0.11	---	2.64
Eohaustorius & Corophium molts	---										
Decapod Crustacean											
Crangon sp. juveniles	0.11	0.22	0.04	1.01	0.07	0.98	0.21	3.10		1.06	6.80
Crangon sp. adults			0.27		1.54		0.73	---		---	2.54
Crangon franciscorum									0.64		0.64
Teleost											
Cottus asper larvae	0.21	0.11	---								0.32
Clupea harengus pallasi larvae	---						0.02	---			0.02
Other											
Unidentified eggs					*		*	0.37			0.37
Totals	11.84	•.55									

* - less than .01 of a gram

important in terms of weight in June, July and August and the sand shrimp, C. *franciscorum,* was important in September. Larval prickly sculpin, *Cottus asper,* contributed significantly to the total weight in May while unidentified teleost eggs were important contributors to weight of catch in August.

The catch results indicate a stable but numerically limited community of invertebrate species associated with the bottom surface in this area of Youngs Bay. Mysids, *Crangon* sp., and amphipods made up almost the entire epibenthic fauna.

BENTHOS

During the sampling period 26 grab samples were taken at the Youngs Bay site, six in May and five each month thereafter. To make the monthly comparisons similar, the sixth grab from May was eliminated from the data. A total of 22 species of organisms plus two types of unidentified eggs and a diptera case were collected.

The relative percentages of benthic invertebrates captured at the Youngs Bay site are shown in Figure 12. The benthic amphipod, C. *salmonis,* was clearly the dominant organism since it represented 75 to 98% of the total numbers of invertebrates in each sample except the second sample in May. That particular benthic grab contained 20% oligochaetes and 12% harpacticoid copepods, *Canuella* sp., and approximately 60% C. *salmonis.* Five invertebrates, in addition to C. salmonis, were common in the samples. These were nematodes, oligochaetes, Neathes sp. (polychaete), Canuella sp. (harpacticoid copepod), and Eurytemora hirundoides (calanoid copepod). Listed along the right margin of Figure 12 are those items occurring rarely.

Table 6 lists the average numbers and weights of benthic organisms per square metre. Average values were used after statistical testing of the five tows. A two-way multivariate analysis (Morrison 1976), test of the average values for each of the five stations, showed no difference in numbers among stations. At the .05 level of significance, c=36.415 with 24 degrees of freedom (taken from a chi square table). The test value is 9.510; therefore, we accept the null hypothesis of no difference among stations.

The amphipod, C. salmonis, ranged from a low of $4837/m^2$ in July to a high of $11,457/m^2$ in May. Other amphipods numbered up to $150/m^2$. Nematode numbers are indicative of relative presence only, since many are smaller than the sieve mesh and wash through. Oligochaete counts averaged 200 to $400/m^2$ except in May when they were $1443/m^2$. The polychaete, Neanthes sp., ranged from $43/m^2$ in July to $517/m^2$ in September. Cladoceran and copepod numbers were calculated simply for general information since they are also small organisms and many excape during the seiving process. Further, except for Canuella sp., they are

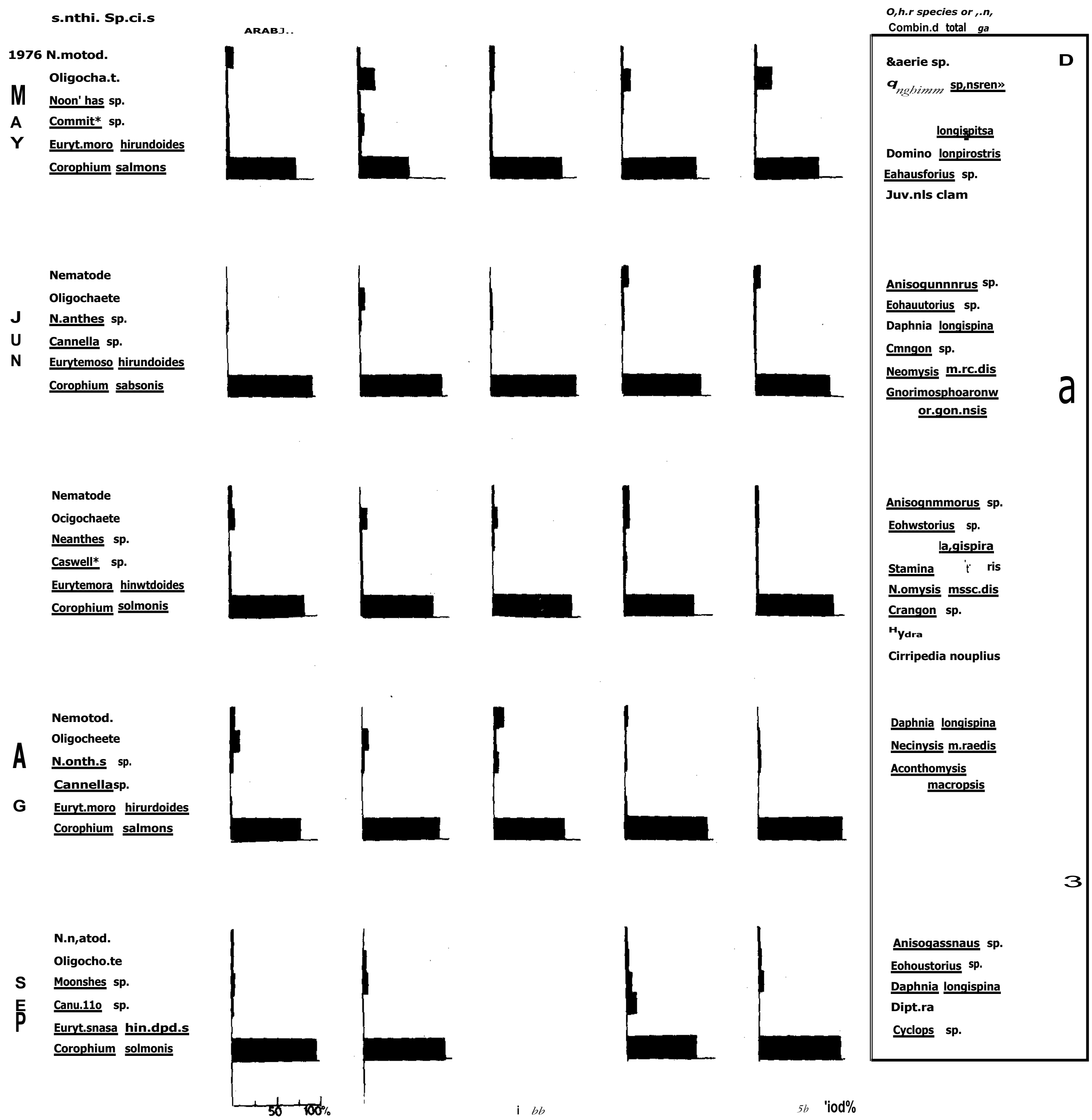

Figure 12. Percentages of six main benthic species and lists of rarer items in grab samples taken at the Youngs Bay site, May through September 1976.

Table 6.--Average numbers and weights per meter^2 (in grams)* of invertebrate and vertebrate species collected in benthic grab samples at the Youngs Bay site, May through September, 1976.

Organism	Numbers May 25	June 7	July 2	Aug. 5	Sept. 8	Weights (g) May 25	June 7	July 2	Aug. 5	Sept. 8
Nematodes	343	237	167	333	23	**	**	**	**	**
Oligochaetes	1443	223	343	393	190	0.43	0.07	0.17	0.07	0.07
Polychaete										
Neanthes sp.	143	53	43	213	517	0.67	0.10	0.13	0.20	0.33
Cladoceran										
Daphnia longispina	3	77	13	7	27	**	**	**	**	**
Bosmina longirostris	3	----	30		----	**		**		
Copepod										
Canuella sp.	233	10	57		73	**	**	0.03		**
Cyclops sp.	----	----	----		3	---	----		- --	**
Eurytemora hirundoides	153	27	47	7		**	**	**	**	
Acartia sp.	30	----	----		---	0.10				
Copepod nauplius			3					**		
Mysid										
Neomysis mercedis		40	7	3			0.20	0.07	**	
Acanthomysis macropsis				3				----	**	
Amphipod										
Corophium salmonis	11457	8037	4837	5077	10627	6.00	3.40	1.87	1.00	5.47
C. spinicorne	7	----	----		----	0.03	----	----	----	----
Anisoqammarus confervicolus	10	3	7		3	0.07	**	**		**
Eohaustorius sp.	150	70	97		7	0.23	**	0.03	----	**
Decapod Crustacean										
Cranqon sp. juveniles		10	3				0.03	**		
Pelecypod										
Pelecypod juveniles	3					**				
Other										
Unidentified eggs		30	3		7		**	**		**
Invertebrate eggs			7					**		---
Diptera					3			----		**
Diptera case			3					**		
Cirripedia nauplius			3					**		
Hydra			3					**		
Gnorimosphaeroma oregonensis		3	----				0.03			
Totals	13978	8820	5673	6036	11480	7.53	3.83	2.30	1.27	5.87

= wet weights after rying on i ter paper or I min

** = less than .01 g

planktonic forms associated with pelagic rather than benthic habitat.

The decreasing number of amphipods from May through July could possibly reflect the cropping of these organisms by juvenile chinook salmon and other species. The increasing number of amphipods in August and September may reflect a reduction in the cropping rate with fewer salmonids. Without more intensive studies these possibilities would have to be considered speculative.

The wet weights indicate C. _salmonis_ is the main contributor to benthic biomass. Lack of a suitable drying oven made it impossible to determine mg/m^2 dry weight biomass. However, C. _salmonis_ contributed 78 to 93% of the total wet weight of the samples. Oligochaetes contributed 1 to 7% of the total weight and _Neanthes_ sp. made up 3 to 16%.

The presence of vertebrates and invertebrates in the benthos, epibenthos, and their occurrence in fish stomachs at the Youngs Bay site is shown in Table 7. The table also reveals species overlap between and among these sampling methods. Benthic grab samples produced 22 species plus a diptera case and two types of unidentified eggs. Epibenthic sled tows yielded eight species plus unidentified eggs and amphipod molts. Examination of stomach contents revealed 17 species plus vegetation seeds, phytoplankton, and digested material. The food utilized by the fish were aquatic forms

Table 7.--Overlap in occurrence of vertebrates and invertebrates in the benthos (B), epibenthos (E), and in fish stomachs (S) at the Youngs Bay site

Species	Type of organism B	E	S
Nematodes	X		
Oligochaetes	X		
Polychaete	-		
Neanthes sp.	X	X	
Cladoceran			
Daphnia longispina	X		X
Bosmina longirostris	X	X	X
Copepod			
Digested copepods	-	-	X
Copepod nauplius	X		-
Eurytemora hirundoides	X	-	X
Eurytemora hirundoides eggs	-	-	X
Acartia sp.	X	-	-
Cyclops sp.	X		
Canuella sp.	X		
Mysid			
Unidentified mysids	-	-	X
Neomysis mercedis	X	X	X
Acanthomysis macropsis	X	-	-
Amphipod			
Corophium salmonis	X	X	X
C. *spinicorne*	X		
Eohaustorius sp.	X		X
Corophium and *Eohaustorius* molts	-	X	
Anisogammarus confervicolus	X		

Species	Type of organ B	E	S
Decapod Crustacean	-	-	-
Crangon sp. juveniles	X	X	X
Crangon sp. adults	-	X	X
Crangon franciscorum	-	X	X
Pelecypod			
Unidentified pelecypod juveniles	X		
Insects			
Diptera	X		
Diptera case	X		
Coleoptera			X
Hemiptera			X
Hymenoptera - Formicidae			X
Teleost			
Unidentified fish larvae	-	-	X
Cottus asper larvae	-	X	
Clupea harengus pallasi larvae	-	X	
Cymatogaster aggregata juvenile			X
Hypomesus pretiosus		-	X
Teleost eggs	X		
Other			
Unidentified eggs	X		
Vegetation seeds		-	X
Cirripedia nauplius	X		
Hydra	X		
Gnorimosphaeroma oregonensis	X	-	X
Digested material	-		X
Phytoplankton			

found in the Youngs Bay area as indicated by the benthic and epibenthic sampling results.

Four organisms occurred in all three sampling methods: the cladoceran, Bosmina longirostris; the mysid, Neomysis mercedis; the amphipod, C. salmonis; and juvenile shrimp, Crangon sp. There were two items found both in the benthos and epibenthos but not the fish stomachs: the polychaete, Neanthes sp., and unidentified eggs.

Estuarine shrimp, Crangon sp. adults and C. franciscorum, were found in the epibenthos and in the fish stomachs but were not collected in the benthos. The cladoceran, Daphnia longispina; the copepod, Erytemora hirundoides; the amphipod, Eohaustorius sp.; and the isopod, Gnorimosphaeroma oregonensis were found both in the benthos and in the fish stomachs but not in the epibenthic samples.

FOOD **UTILIZATION**

A total of 544 stomachs of 14 species of fish were examined during the study. This represents 1.7% of all fish captured at the three sites. The monthly subsampling for food utilization is categorized as follows:

Month	Youngs Bay	Hammond Beach	Sand Island	
May	**64**	30	26	120
June	**64**	35	**44**	143
July	53	29		82
August	54	**43**	--	97
September	**41**	61		102
Total	276	**198**	70	**544**

A description of food utilized by the dominant or economically important finfish follows.

Chum Salmon

Juvenile chum salmon, *Oncorhynchus keta,* were not abundant at the sample sites but nine were examined. The fish collected in May at the Youngs Bay site had eaten exclusively *Corophium salmonis* (Figure 13). The single fish subsampled at that site in August contained digested material.

Six chum salmon having food items were sampled at the Hammond Beach site in June. All had eaten the cladoceran, *Daphnia longispina,* which contributed 48% of the numerical importance and 77% of the weight. Another cladoceran, *Bosmina longirostris,* was eaten by five fish and made up 12% of the number and 22% of the weight. The third food item, consumed by four chum, was the copepod, *Cyclops vernalis.*

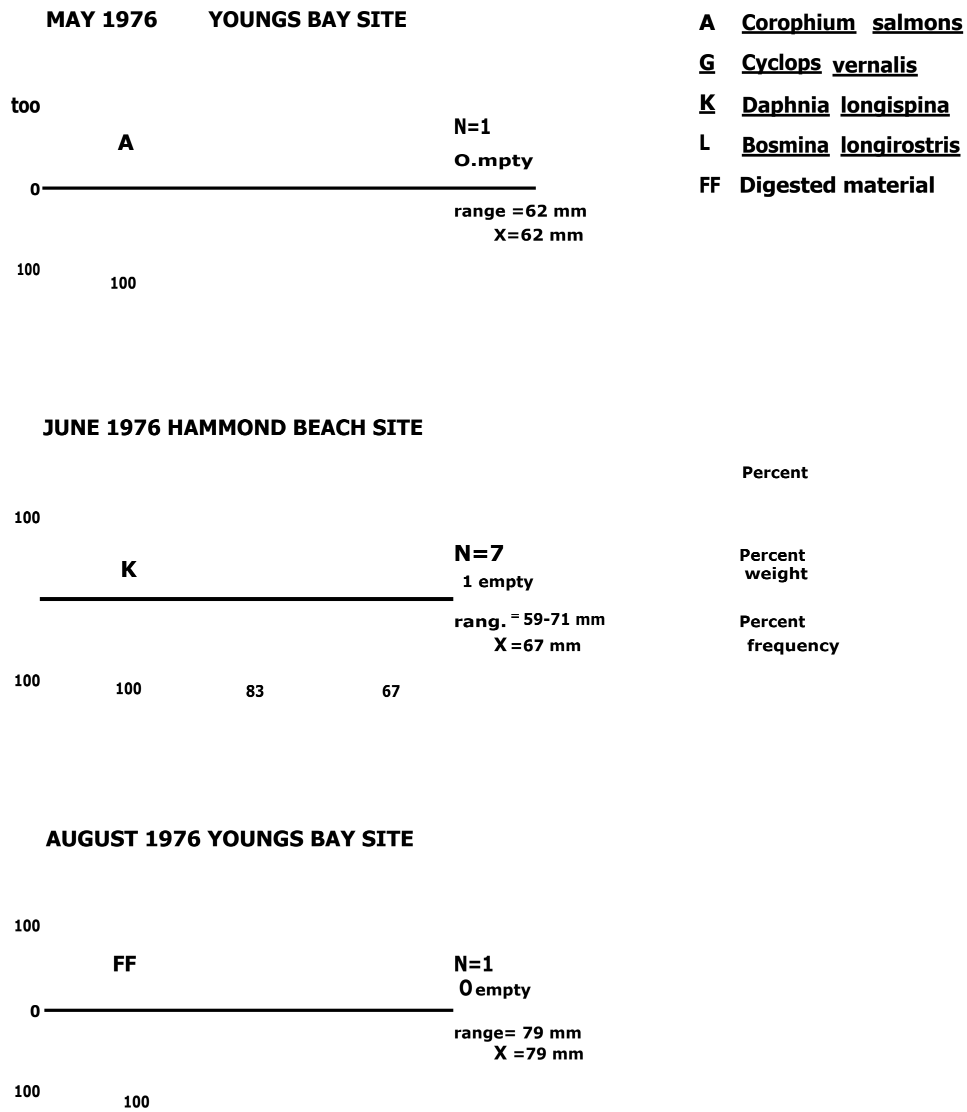

Figure 13. **Relative importance of food consumed** by **chum salmon juveniles at two sites in the Columbia River** estuary, 1976.

Coho Salmon

Juvenile coho salmon (18) were subsampled at all three sites in May (Figure **14)**. Coho salmon stomachs from the Youngs Bay site had Corophium salmonis exclusively. Three had consumed C. salmonis which made up 95% of the items consumed and 85% of the weight. The remaining coho had digested material in the gut.

Three fish with food were examined from the Sand Island site. One had unidentified insect parts which accounted for half the total weight. Another consumed an insect of the Order Diptera (20% of the weight) and the third contained digested material (30% of the weight).

Fall Chinook Salmon

Examination of 119 juvenile fall chinook salmon stomachs from the Youngs Bay site yielded 101 (85%) with food. Clearly, Corophium salmonis was the important food item (Figure 15). It was the only food consumed in May and through August ranked from 75 to 100% frequency of occurrence; 80 to 100% of the organisms; and 10 to 100% of the total gram weight. A larval shiner perch made up 70% of the weight in August, diminishing the gravimetric importance of C. salmonis that month. In September, a complete diet change was indicated though it should be noted the sample of chinook was less than examined in earlier months. The food items found during September were primarily insects of the Order Hymenoptera, Family Formicidae (ants) and the isopod,

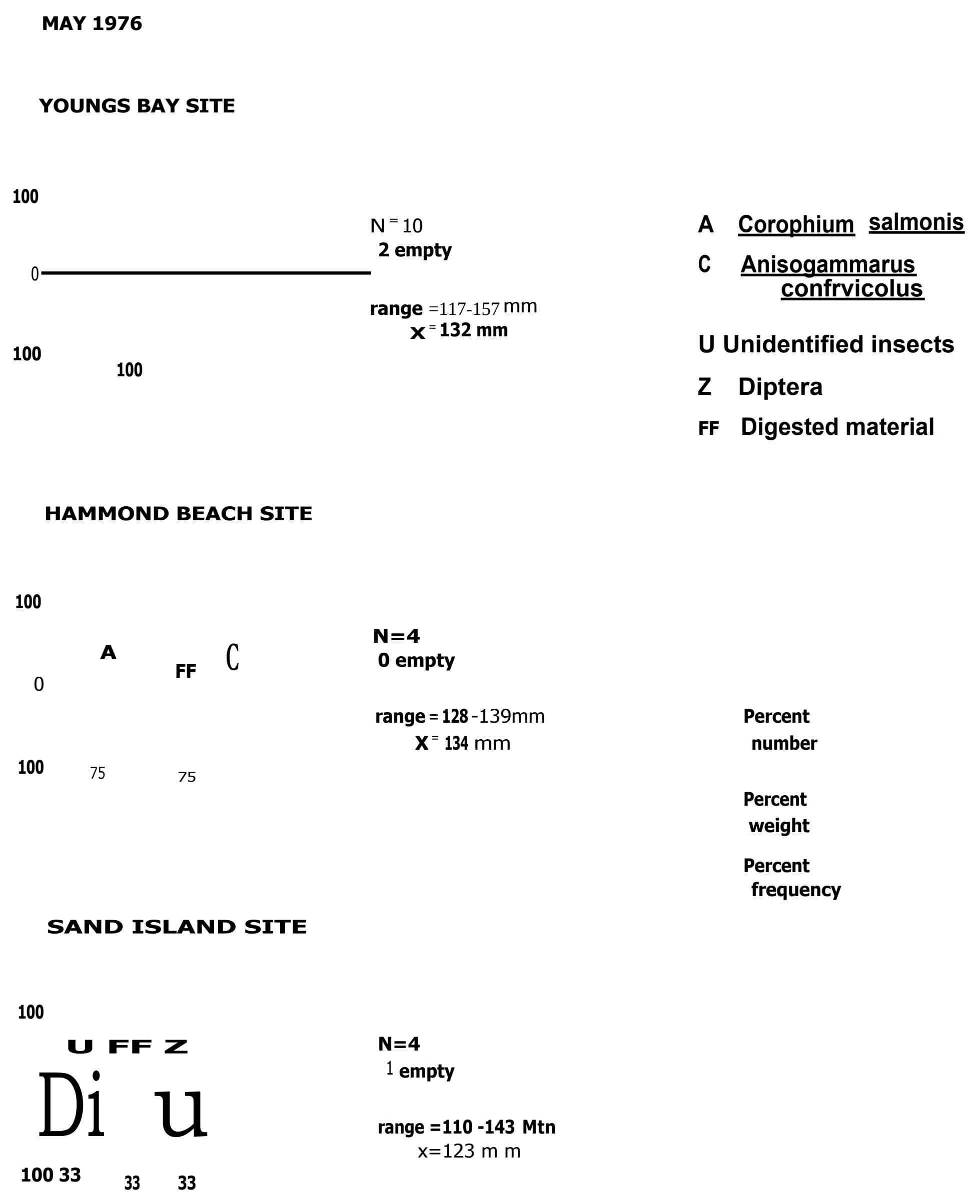

Figure 14. Relative importance of food of coho salmon juveniles at three sites in the Columbia River estuary, May 1976.

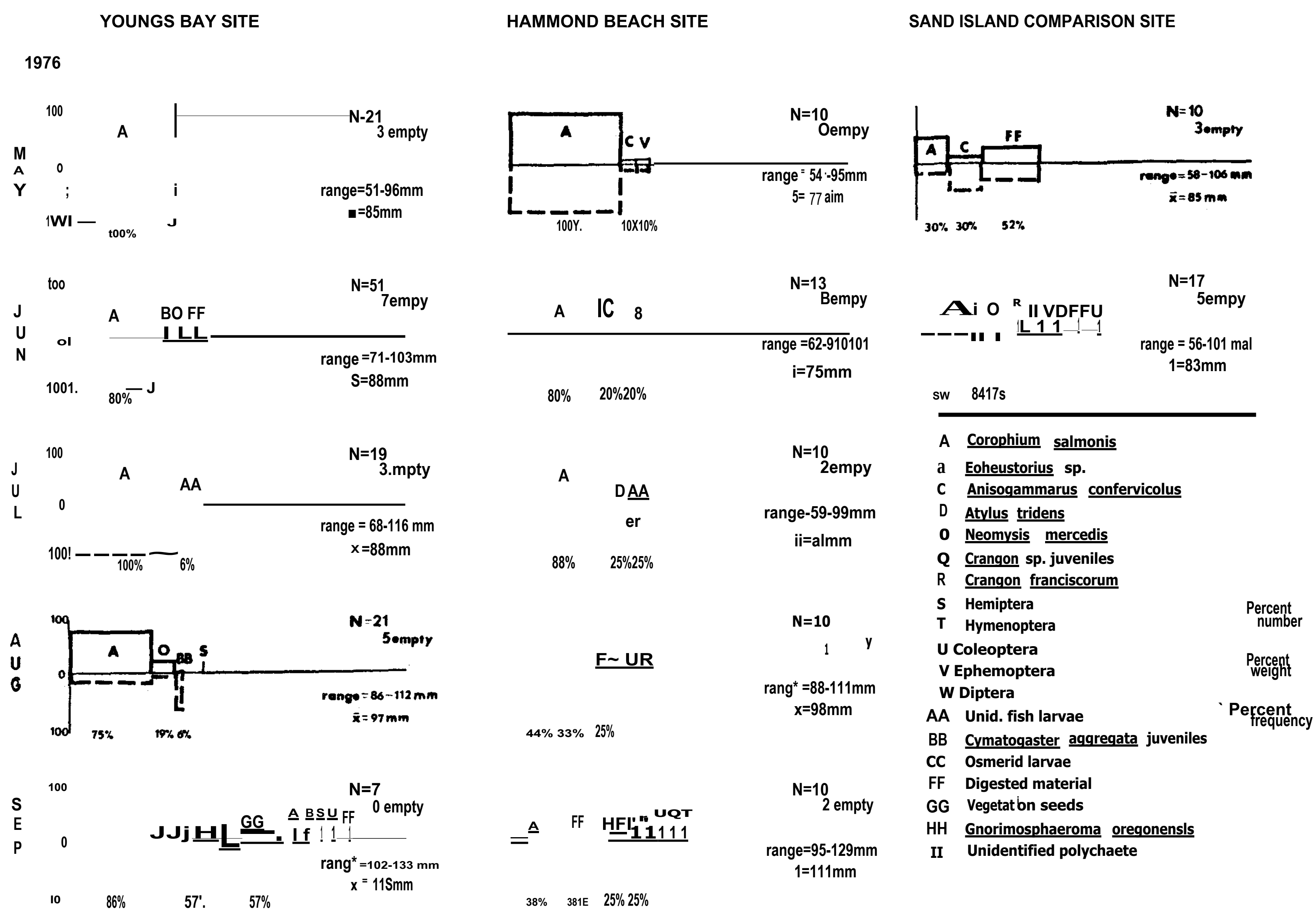

Figure 15. Relative importance of food consumed by juvenile fall chinook salmon at three sites in the *Columbia River estuary, May through September, 1976.*

G. orgeonesis. Seeds were numerically important and frequently found but gravimetrically important items were ants and isopods.

Subsampling at the Hammond Beach site consisted of 53 fall chinook stomachs of which 40 (75%) contained food. Again, C. salmonis was the most important food item, ranking from 38 to 100% frequency of occurrence; 29 to 90% of the total numbers; and 23 to 85% of the total weight. During June an amphipod, Anisogammarus confervicolus, accounted for 33% of the total weight and in July unidentified fish larvae made up 42% of the weight. The importance of C. salmonis was reduced in August by Diptera (flies) which made up 59% of the numbers and 48% of the total weight. A wider variation in diet occurred in September when isopods, G. oregonensis, C. salmonis, seeds, and digested material all were important by numbers and weights.

Juvenile fall chinook stomachs were collected from the Sand Island site in May and June. A total of 27 were examined of which 19 (70%) contained food. Corophium salmonis was consumed by 30 and 50% of the fish and made up 50 and 40% of the total numbers, respectively. In May, A. confervicolus was consumed by 30% of the fish and made up 49% of the total gram weight. The remaining stomach contents were digested. For June, an osmerid larva accounted for 25% of the weight and the mysid, Neomysis mercedis, made up 27% of both the total number and weight.

Pacific Staghorn Sculpin

A total of 25 Pacific staghorn sculpin, *Leptocottus armatus,* stomachs were examined from the Youngs Bay site June through September of which 21 **(84%)** contained food (Figure 16). All the contents were digested in June. July through September, C. *salmonis,* was the most important food item. It was consumed by 80 to 100% of the fish and made up 80 to 100% of the total number and 1 to 100% of the weight. Larval shiner perch, *Cymatogaster aggregata,* were eaten by 75% of the sculpin in August and by 40% in September, contributing 83 and 96% of the weight, respectively.

A smaller sample of 7 fish was examined from the Hammond Beach site in August and September and all the stomachs contained food. In August, one fish consumed an osmerid adult which made up 97% of the total weight. In September most of the stomach contents in the sampled fish were digested, but one sculpin ate a larval C. *aggregata* which made up 97% of the total weight of the stomach contents.

Surf Smelt

Surf smelt were selected for stomach analysis at the Youngs Bay site in May, July, August, and September. An error in subsampling occurred in June and none were saved. A total of 27 stomachs were examined of which 13 contained food (Figure 17). In May, all the smelt consumed the benthic amphipod *Corophium salmonis* while in July 11

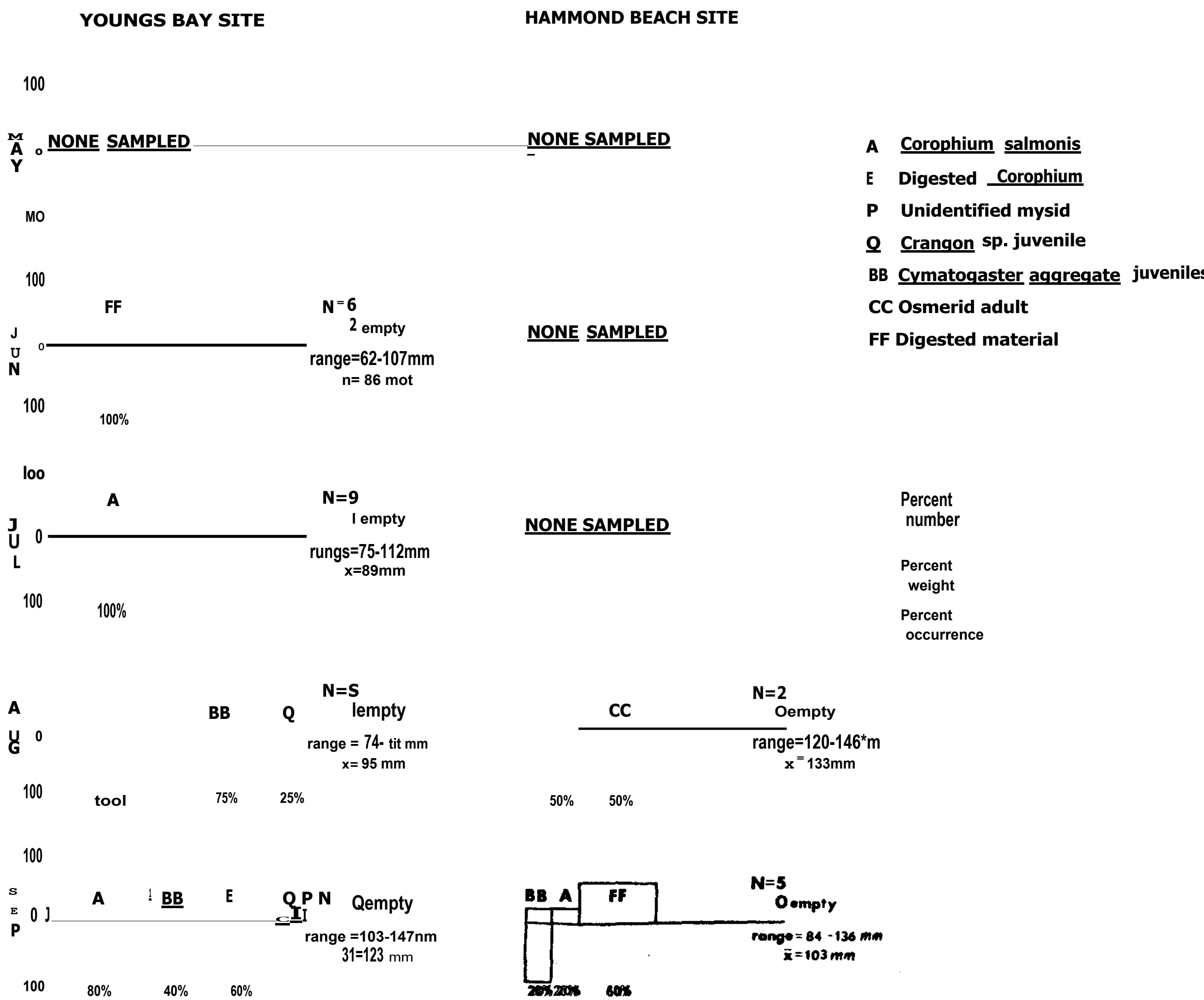

Figure 16. Relative importance of food consumed by Pacific staghorn sculpin at tvo sites in the Columbia River estuary. 1976.

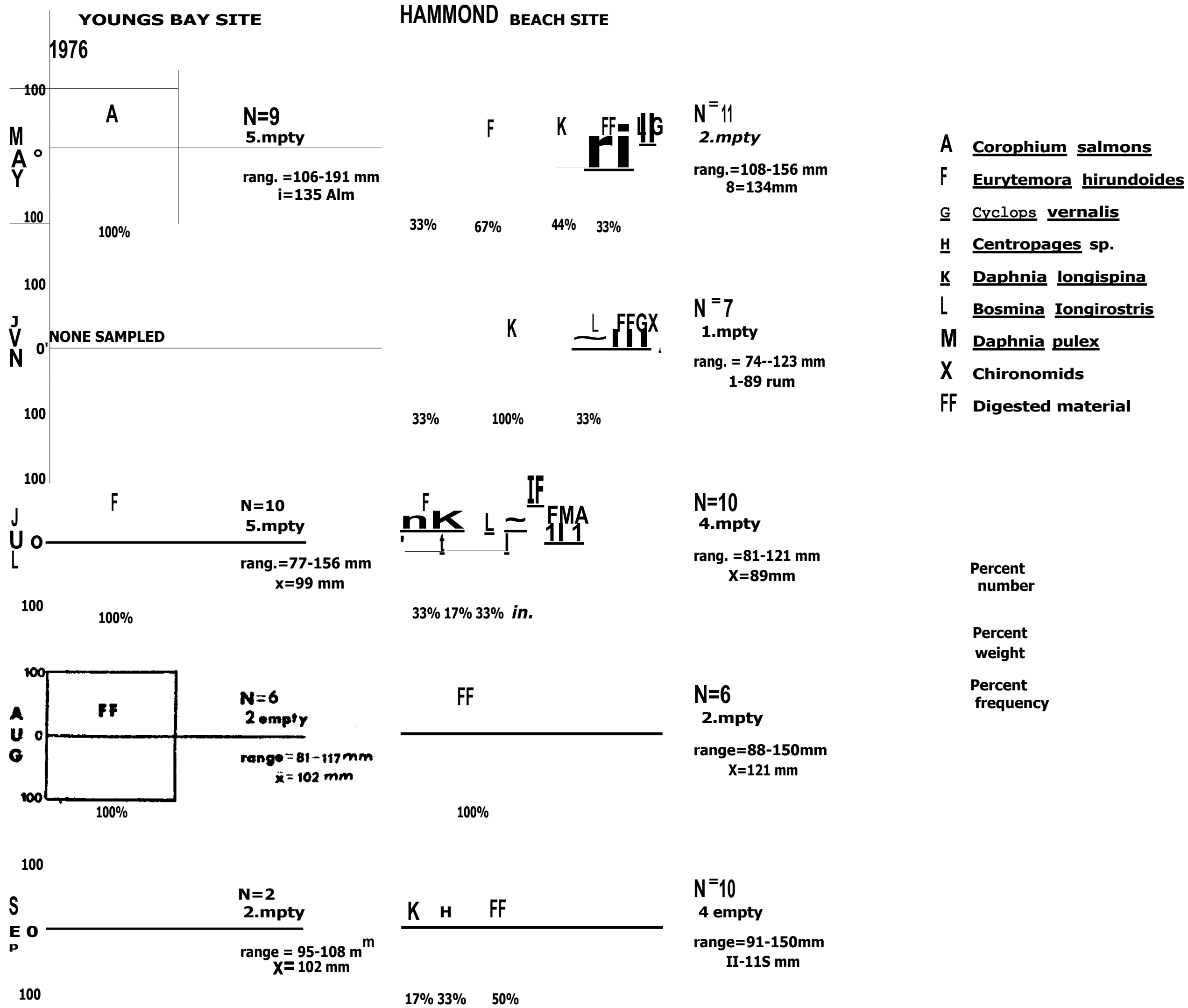

Figure IT. Relative importance of food consumed by surf smelt at two sites in the Columbia River estuary, May through September 1976.

stomachs sampled contained the planktonic copepod, <u>Eurytemora</u> <u>hirundoides.</u> The stomach contents studied in September contained digested material.

A total of 44 stomachs was examined from the Hammond Beach site of which 30 contained food. Other than a few C. <u>salmonis</u> in three of the May stomachs, all food items consumed were planktonic in habitat. During May, 67% of the smelt consumed the planktonic copepod, E. <u>hirundoides,</u> which accounted for 97% of the total number and 43% of the total weight. Cladocerans, <u>Daphnia</u> <u>longispina,</u> were eaten by 44% of the smelt and in June by 100% of the smelt. During June, D. <u>longispina</u> accounted for 68% of the numbers. A second cladoceran, <u>Bosmina</u> <u>longirostris,</u> was eaten by 33% of the smelt as was the copepod, E. <u>hirundoides.</u> In July, two copepods were the important food items, E. <u>hirundoides</u> and <u>Cyclops</u> <u>vernalis,</u> which made up 38 and 50% of the numbers, respectively. The weights were small for all items consumed in July. All stomach contents were digested in August. In September, D. <u>longispina</u> contributed 54% of the total number while a copepod, <u>Centropages</u> sp. made up 42%.

Pacific Herring

Pacific herring were subsampled at the Youngs Bay site in June and July. Of the 9 stomachs examined, 8 contained food (Figure 18). In June, 75% of the fish consumed the copepod, E. <u>hirundoides,</u> and copepod eggs, most likely from the aforementioned species. Combined, these represent 99%

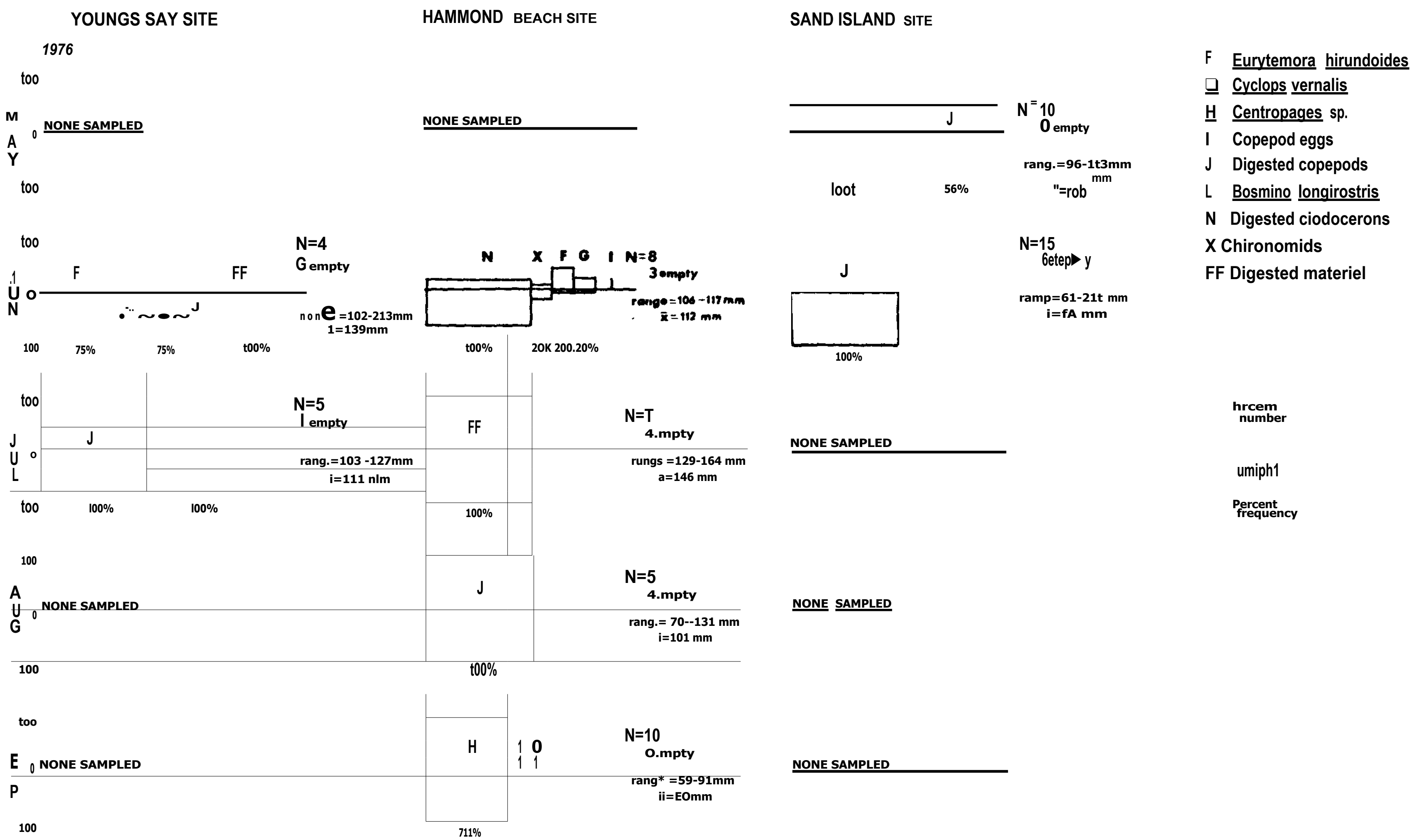

Figure 18. Relative importance of food consumed by Pacific herring at three sites in the Columbia River estuary, 1976.

of the total number and 90% of the gram weight. The eggs are contained in sacs that are attached to the posterior of the copepod and become dislodged easily. In July, all the fish consumed digested copepods and copepod eggs. Again, it is likely that they were E. hirundoides, although vital parts needed for identification were digested.

A total of 30 herring stomachs were examined from the Hammond Beach site of which 19 contained food. A varied diet was evident for June with digested cladocerans being the most important food, making up 80% of the weight. Chironomid larvae, E. hirundoides, and C. vernalis were consumed by 20% of the herring. Again, the food was planktonic. During July the contents were totally digested and during August digested copepods were the exclusive item found. It is not known why the contents were in an advanced stage of digestion but three reasons are suggested: (1) that the Formalin was weak; (2) that the warm weather increased metabolism, e.g., digestion; or (3) herring were captured considerably after their feeding period. In September the copepod, Centropages sp., was the dominant food item and was eaten by 78% of the herring. It composed 99% of both the total number and weight.

A total of 25 Pacific herring stomachs were examined from the Sand Island site in May and June of which 19 contained food. In May digested copepods and copepod eggs made up 100% of the total number and weight. During June digested copepods were the only items found within the guts.

Starry Flounder

A total of 20 starry flounder, Platichthys stellatus, stomachs were examined from the Youngs Bay site in May, June, August, and September of which 14 contained food (Figure 19). The amphipod, C. salmonis, was clearly the most important food item to the flounder. In May it was consumed by 67% of the flounder and made up 99% of the total number and 48% of the weight. One flounder consumed a surf smelt, H. pretiosus, which accounted for 52% of the weight. June, August, and September samples all contained C. salmonis exclusively.

Starry flounder were subsampled at the Hammond Beach site in May, August, and September. The single fish captured in May having consumed food had the amphipod, Eohaustorius sp. while one flounder in August contained digested material. In September, 100% of the flounder had eaten C. salmonis.

American Shad

The stomachs of 12 American shad, Alosa sapidissima, were examined in May from the Youngs Bay site; 11 contained food. The amphipod, C. salmonis was eaten by 91% of the fish and made up 74% of the number and 89% of the weight. Copepods, E. hirundoides, accounted for 26% of the total number.

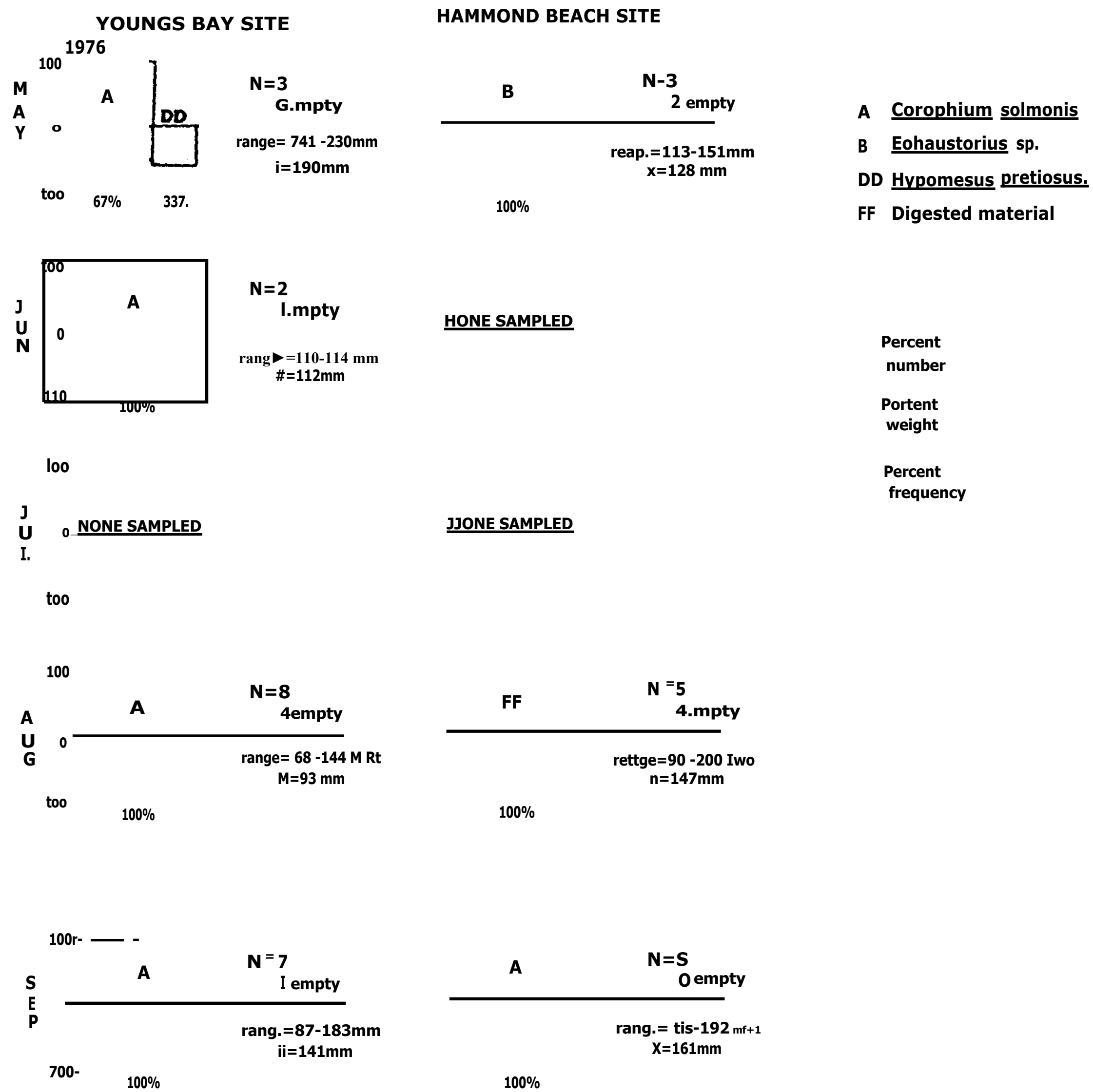

Figure 19. Relative importance of food consumed by starry flounder at tvo'sites in the Columbia River estuary, 1976.

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Digested material was the only food found in **six** shad stomachs sampled from the Sand Island site in June.

Spring Chinook Salmon

One juvenile spring chinook salmon was examined from the Youngs Bay site in May. The stomach contained C. <u>salmonis</u> exclusively. Two fish were studied from the Hammond Beach site in May of which one contained C. <u>salmonis</u> and the other an unidentified smelt. The stomachs of two juvenile spring chinook salmon examined from the Sand Island site in May were empty.

Peamouth

A total of five peamouth were examined from the Youngs Bay site in May and August. Four were empty and one contained digested material. Four fish were examined from the Hammond Beach site in August and September; all were empty.

Shiner Perch

A total of 31 shiner perch were examined from the Youngs Bay site from June through September of which 12 contained food consisting of digested C. <u>salmonis.</u> At the Hammond Beach site, 22 perch were examined from July through September and 12 contained digested <u>Corophium</u> parts. Five perch with empty stomachs taken at the Sand Island site were examined in June.

Pacific Tomcod

One Pacific tomcod, Microgadus proximus, stomach was examined from the Sand Island site in June and it contained a Crangon sp. shrimp.

Northern Anchovy

Ten anchovy stomachs were examined from the Youngs Bay site in September and all contained digested material. From the Hammond Beach site two stomachs containing digested material were studied in August and ten containing calanoid copepods were examined in September.

DISCUSSION

The 23 seine hauls captured 20 species of fish and one decapod shellfish species at three estuarine sites. A total of 31,647 animals were captured or an average of 1,289 per seine set. Eleven species were marine, five were anadromous and five were considered fresh water species. There were eleven species common to all three sites. Of the marine species, five probably use the brackish habitat for spawning while the remainder use it as nursery area or for feeding purposes. Previous finfish studies in the Columbia River estuary (Durkin 1974, [1/], 1975 [2/]; Durkin and McConnell 1973; [3/] Haertel and Osterberg **1966**; Higley and Holton 1975; [4/] Higley, et al. 1976; [5/] Johnsen and Sims 1973; Misitano 1974; Montagne 1976; [6/] and Sims and Johnsen 1974) have provided some specific knowledge of the indigenous estuarine species. Unfortunately all studies, including this present study, have been limited in scope or duration. Seasonal distribution patterns, relative abundance, and species interrelationships remain to be determined for nearly all species. For example, none of the studies lists more than 31 species of finfish yet NMFS records indicate that well over 55 species do occur in the estuary.

Of the estuarine finfish, chinook, coho, and chum salmon are the most economically important species found at the beach sites. The presence of these species at the Hammond Beach site was expected because it is a pathway to the ocean.

This study provides additional evidence that considerable numbers of juvenile chinook and coho salmon move into Youngs Bay and Baker Bay and this would indicate these estuarine embayments are used extensively and may be valuable in preparing juvenile salmon for their transition to an ocean habitat. The number of young smolts caught at Youngs Bay and Hammond does decrease in July, August, and September. Based on Columbia River beach seine catches 50 km (30 miles) above the mouth, the normal peak migration of fall chinook subyearlings entering the estuary occurs in July and August. Obviously if they numerically decrease at mid and lower estuarine beaches during this peak migration period a behavioral change is indicated. Future studies should determine why fall chinook avoid estuarine beaches after July. One factor that should be examined closely is the food intake of the estuarine salmonids, how it changes, and why it changes.

Diversity tests reveal one or two species dominate the beach seine catches even though other species are consistently taken. It is not probable that additional sampling would greatly modify the diversity indices at least during the May through September sampling period. Future beach sampling during autumn and winter should provide base information in portraying seasonal changes of the estuarine species.

Based on the length-frequency histograms, most dominant species appeared to grow. This supports the contention that the Columbia River estuary has great value as a nursery or feeding zone.

Developmental impacts on estuarine finfish would probably relate directly to the type and extent of the project and its location. Dredge spoil disposal on Sand Island could have a minor effect if placed inland away from the beach. Pacific herring, surf smelt, and fall chinook salmon are all important occupants of the intertidal and subtidal area. At Hammond, elimination of beach area by placing bulkheaded port facilities would probably affect surf smelt, shiner perch, fall chinook salmon, northern anchovy, and Pacific herring. Requiring these species to migrate in a deep water route and the resultant loss of their shoreline habitat should be a concern. At the Youngs Bay site, extensive filling or bulkheading would affect shiner perch, fall chinook salmon, and surf smelt by removing habitat and eliminating food organisms. The shallow intertidal and subtidal area is used for spawning, serves as a predation restricted nursery, and is an important feeding zone. Dredging to depths of 9-12 m (30 or 40 feet) would effectively nullify the habitat for juvenile fish or small species. It is unlikely, even if the sediment substrate allowed some invertebrate recolonization, juvenile fish would utilize the benthic infauna as they do on the subtidal and intertidal flats.

Eight species of epibenthic organisms were encountered at the Youngs Bay site along with unidentified eggs and molts of Corophium sp. and Eohaustorius sp. Juvenile and adult mysids, N. mercedis, were the most abundant invertebrate collected and were noted during all seasons in 1974 by Haertel and Osterberg **(1966)**. Few C. salmonis were captured in the epibenthos. Juvenile shrimp, Crangon sp., were taken every month although the adults were infrequent. Two fish larvae, prickly scuplin and Pacific herring, were species recorded by Misitano (1977) as being present near the Youngs Bay site from April through June and by Higley and Holton (1975) [4/] during August.

Twenty-two species of benthic invertebrates were collected along with two types of unidentified eggs and a diptera case. The numbers per square meter ranged from 5,077 to 11,457. Higley and Holton (1975) [4/] sampled a nearby area during 1974 and found C. salmonis in densities of 23,017 and 13,790/m^2 in June. Several possibilities for the differences in densities are that Higley and Holton washed the samples through a 0.425-mm sieve while we used a 0.75-mm mesh, and possibly the other site had a higher standing crop. Estimated densities of oligochaetes are subject to the same qualifications. Higley and Holton[4/] found densities of 1,702 and 2,080/m^2 in May and 3,225/m^2 in June while our numbers ranged from 190 to 1,443/m^2. Some families of oligochaetes can be small as 0.1 mm in diameter (Smith and Carlton 1975) and could easily wash through a 0.425-mm or 0.752-mm sieve. Nereid polychaete numbers ranged from 43 to 517/m^2 while Higley and Holton[4/] recorded 348 and 840/m^2 in May of 1974. Considering the qualifications to both studies' estimates, both Higley and Holton's[4/] results and this present study are similar and confirm the importance and abundance of C. salmonis in Youngs Bay as does the report by Montagne and Associates (1976).[7/]

Herring, chum salmon, and some surf smelt were predominantly plankton feeders whereas other fish consumed primarily benthic organisms. In addition, some of the fall chinook salmon and coho salmon juveniles consumed insects. Sims (1975) [8/] reported that chum fry utilized planktonic copepods and cladocerans in freshwater areas of the upper estuary, while epibenthic animals were the most important food source for chum fry in the lower, brackish water areas.

The most important planktonic food sources were the copepods, E. hirundoides and Cyclops vernalis, and the cladoceran, Daphnia longispina. Misitano (1974) noted E. hirundoides and C. vernalis in the Youngs Bay area from May through September. Haertel and Osterberg (1966) reported the importance of C. vernalis, and D. longispina in the freshwater plankton of the Columbia River and of E. hirundoides in the brackish water areas.

Craddock et al. (1976) concluded that juvenile chinook salmon in the Columbia River were selective in their feeding habits and consistently consumed Daphnia sp. in a much higher percentage than its proportion in zooplankton samples. It may have been selected because of its size, being somewhat larger than other cladocerans in the estuary.

All fish examined were primarily benthic feeders with the exception of the Pacific herring. Chum salmon and surf smelt utilized both planktonic and benthic organisms. Juvenile fall chinook salmon, coho salmon, starry flounder, and Pacific staghorn sculpin stomachs contained large numbers of C. salmonis. Utilization of C. salmonis has been recorded for juvenile staghorn scuplin in San Francisco Bay

(Jones 1962); juvenile starry flounder in Monterey Bay (Orcutt 1950); juvenile chinook salmon in Tillamook Bay {Flynn and Frolander 1975); and by juvenile fall chinook salmon, chum salmon, shiner perch, and staghorn sculpin in the lower Columbia River estuary (Durkin et al. 1977; [9/] Haertel and Osterberg **1966**; Higley and Holton 1975; [4/] Sims 1975 [10/]).

Personal communication with other fish food specialists (Fish Food Habits Studies Technical Workshop, Astoria, Oregon, 1976) revealed that Corophium sp. are important food for a variety of northeastern Pacific estuarine fish, including juvenile salmon. While C. salmonis is a tube-dwelling amphipod and was not dominant in the epibenthic tows, it was an important food source to fish in the Youngs Bay, Hammond, and Sand Island sites. Sand was not encountered in stomachs containing C. salmonis which indicates that it is eaten while out of the benthic environment. This may suggest a nocturnal or diminished-light behavior. (Behavior studies of Corophium sp. are currently being conducted by Steven Davis, a graduate student at Oregon State University, Corvallis). Other benthic food sources important to fish in these three sites were two amphipods, Eohaustorius sp. and Anisogammarus confervicolus.

Food habits offish from the Hammond Beach site were similar to those from Youngs Bay although the contents were more digested and the incidence of empty stomachs was higher.

Food items consumed at the Youngs Bay site were also collectd either in benthic or epibenthic samples except the insects, Cymatogaster aggregata juveniles, Hypomesus pretiosus, seeds, and Gnorimosphaeroma oregonensis. The limited overlap of benthic, epibenthic, and food item species indicates food selectivity. It has been suggested that fish are opportunistic feeders, preying on those species that are abundant (Haertel and Osterberg, 1966). Obviously, the most abundant benthic invertebrate, C. salmonis, was also the food item most consumed by fall chinook and coho salmon juveniles, starry flounder, and Pacific staghorn sculpin. Further, shiner perch stomachs contained digested remains of C. salmonis. The data does not show that abundant epibenthic organisms Bosmina longirostris, N. mercedis, or Crangon sp., were favored food items. If the salmon and other species were opportunistic feeders, then they would probably also feed on the mysids which were abundant in the area. This leads to the question of why the salmon and other species were found in large numbers over the proposed Brown and Root construction site. If the fish do select for food, especially C. salmonis, then they may seek areas where this amphipod is abundant rather than simply eating what is available. In either case, we need to know what areas of the estuary are productive in terms of C. <u>salmonis.</u> If areas are limited, then each is vital to the survival of the fish populations. We do not have enough knowledge of the behavior, distributions, and recolonization habits of C. <u>salmonis</u> to know if it will recolonize dredge or fill areas. If it does not, the proposed fill will eliminate an important feeding area for the economically important juvenile salmon and for noncommercial species of fish. Mortenson et al. (1976) [11/] questions whether dredging activities may further affect salmonid migration patterns should the fish avoid construction activity in the area. We also need to know if areas adjacent to a development will have a reduction in standing crop of vertebrate and invertebrate aquatic life.

CONCLUSIONS

The Columbia River estuary is the pathway through which anadromous fish resources of the Columbia basin must travel to and from the ocean and for some it is also an extremely important nursery area. Sport, commercial, and Indian fisheries, as well as surviving brood stock, could suffer irreparable harm if additional massive bulkheading, dredging, filling, or general stresses to the estuary were to occur. Until more complete biological information is available, the only logical course for assuring arrival of important life forms is to use caution in approving permits for estuarine alteration. In approved permit actions, habitat replacement or in kind compensation must be the method for protecting anadromous fish runs and important estuarine and marine species. Thus the conclusion is to proceed with caution in recommending approval of estuarine alteration and to require full, in kind, compensation. This conclusion is consistent with the recommendations of "A Marine Fisheries Program for the Nation", U.S. Department of Commerce, Washington, D.C., July 1976. Pertinent recommendations are as follows:

<u>Recommendation 2, Page 37</u>

Reverse the downward trends in quantity and quality of fish habitats by minimizing further losses and degradation of these habitats, restoring and enhancing them where possible, and establishing protected areas where necessary, while recognizing other compatible essential uses of fish habitat areas.

<u>Recommendation 2.1, Page 39</u>

Improve the consideration given to fish habitats in key decisionmaking processes.

<u>Recommendation 2.2, Page 40</u>

Mitigate losses of habitat, where possible, restore habitats lost or degraded, and develop economically feasible enhancement opportunities.

<u>Recommendation 2.4, Page 41</u>

Improve the quality, and increase the dissemination of information required for effective fish habitat conservation.

SUMMARY

Three estuarine beach sites were examined during this study: the proposed Brown and Root development site on Youngs Bay, the Hammond Beach, and eastern Sand Island near Chinook Channel.

Dredge spoil disposal on Sand Island could have a minor aquatic effect if placed inland away from the beach. Pacific herring, surf smelt, and fall chinook salmon are numerically important occupants of the intertidal and subtidal area. At Hammond, elimination of intertidal beaches by bulkheaded port facilities would affect surf smelt, shiner perch, fall chinook salmon, northern anchovy, and Pacific herring by requiring them to move in deep water. Loss of their shoreline habitat should be a concern.

Impacts of the Brown and Root development site on estuarine finfish would probably relate closely to the size, type, extent, and precise location of the project. Extensive filling and bulkheading would affect shiner perch, fall chinook salmon, and surf smelt by removing habitat and eliminating numerous food organisms. This particular shallow intertidal and subtidal site is used for spawning, serves as a predation restricted nursery, and is an important feeding area. Dredging to depths of 30 or 40 feet would also effectively nullify it as habitat for juvenile fish or small species. If comparable invertebrate

recolonization occurs at dredge sites, it is unlikely that juvenile fish would be able to utilize the benthic infauna as they do in the subtidal and intertidal flats. Moreover, the estuarine intertidal habitat already has been extensively modified from Tongue Point west to Smith Point and throughout Youngs Bay by dredging, filling and diking. Continued man-caused alterations in this portion of the estuary will not be without serious consequences on the aquatic life that reside there and those species that depend on those organisms.

The 23 seine hauls carried out in this present study resulted in 20 species of fish and one decapod shellfish species at the three sites. A total of 31,647 individuals were captured, an average of 1,289 per seine set. Eleven fish species were exclusively marine, five were anadromous, and five were freshwater. Eleven species were common to all sites. Of the marine species, five probably use the brackish habitat for spawning while the remainder use it as a nursery or feeding area (see figures 13-19). No published study lists more than 31 species of finfish in the Columbia River estuary yet NMFS records indicate that well over 55 species occur there. This study provides evidence that considerable numbers of juvenile chinook and coho salmon move into and use Youngs Bay and Baker Bay, possibly in preparation for their physiological transition to an ocean habitat. Based on the length-frequency histograms, most dominant species appeared to be growing, supporting the contention that the Columbia River estuary has definite value as a nursery and feeding zone.

Herring, chum salmon, and some surf smelt were predominantly plankton feeders whereas the primary consumption by other fishes was benthic organisms. In addition, some fall chinook and coho juveniles consumed insects. One unpublished study reported chum fry utilized planktonic copepods and cladocerans in freshwater areas of the upper estuary while epibenthic invertebrate were the important food source for chum fry in the lower brackish water areas. Personal communication with other fish food specialists revealed that Corophium sp. are important food for a variety of northeastern Pacific estuarine fish, including juvenile salmon. While C. salmonis is a tube-dwelling amphipod and was not numerically important in the epibenthic sled tows, it was an important food source to fish found at all three sites.

Salmon and other species of finfish were found in large numbers over the proposed Brown and Root construction site for several reasons. Continued evidence supports Youngs Bay as an important shallow water salmon feeding area to the south of their oceanward migration path. This bay is also a refuge from large piciverous predators. Youngs and Baker bays appear to be important for spawning of surf smelt and shiner perch. Further, if the fish do select food, especially C. salmonis, then they may seek areas where this amphipod is abundant rather than simply eating what is available. In either case, we need to know what areas of the estuary are productive in terms of C. salmonis. If such areas are limited, then each is vital to the fishery. We do not have enough knowledge of the behavior, distributions, productively, and recolonization habits of C. salmonis to make an intelligent decision on whether the proposed fill will eliminate an important feeding area for the economically important juvenile salmon and for other species of fish.

Dredging activities may further affect salmonid migration patterns should salmonids avoid dredging activity and cease feeding in the area. Moreover, it is important to know how the areas adjacent to development sites will be affected in terms of standing crop of vertebrate and invertebrate aquatic life. A development such as an oil platform construction site may have a far greater affect on the surrounding area than just simply on the land it occupies. Until such information is gathered, analyzed, and evaluated construction activity in intertidal and subtidal areas should be considered biologically hazardous.

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APPENDIX

Shannon-Weaver **index**: $H' = -\Sigma pi \log_2 pi$ where pi = Na

xa is the number of a given species in a sample; and N is the total of all individuals in the sample. Index values increase as both species and equitability of species abundance increase. References include Shannon and Weaver (1963) and Clifford and Stephenson (1975).

Species richness index: SR = $\frac{(S-1)}{\ln N}$ where S is the number of

species and In N is the natural logarithm of the total catch. Here again index values increase as the species and their equitability increase. Margalef (1951) is a source reference.

Equitability or evenness index: J = to$_{g\,2}$ ' S where H' is the

Shannon-Weaver index and S is the number of species in the sample. The index scale of this test is 0 to 1.0 for low to perfect equitability. Refer to Pielou **(1966)** for other information on the test.

Index of relative importance: IRI=(N+V)F where N represents the numerical percentage, V the gram weight percentage, and F the frequency of occurrence percentage. Comparative value of each organism is indicated for each sample. Tests are further described by Pinkas et al. (1971); however, in his tests he uses volume percentage rather than gram weight.