BENTHIC INVERTEBRATES, WATER QUALITY, AND SUBSTRATE TEXTURE IN BAKER BAY, YOUNGS BAY, AND ADJACENT AREAS OF THE COLUMBIA RIVER ESTUARY

by

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ABSTRACT

The study provides federal resource agencies base line classification information on an important west coast estuary. Estuarine characterization data were gathered at 3-month intervals from 45 sites in the Columbia River estuary. Replicate samples of benthic invertebrates and sediment structure were taken at each site. The four survey periods, during June, September, and December 1977 and March 1978, resulted in 359 invertebrate samples and 360 sediment samples.

Invertebrate samples, taken with a 0.05 m^2 Ponar dredge, were preserved, stained, identified to taxonomic group, counted, verified, and weighed. The study involved 212,797 benthic invertebrates--an average of 593 organisms per sample.

Embayments on the Oregon side of the estuary had greater numbers of benthic organism whereas weights averaged more on the Washington side. Seasonal shifts in numbers and weights were noted, but changes were not consistent between areas. Important species observed included amphipods: Corophium salmonis, C. brevis, and C. spinicorne; bivalves: Macoma balthica and Corbicula Manilensis; polychaetes: Neanthes limnicola and Hobsonia florida; copepod: Canuella canadensis; and groups such as nematoda, oligochaeta, nemertea, cumacea, cirripedia, and insecta.

Substrate samples were separated into nine particle size categories. Texture was usually silt to fine sand (0.002 to 0.125 mm) in Oregon embayments, but was fine sand to medium sand (0.125 to 0.25 mm) in Baker Bay and near the navigation channel. Over 20% of sediment samples exceeded the Environmental Protection Agency's acceptable volatile solid levels, but other water quality measurements such as oxygen, pH, and temperature were acceptable for aquatic life.

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INTRODUCTION

Classification of estuaries is based upon a number of geographic, physical, and biological characteristics. This report deals with data, collected between June 1977 and March 1978, that are adaptable for use by the U.S. Fish and Wildlife Service (FWS) in habitat classification (Cowardin et al. 1976).

The Columbia River estuary (37,232 ha) provides a habitat for valued species of fish, decapod shellfish, and other animals. Many of these species consume benthic invertebrates, particularly those associated with intertidal and shallow subtidal zones. Studies in this area by Higley and Holton (1975); Durkin et al. (1976, 1977); Higley, Holton, and Komar (1976); and Durkin, Lipovsky, and McConnell (1979) have established that benthic invertebrates, particularly amphipods and bivalves, are extensively used by juveniles of many economically important fish species. Other meaningful studies of the area have been described by Haertel and Osterberg (1966); Conrow et al. (1975); Johnson and Cutshall (1975); Sanborn (1975a, 1975b); Blahm, McConnell, and Davis (1977); and McConnell et al. (1978).

In 1977, the NMFS agreed to cooperatively provide the FWS specific information on two designated component areas within the Columbia River estuary. The collected information deals specifically with benthic invertebrate numbers and weights and associated sediment texture, volatile solids, and water quality measurements at sites within the two areas. Baker Bay, a shallow marine-oriented habitat formed one study unit; whereas, shallow, oligohaline Youngs Bay together with the shoreline area from Hammon, Oregon east to Tongue Point, Oregon formed the other unit (Figure 1).

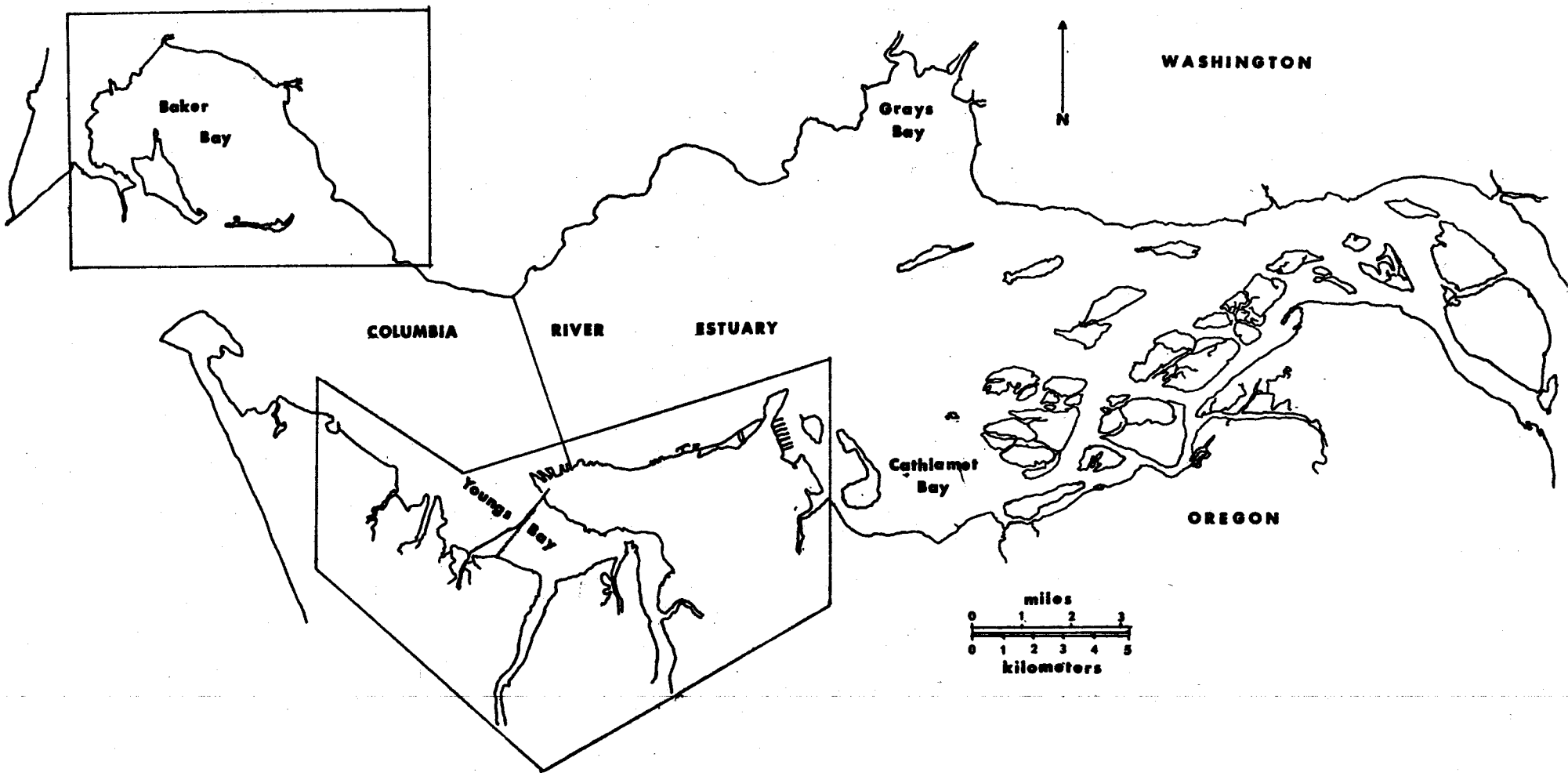

Figure 1.-- Columbia River estuary with Baker Bay and Youngs Bay study areas indicated in the blocked areas.

SAMPLING SITES

The locations of individual sites; shown in Figures 2 and 3, were based on several criteria: random geographic distribution within the study area, proximity to proposed development projects, water depth, relationship to shore-based activities, and the provision of sampling continuity at sites used in previous studies. Fixed objects such as dolphins, pilings, or navigation buoys were used to designate 26 sites while 19 sites were marked by anchored net floats. All sites were fixed by visual references or radar, and their locations in latitude, longitude, and water depth together with pertinent remarks are provided in Appendix A.

SAMPLING PROCEDURE

Paired invertebrate and sediment samples were taken at each site every 3 months for a year; water quality measurements were also taken at the surface and just above the bottom. The effort resulted in 360 sediment samples and 359 invertebrate samples.

Benthic samples collected with a 0.05 m^2 Ponar dredge were placed in a sieve **box** and washed by manually agitating until particles finer than 0.595 mm (No. 30 screen) were eliminated. Remaining sediments were transferred to **individually** marked sample bottles, and a Formalin-isopropyl alcohol solution was added to preserve the organisms,.[1] Rose-bengal, an organic stain, was added to each sample to facilitate visual separation of invertebrates. We know that some organisms wash through the 0.595 mm mesh and sampling in this manner also results in capture of some epibenthic

1/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

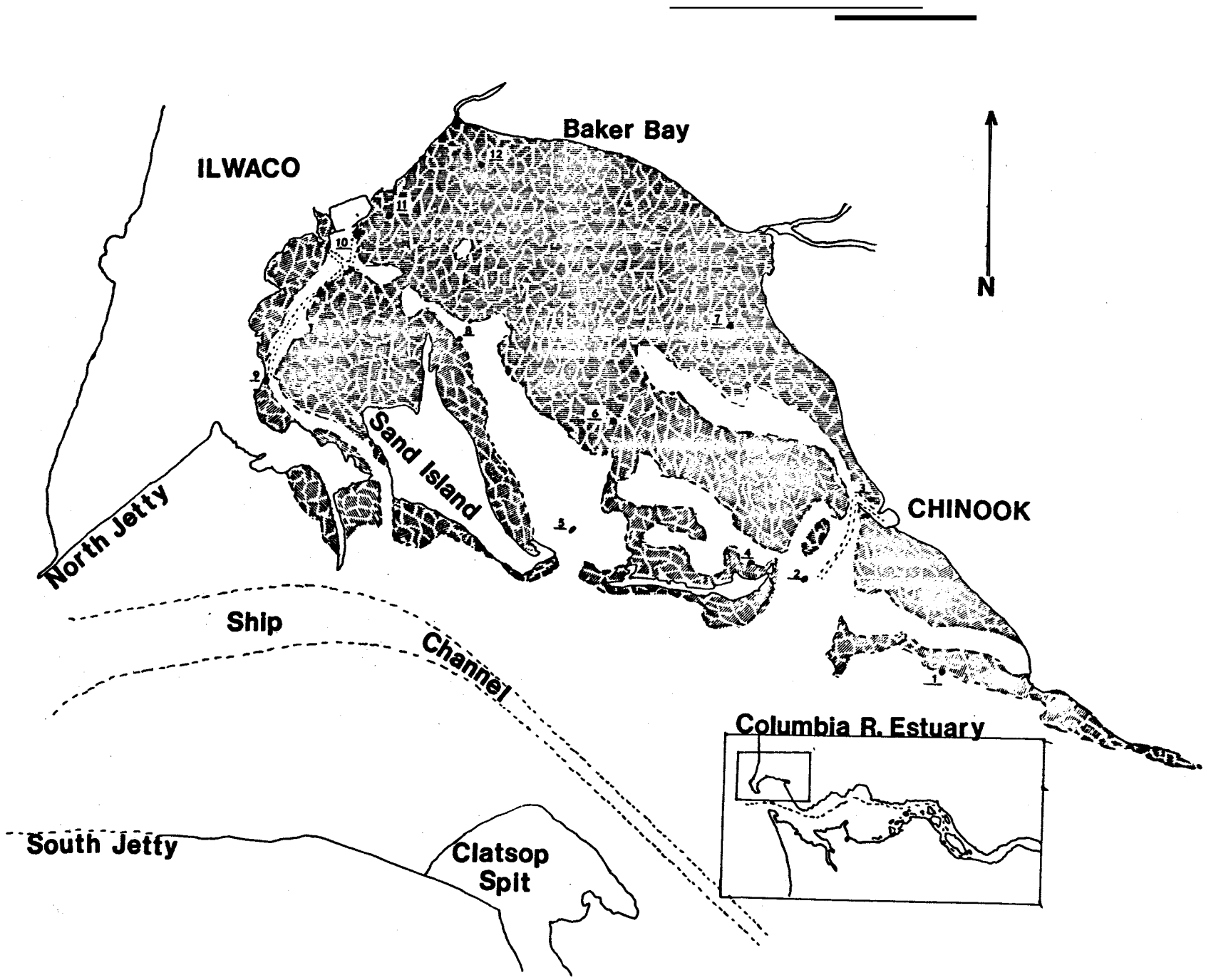

Figure 2.-- Baker Bay study area with 12 sampling sites shown. The intertidal area above -0.5 elevation is indicated by the shaded area of the map.

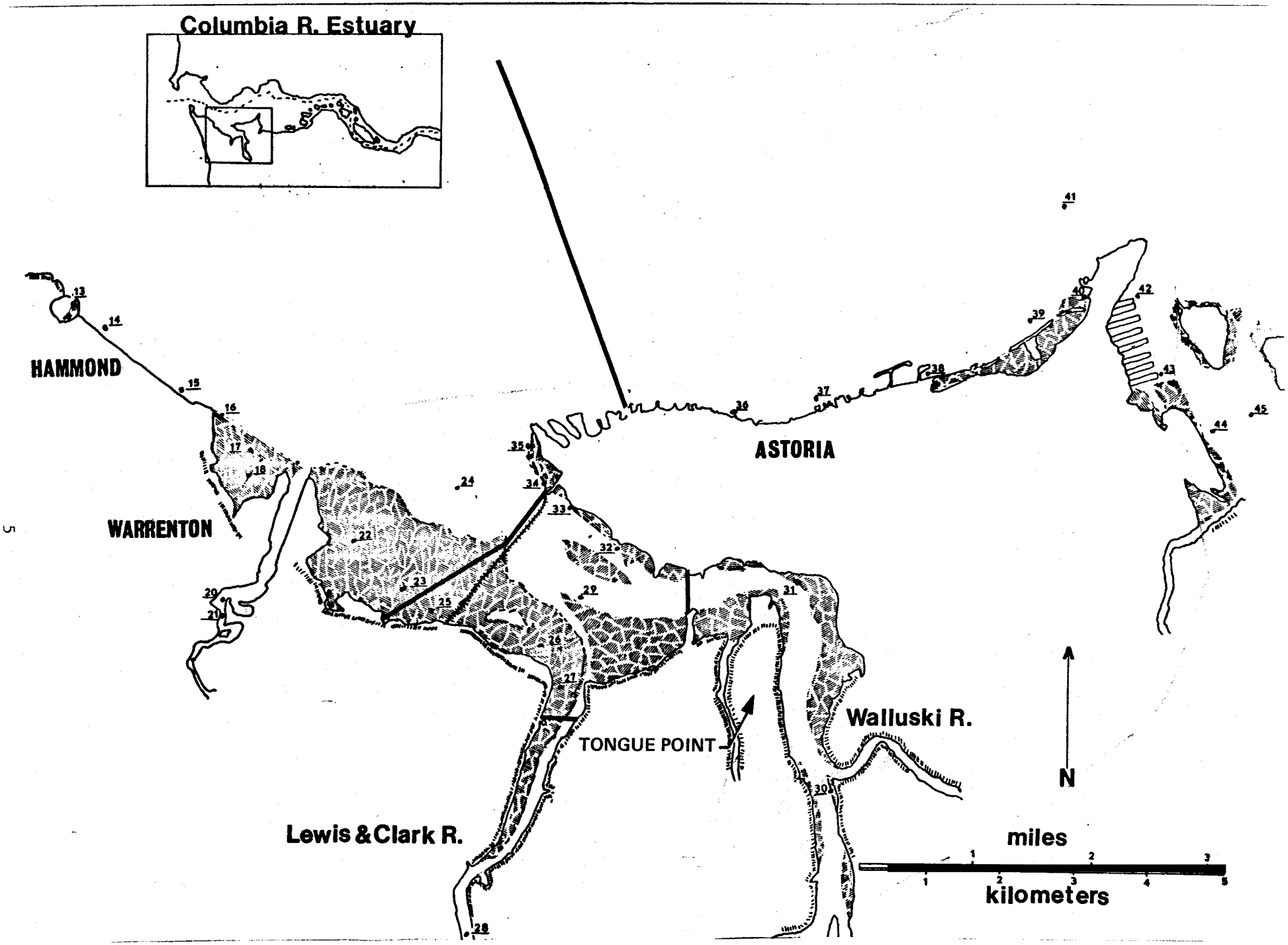

Figure 3.-- Youngs Bay - Hammond to Tongue Point study area with 33 sampling sites shown. Intertidal area above -0.5 elevation is indicated by the shaded portion of the map.

and pelagic species. However, rather than arbitrarily decide which organisms to include or delete, we counted all specimens found in the processed samples. The presence of individuals in certain habitats, during particular seasons, or in specific locales is useful information even though unknown proportions may escape.

Various magnification levels were used to extract specimens and separate them into specific groups. The group counts were verified with 10 power magnification, blotter dried, and weighed on a Mettler type H6T balance to the nearest 0.0001 g.

Identification of invertebrate organisms was made using the following references: Bradley (1908); Pennak (1953); Bosworth (1973); Barnes (1974); Smith and Carlton (1975); and Kujala (1977). In addition, Duane Higley, Oregon State University (OSU), Corvallis, Oregon, reviewed a number of difficult or controversial specimens. We, as well as earlier investigators, made no attempt to determine species of nematoda, nemertea, oligochaeta, and insecta. All sample specimens are preserved at the Hammond Facility, and if desired can be further classified by specialized researchers.

A separate Ponar grab was made to obtain material for sediment texture analysis, and 3.8 cm diameter corer was used to extract the sample. Sediment samples were individually numbered, placed in polyethylene bags, and refrigerated. Sediments were analyzed under contract by Northwest Testing Laboratory, Portland, Oregon for: 1) particle size, following procedures described by Black (1965), and 2) organic content based on the procedure described by Environmental Protection Agency (EPA) (1969). Classification of particle size was based on Wentworths grade scale (Twenhofel and Tyler, 1941).

WATER QUALITY

Measurements taken just below the surface and just above the bottom at the 45 sites are presented in Appendix B. Temperature, conductivity, salinity, turbidity, pH, and oxygen levels provided the status of conditions at the time invertebrate samples were gathered. Tables have been extracted from these data to show the ranges in water quality measurements during each survey.

Water temperatures (°C) shown in Table 1 were taken with a Beckman RS5-3 portable salinometer equipped with a 46 m probe. Lowest temperatures were associated with marine conditions in Baker Bay through the first three surveys but also occurred at Tongue Point, a freshwater site, in March. Warmest waters occurred at Youngs Bay or Tongue Point until March, and then were found at Baker Bay. During prior estuary investigations lower temperatures (0.49°C) were reported by Durkin et al. (1979) and higher temperatures (21.5°C) were reported by Haertel (1969).

The ranges of water conductivities (millimhos/cm), measured with the Beckman RS5-3 salinometer at the surface and bottom, are shown in Table 2. Low readings were associated with freshwater sites whereas high readings occurred at either Baker Bay or Tansy Point.

Salinity (ppt) was also measured with the Beckman RS5-3 salinometer (Table 3). Low salinities were found at or near Tongue Point and usually at the surface. We detected salinity at all Youngs Bay sites during the three 1977 surveys. In March, however, water at several sites in Youngs Bay was entirely without salt. Sites 30 in Youngs River and 28 in Lewis and Clark River had readings of 7.6 and 7.4 ppt during the September survey indicating substantial salt intrusion. Highest salinity readings were associated with Baker Bay and usually at Site 5 situated between Upper and

TABLE 1.--Low and high water temperatures (°C) measured during each of four surveys on the Columbia River estuary 1977-1978.

Survey	Low temp.	Site	Geographic area	Depth (feet)	Date/ time (day/h)	**High** temp.	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	12.8	8	**Baker Bay**	14	27/1150	19.4	26/27/31	Youngs Bay	Surface	23/1530 29/1225
Sept 1977	11.6	5	Baker Bay	5	15/1420	19.8	42	Tongue Pt.	Surface	14/1220
Dec 1977	5.1	6	**Baker Bay**	Surface	30/1400	9.2	25	Youngs Bay	Surface	13/1410
March 1978	5.7	41	Tongue Pt.	Surface	14/1055	9.8	5	Baker Bay	15	10/1215

TABLE 2.--Water conductivity (milli mho/cm) ranges measured during each of four surveys between June 1977 and March 1978.

Survey	Low temp.	Site	Geographic area	Depth (feet)	Date/ time (day/h)	**High temp.**	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	0.14	42	Tongue Pt.	26	7/1340	28.55	2	Baker Bay	7	24/1051
Sept 1977	0.41	37	Astoria	Surface	4/1100	34.31	5	Baker Bay	5	15/1420
Dec 1977	0.08	45	Tongue Pt.	Surface	12/1130	32.08	16	Tansy Pt.	31	30/1540
March 1978	0.17	44	Tongue Pt.	16	14/1140	34.54	5	Baker Bay	15	10/1215

TABLE 3.--Salinity (ppt) ranges occurring during each of four surveys in the Columbia River estuary between June 1977 and March 1978.

Survey	Low salinity	Site	Geographic area	Depth (feet)	Date/ time (day/h)	High salinity	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	0.06	45	Tongue Pt.	Surface	17/1425	23.91	2	Baker Bay	7	24/1051
Sept 1977	0.28	37	Astoria	Surface	14/1100	29.60	5	Baker Bay	15	15/1420
Dec 1977	0.06	45	Tongue Pt.	Surface	12/1130	29.41	5	Baker Bay	20	30/1510
March 1978	0.14	45	Tongue Pt.	22	14/1200	31.42	5	Baker Bay	15	10/1215

Lower Sand Island. Salinity in the Columbia River estuary has been studied by Neal (1965), Haertel and Osterberg (1966), and McConnell et al. (1979). The studies provide an understanding of salinity movement and levels in this system.

Turbidity of the water was measured with an H.F. Instrument Model DRT 100 nephelometric turbidimeter (Table 4). A 3-1 Van Dorn bottle was used to take the water samples for turbidity and pH analyses. Data are expressed as formazin turbidity units (FTU). Clearest water was always found near the bottom of Baker Bay and usually just north of Sand Island. Water with the least clarity occurred either in the Lewis and Clark River, Youngs River, or Youngs Bay. A high reading of 84.0 FTU in the Lewis and Clark River during December reflects suspended sediments brought in by heavy rainfall. Previous measurements of estuarine turbidity were made by Haertel and Osterberg (1966). Although their results were based on Secchi disc readings, they also found the clearest water associated with the mouth of the Columbia River.

Ion activity was measured with a Leeds and Northrup Model 7404 meter and expressed in pH values (Table 5). Low levels were found at different sites during each survey and were not geographically related. High pH levels were associated with Baker Bay; usually at Site 5. This agrees with Park, Osterberg, and Forster (1972) who report a relationship between high pH and salinity.

Oxygen concentrations (mg/1) were determined with a YSI Model 57 oxygen meter after it had been calibrated using the modified Winkler method (EPA 1974). All oxygen concentrations were within safe limits for aquatic life (Table 6). The December and March surveys revealed levels at many

TABLE 4.--Turbidity (FTU) ranges occurring during each of four surveys in the Columbia River estuary between June 1977 and March 1978.

Survey	Low turbidity	Site	Geographic area	Depth (feet)	Date/ time (day/h)	**High** turbidity	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	1.3	8	**Baker Bay**	Surface	27/1150	20.0	8	Lewis & Clark River	9	23/1515
Sept 1977	1.7	5/6	**Baker Bay**	Surface 2.5 m	15/1420	30.0	25	Youngs Bay	1.5	14/1425
Dec 1977	5.4	10	**Baker Bay**	Surface	30/1145	84.0	28	Lewis & Clark River	14	13/1245
March 1978	5.2	8	**Baker Bay**	5	10/1400	21.0	30	Youngs River	8	13/1420

TABLE 5.--Ranges of pH occurring during each of four surveys in the Columbia River estuary between June 1977 and March 1978.

Survey	Low pH	Site	Geographic area	Depth (feet)	Date/ time (day/h)	High pH	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	7.0	25	Youngs Bay	Surface-4	23/1325	8.75	5-10	Baker Bay	9	24/1220
Sept 1977	7.3	15	Tansy Pt.	Surface	12/1130	8.5	5	Baker Bay	15	15/1420
Dec 1977	6.45	28	Lewis & Clark Riv.	Surface	13/1245	9.0	2-3	Baker Bay	10-6	15/1230
March 1978	6.5	9	Baker Bay	Surface-23	10/1535	8.2	5	Baker Bay	Surface	10/1215

TABLE 6.--Ranges of dissolved oxygen (mg/1) occurring during each of four surveys in the Columbia River estuary between June 1977 and March 1978.

Survey	Low O_2	Site	Geographic area	Depth (feet)	Date/ time (day/h)	High O_2	Site	Geographic area	Depth (feet)	Date/ time (day/h)
June 1977	6.1	28	Lewis & Clark Riv.	9	23/1315	10.1	10	Baker Bay	7	24/1320
Sept 1977	6.0	20-21	Skipanon R.	Surface	13/1045	8.6	37	Astoria	Surface	14/1100
Dec 1977	9.1	16-21	Alder Slough & Skipanon R.	12	13/1045	12.1	41	Tongue Pt.	42	12/1025
March 1978	8.6	10	Baker Bay	8	10/1515	12.2	41	Tongue Pt.	43	14/1055

sites approaching saturation. Oxygen concentrations during this study exceed those reported by Haertel and Osterberg (1966), and Haertel (1969).

Our water quality data reveal that estuarine temperature and oxygen levels were within acceptable limits for aquatic life.

SUBSTRATE SAMPLES

Individual Sites

We used nine standard particle groups ranging in size from clay (< 0.002 mm) to medium gravel (> 8 mm). The categories are presented as a percent value of the total sample (Appendix B).

Mean values and standard deviations for the various categories in the eight-sample group were determined for each of the 45 sites. The small standard deviation of the means indicated sample consistency. Based on these data, texture size in Baker Bay is shown graphically in Figure 4. The fine sand category (0.125-0.25 mm) was the predominant particle **size** at 10 of the 12 sites. This category ranged from 38.8% at Site 8 to 64.2% at Site 6. Medium sand (0.25-0.5 mm) was the next most predominant category. Site 10 near the Illwaco Harbor entrance differed by having a high percentage of silt, very fine sand, and clay whereas Site 12 near the mouth of the Wallacut River had about 40% very fine sand, 27% fine sand, and 18% silt. Little coarse sand or larger material was found in Baker **Bay**.

NMFS Sites 2, 3, 5, 6, and 8 appear geographically close to OSU Stations 16, 18, 8, 5, and 4 (Higley, Holton, and Komar 1976). Our sediment texture data agree with theirs only at NMFS Site 5. The OSU data indicated a higher proportion of silt-clay material than ours.

Sediment classifications at sites on the south side of the Columbia River estuary are shown in Figure 5. Fine sand is a major component of the sites off Hammond, in the Skipanon River, and along sites at the northeast

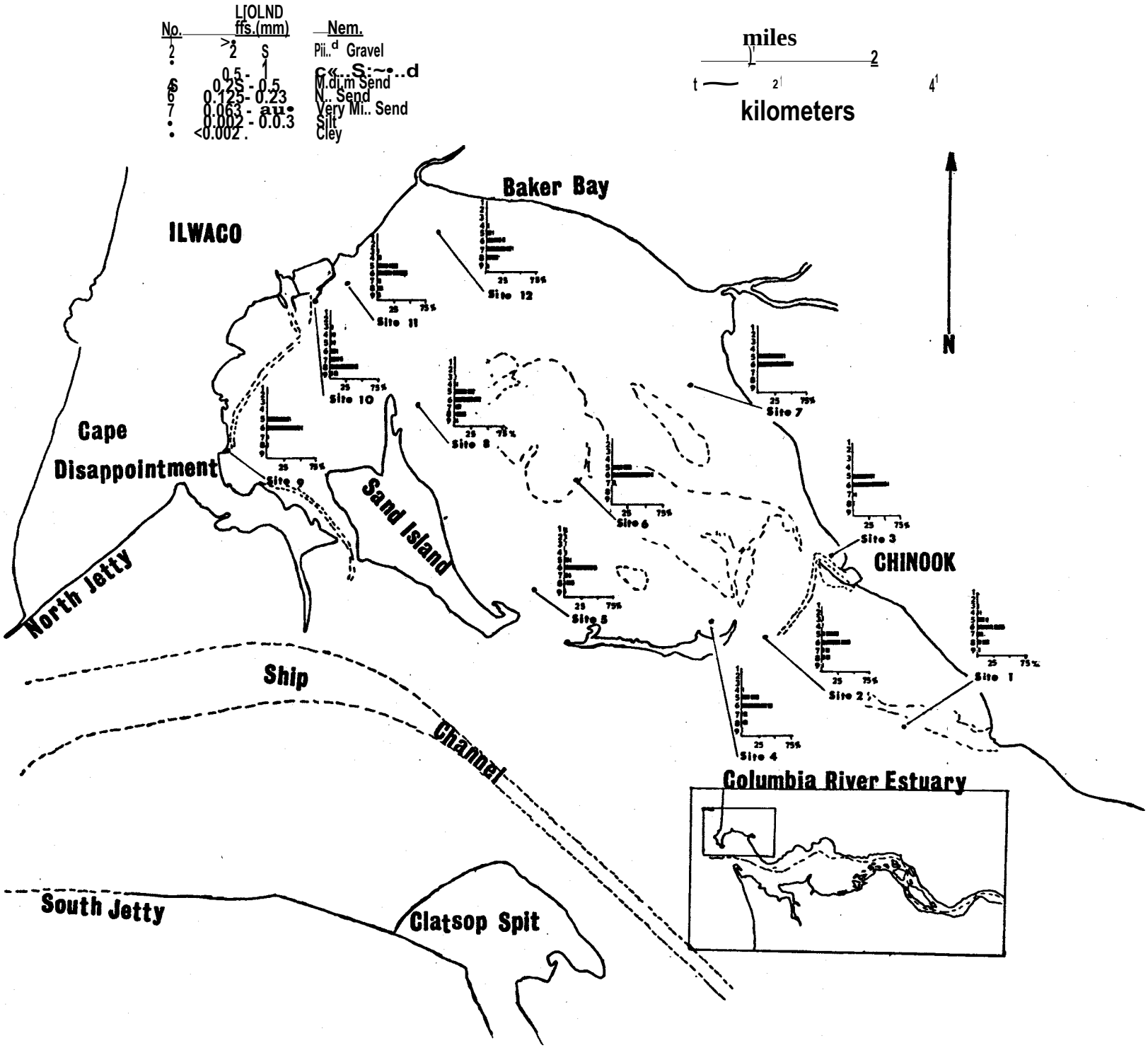

Figure 4.-- Mean particle size found at 11 sampling sites in Baker Bay between June 1977 and March 1973.

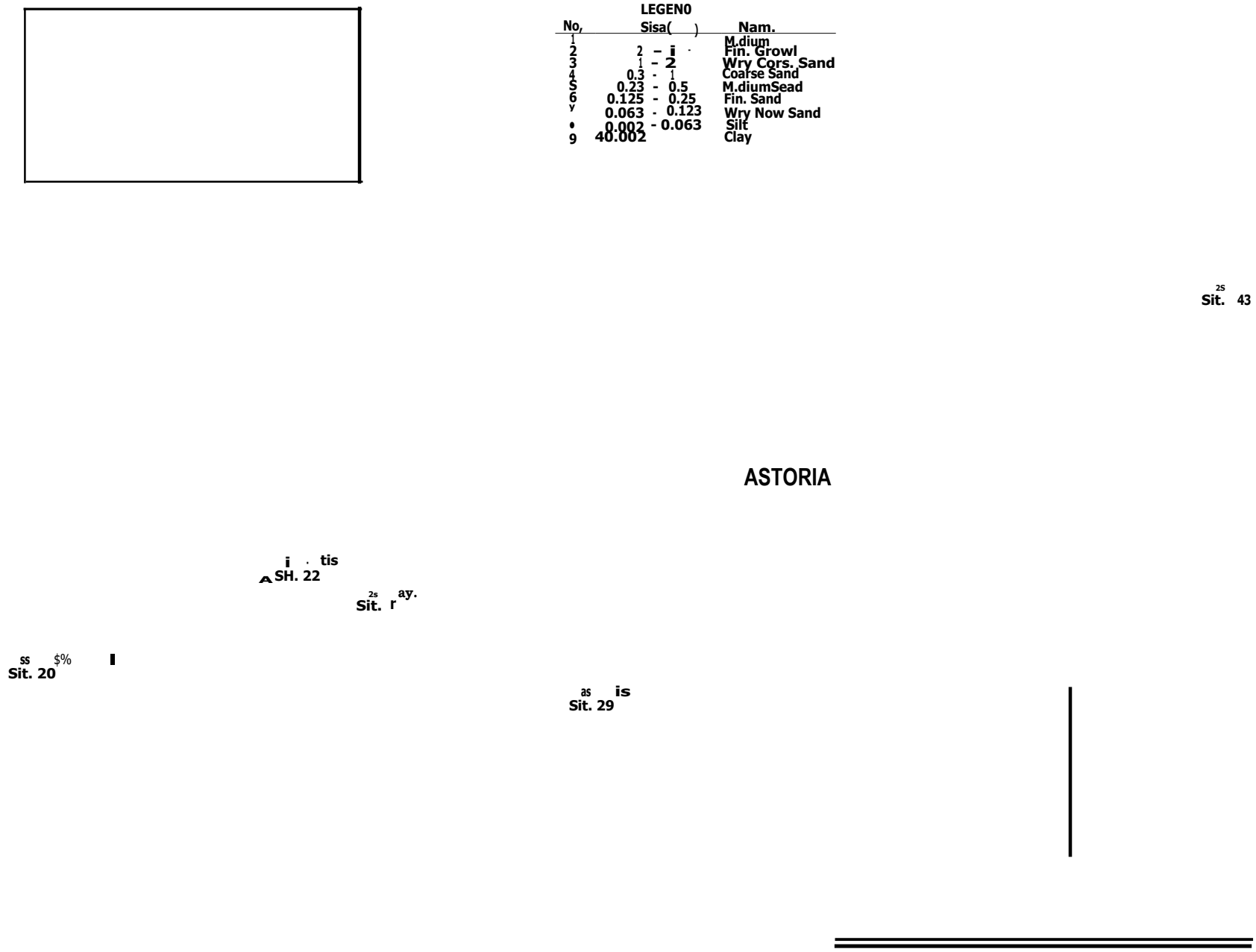

Figure S.--Mean particle size found at 33 sampling sites in Youngs Bay-Hammond to Tongue Point area between June 1977 and March 1978.

side of Youngs Bay. Sites on the south or west portions of Youngs Bay had dominant categories of silt and very fine sand. Off Astoria, the major sediment component varied considerably -- fine grain at one site, silt at another, very fine sand at a third, and medium sand at a fourth. Sediment at Site 41, near the navigation channel station off Tongue Point, was primarily medium sand. Sites in and near the east side of Tongue Point were a consistent mixture of very fine sand and silt.

Review of OSU samples taken outside Youngs Bay by Higley, Holton, and Komar (1976), indicates there were only a few sites geographically comparable to ours: OSU Station 23 appeared similar to NMFS Site 13, OSU 42 to NMFS 18, OSU 40 with NMFS 35, and OSU 2 with NMFS 40. NMFS results generally agreed with OSU findings at two stations but not at the other sites. Within Youngs Bay seven NMFS sites correspond with OSU sites studied in 1974 by Higley and Holton (1975). NMFS sediment texture data agreed with some but not all OSU data. OSU's use of only four sediment texture categories made comparison difficult. Conrow, Williamson, and Klein (1975) in their study of Youngs Bay sediments presented a chart showing the median grain size distribution. Graphs of sediment diameter in phi units were also provided. Our overall data tends to agree with their charts, though few of their sample sites were directly comparable.

Sediment particle size characterization falls into three broad categories (Figure 6). Very fine sand and silt typify the Tongue Point area as well as the southwest portion of Youngs Bay, Hammond, Youngs River, and Lewis and Clark River. Medium to fine grain sand characterize the Tansy Point, Alder Cove, and Baker Bay areas as well as the northeast portion of Youngs Bay. Sites off Astoria have variable sediment texture.

Figure 6.-- Mean annual sediment particle [illegible] similar sites in the Columbia River estuary.

Seasonal Change

Comparison of seasonal change in sediments was limited to five groups of sites having geographic proximity. Baker Bay Sites 1 to 12; Tansy Point Sites 14 to 16 and 19; Youngs Bay Sites 22 to 27, 29, and 31 to 35; Astoria Sites 36 to 40; and Tongue Point Sites 42 to 45. Grouping the results provided a larger sample base for determining change. The data from Baker Bay sites (Table 7) changed little in the first three surveys. However, the March results showed a small increase in fine sand with a decrease in coarse sand and clay.

Youngs Bay samples also revealed seasonal stability comparable to Baker Bay (Table 7). The mean grain site for each cateogry did not change greatly through the initial three surveys (June¯December). In March silt increased about 6% while the coarse sand and clay categories diminished.

The Tansy Point sediment group included four sites and their combined results appear in Table 7. Medium and fine sand typified the June and September surveys while December and March surveys revealed proportionately greater amounts of silt and very fine sand.

The Astoria area sediment group included five sites (Table 7). The greatest change in particle texture occurred between the September and December survey. In December, fine gravel appeared and remained through the March survey. Increases in the fine gravel were balanced by a decrease in medium sand. The proportion of clay increased in December but diminished in March.

The final group examined for seasonal sediment change was made up of four sites located just east of Tongue Point (Table 7). The proportion of coarse, medium, and fine sand categories diminished each survey while silt and clay usually increased.

TABLE 7.--The mean proportion and standard deviation of sediment particle categories by seasonal survey for groups of geographically similar stations.

Geographic group/category	June Mean (%)	June SD (%)	Sept. Mean (%)	Sept. SD (%)	Dec. 'Mean (%)	Dec. (%)	March Mean (%)	March SD (%)
Baker Bay (12 sites)								
1. Gravel	1.66	4.94	0.09	0.49	0.00	0.00	0.01	0.07
2. Fine gravel	0.46	1.21	0.84	3.05	0.67	0.94	0.12	0.19
3. Very coarse sand	1.30	1.44	1.35	1.96	1.33	1.15	0.00	0.00
4. Coarse sand	4.27	4.70	3.91	4.07	2.17	1.94	0.10	0.15
5. Medium sand	22.89	15.23	25.99	16.60	24.04	14.34	24.62	15.36
6. Fine sand	40.05	19.82	**39.96**	17.92	45.77	17.98	52.81	16.95
7. Very fine sand	13.27	11.38	10.27	10.62	9.87	11.62	10.03	12.50
8. Silt	12.86	12.65	15.75	15.93	11.99	13.58	11.09	17.79
9. Clay	3.19	4.19	1.82	2.63	4.16	5.70	0.94	1.80
Youngs Bay (12 sites)								
1. Gravel	0.00	0.00	0.00	0.00	0.07	0.24	0.02	0.11
2. Fine sand	0.01	0.06	0.01	0.05	0.16	0.26	0.02	0.06
3. Very coarse sand	0.24	0.54	0.66	1.52	0.55	0.79	0.02	0.04
4. Coarse sand	2.85	4.38	2.35	3.59	1.65	1.43	0.17	0.18
5. Medium sand	13.95	13.79	13.87	12.12	9.77	12.66	10.77	12.70
6. Fine sand	37.61	26.78	38.68	25.61	34.49	24.45	38.09	27.04
7. Very fine sand	19.85	12.11	20.24	13.02	23.87	14.82	20.42	12.35
8. Silt	20.74	22.58	20.57	21.21	21.86	21.28	27.62	28.51
9. Clay	3.85	5.29	3.56	4.49	7.57	7.21	2.80	3.51
Tansy Point (4 sites)								
1. Gravel	0.00	0.00	0.00	0.00	0.19	0.38	0.00	0.00
2. Fine gravel	0.00	0.00	0.06	0.12	3.35	6.44	0.03	0.05
3. Very coarse sand	0.36	0.57	0.24	0.22	1.36	1.95	0.00	0.00
4. Coarse sand	1.26	1.33	0.89	0.90	2.02	1.79	0.09	0.08
5. Medium sand	26.99	11.69	42.85	18.54	25.35	6.41	26.11	15.61
6. Fine sand	62.15	12.76	53.32	18.57	47.21	13.73	49.51	19.74
7. Very fine sand	5.19	3.30	1.72	0.89	7.44	4.20	9.32	6.17
8. Silt	3.26	4.70	0.92	0.51	9.27	6.95	13.40	11.07
9. Clay	0.78	2.21	0.00	0.00	3.83	2.99	1.34	1.30

TABLE 7.--The mean proportion and standard deviation of sediment particle categories by seasonal survey for groups of geographically similar stations. (Cont'd)

Geographic	particle group/category	June Mean ( )	June SD (%)	Sept. Mean (%)	Sept. SD (%)	Dec. Mean (%)	Dec. SD (%)	March Mean (%)	March SD (%)
Astoria (5 sites)									
	1. Gravel	1.19	3.77	1.91	6.05	2.77	4.74	2.20	3.34
	2. Fine gravel	3.41	4.05	3.22	5.72	14.74	26.47	13.61	20.81
	3. Very coarse sand	2.73	1.81	2.45	2.25	2.91	3.71	4.12	5.30
	4. Coarse sand	6.52	4.68	4.35	3.35	3.19	2.11	2.73	2.15
	5. Medium sand	12.52	5.70	11.95	5.47	7.90	4.64	6.72	3.22
	6. Fine sand	34.28	23.29	28.59	21.42	21.20	21.30	25.35	23.60
	7. Very fine sand	21.83	9.24	23.86	7.14	19.49	11.46	19.91	10.74
	8. Silt	15.50	9.80	21.07	15.13	18.66	14.87	21.89	16.54
	9. Clay	2.01	3.25	2.59	3.41	9.10	7.35	3.49	3.41
Tongue Point (4 sites)									
	1. Gravel	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00
	2. Fine gravel	0.00	0.00	0.01	0.04	0.00	0.00	0.04	0.11
	3. Very coarse sand	1.65	1.27	0.95	0.71	0.34	0.31	0.01	0.02
	4. Coarse sand	7.26	3.47	4.42	1.66	2.72	1.22	0.18	0.09
	5. Medium sand	6.54	3.72	4.78	1.71	4.41	1.75	0.23	0.14
	6. Fine sand	11.58	8.79	8.91	2.91	8.46	3.25	5.81	3.61
	7. Very fine sand	29.47	7.46	30.95	10.08	29.05	5.78	32.53	6.31
	8. Silt	34.79	10.29	42.85	9.79	35.06	8.90	51.12	7.06
	9. Clay	8.64	2.52	7.12	1.59	19.97	4.81	10.08	2.37

Organic Content

Percentages of volatile solids were determined for each of the 360 sediment samples. In some locations, decaying marsh vegetation or wood products caused high total volatile solid (TVS) readings. At other sites, other domestic waste products appeared responsible for excess levels. When measurements exceed 6% they exceed the EPA's standards and such a site may be suspected of being polluted. There was no attempt to determine the type of organic material involved when the 6% level was exceeded. The volatile solid data are provided simply to add a further dimension to habitat classification. The organic content data are listed for each sample in Appendix B.

Of the 360 TVS samples, 75 or 20.8% exceeded the 6% level. Lewis and Clark River Site 28, situated downstream from a log sorting yard, had consistently high organic levels, as did Skipanon River Sites 20 and 21. Other sites usually exceeding the EPA standard were Site 10 at the Ilwaco Harbor mouth, Site 25 in Youngs Bay, Site 31 near the Astoria sanitary landfill, Site 37 west of the east Mooring Basin, Site 39 west of the Astoria sewer disposal lagoon, Site 43 at the southern end of the Tongue Point facility, and Site 44 at the former Maritime Base pier.

The annual average TVS levels for geographically similar sites are presented in Figure 7. Presented in the same figure are seasonal TVS measurements at sites where combined samples **provide** a more reliable indication of levels. Based on these data, there appears to be a TVS increase from the September to the December survey in four of the five groups.

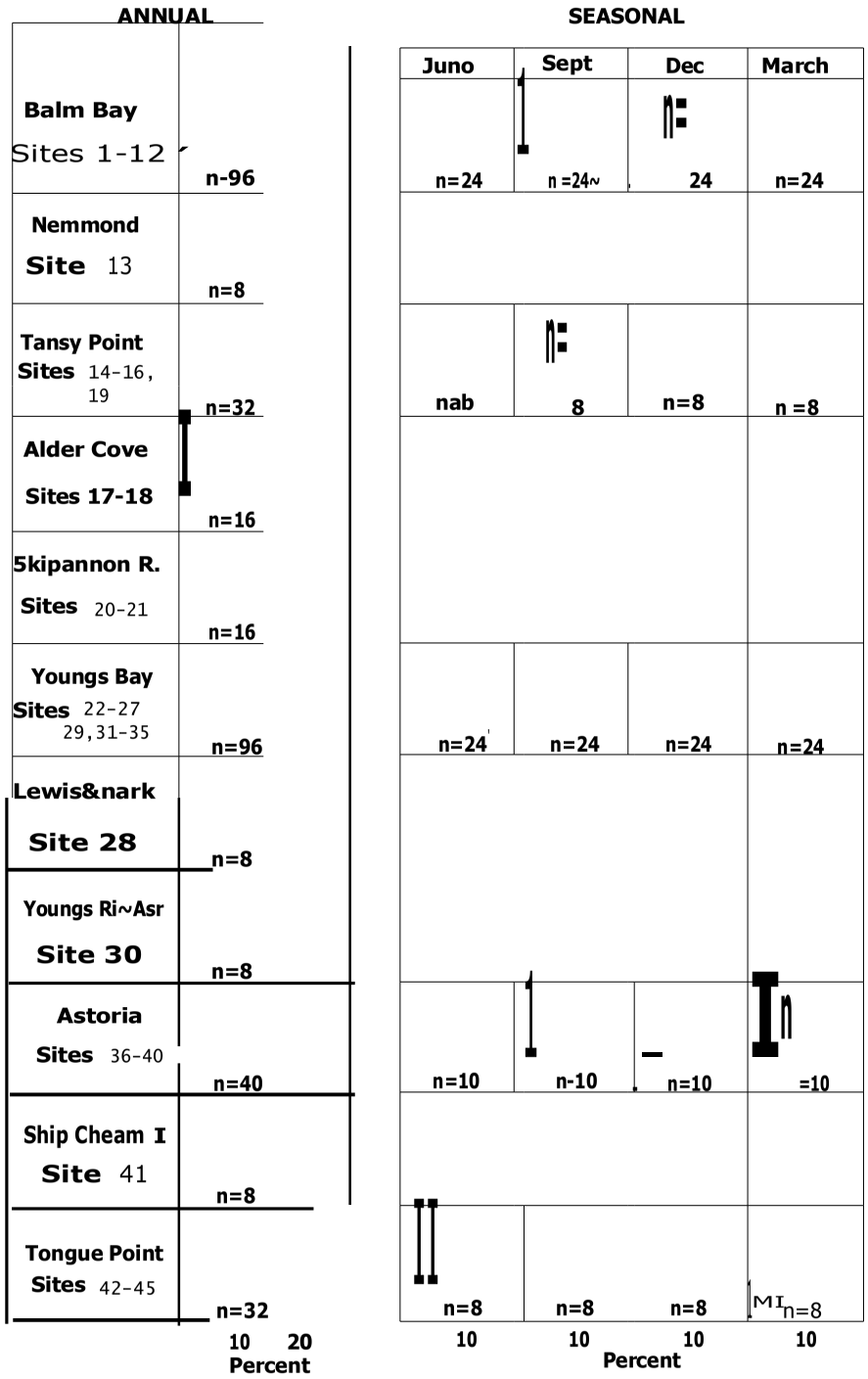

Figure 7.-- Mean annual [illegible] sites, and [illegible] in [illegible] geograp[illegible] as where [illegible] v similar estuarine more samples were tak

BENTHIC INVERTEBRATES

Species

There were 43 groups and species (Table 8) of benthic invertebrates identified during this study; Higley and Holton (1978) listed 66 groups and species. Most of the difference undoubtedly relates to sampling station location. Higley and Holton (1978) sampled in the ocean at sites west of Baker Bay and locations north and east of Tongue Point. Benthic invertebrate communities at the estuary mouth contain stenohaline marine species which do not penetrate deeply into the estuary. Freshwater species that we did not encounter occur further east of Tongue Point according to the 1978 OSU report. Most benthic invertebrates found in our estuary study area were euryhaline probably due to the variation, magnitude, and intrusion distance of salinity.

Species captured that were not previously reported include: Mya arenaria, the eastern soft shell clam; Mytilus edulis, the bay mussel; Clinocardium nuttalli, the common cockle; Asellus tomalensis (isopoda); and Hobsonia florida (polychaeta). [Amphicteus floridus (polychaeta) previously reported by Higley and Holton (1978) apparently is not that species but is a new genus and species Hobsonia florida].?

The study revealed the benthic invertebrate community of Baker Bay distinctly differed from that of Youngs Bay and adjacent areas. The principal component of the Baker Bay community was the bivalve, Macoma balthica. Other important species included the polychaeta, Neanthes limnicola and amphipods, Eohaustorius estuaris and Corpohium brevis.

?~ Karl Banse, Zoology Dept., Univ. of Washington, Seattle, Washington, personal communication.

Table 8.--Taxonomic groups and species found during an investigation of 45 sites in the Columbia River estuary.

Phylum Ne-ortinea

Phylum Nematoda

Phylum Platyhelmenthes
- Class Turbellaria

Phylum Annelida
- Class Polychaeta
  - Subclass Errantia
    - Family Nlereidae
      - Neanthes limnicola
    - Family 7hylrocodidae
      - Eteone sp.
    - Family Goniadidae
      - Glycinde sp.
  - Subilass Sedentaria
    - Family Ampharetidae
      - Hobsonia florida
    - Family Spionidae
      - nolydora sp.
- Class Oligochaeta
- Class Hirudinea

Phylum Ao.ilusca
- Class Gastropoda
  - Order Ctenobranchiatae
    - Family Pleuroceridae
      - Goniobases sp.
- Class Bivalvia
  - Family Cyrenidae
    - CO biCul&jujulapAis
  - Family le en ae
    - Mafmbalthiea
  - Family ;Tyi dae
    - Mya arenaria
  - Family Mytilidae
    - lytilus edulis
  - Family Cardiidae
    - Clinocardium nuttalli

Phylum Arthropoda
- Subphylum Chelicerata
  - Class Arachnida
    - Order Acarina
      - Suborder Hydracarina
- Subphylum 'landibulata
  - Class Crustacea
    - Subclass Ostracoda
    - Subclass Branchiopoda
      - Order Diplostraca
        - Suborder Cladocera
          - Family Daphnidae
            - Daphnia longispina
          - Family W sminidae
            - Bosmina sp.

Table S.--Continued

Subclass Copepoda
Order Iiarpacticoida
Family Canuellidae
Cannella canadensis
Order Calanoida
Family Temoridae
Eurytemora hirundoi-aes
Suhlcass Cirrepedia
Order Thoracica
Family Balanidae
Balanus amphitrite am[p]hitrite
Suhlcass rialacostraca
Superorder Peracarida
Order "iysidacea
Family ' ivsidae
'Jeomysis mercedis
Order Cumacea
Order Isouoda
Suborder Flabellifera
Family .S haeromaticae
Gnorimosphaeroma oregonensis
Suborder Valvifera
Family Idoteidae
Aesidontea (=Saduria) entoron
Suborder Asellota
Family Iksellidae
Asellus tonalensis
Order Amphipoda
Suborder Gammaridea
Family Corophiidae
Corophiumsalmonis
Corophium spinicorne
Corophium brevis
Family Gammaridae
Anisogammarus confervicolus
Family Haustoriidae
Eohaustorius estuaris
rohaustorius sp.
Family Phoxocephalidae
"araphoxus nilleri
Superorder Eucarida
Order Decapoda
Suborder Natantia
Cragon franciscorum
Class Insecta
Order Odonata
Suborder Zygoptera
Family Coenagrionidae
Order Diptera
Family Chironomidae (=Tendinedidae)
Order Tricoptera
Order Ephemeroptera
Order Plecoptera

The Youngs Bay benthic infauna assemblage had a large population of oligochaeta and amphipods, Corophium salmonis and Corophuim spinicorne. The higher densities appeared associated with a fine sand-silt substrate. Though the polychaeta, N. limnicola occurred in both bays, it had a higher population in Youngs Bay where it was associated with the sedentary polychaeta, Hobsonia florida. Bivalves of Youngs Bay included M. balthica, but it didn't occur as abundantly as in Baker Bay. The exotic Asian freshwater clam, Corbicula manilensis extended its range into Youngs Bay though it was not tolerant of the higher salinities found in Baker Bay.

The soft shell clam, Mya arenaria and cockle, Clinocardium nuttalli are common in west coast estuaries with high salinities and the proper substrate. Both were found at a wide number of sites during the September and December surveys, but only a few were found in March 1978.

Invertebrate Numbers

The number of benthic invertebrates found in each sample is presented in Appendix C. Though many samples show close similarity of groups and numbers, other samples are inconsistent. The differences in invertebrate numbers may result from distributional patchiness, sediment texture change, or a degree of flaw in the collection technique. However, the funding necessary for increased sampling to resolve sample variation was not available.

The mean number of each major benthic invertebrate group is presented for Baker Bay in Figure 8 and for Oregon sites in Figure 9. Baker Bay samples are not numerically great; with bivalves usually most important. Sites with bivalves have at least some silt, clay, and very fine sand. Polychaetes tend to be found in quantity at interior sites that have a

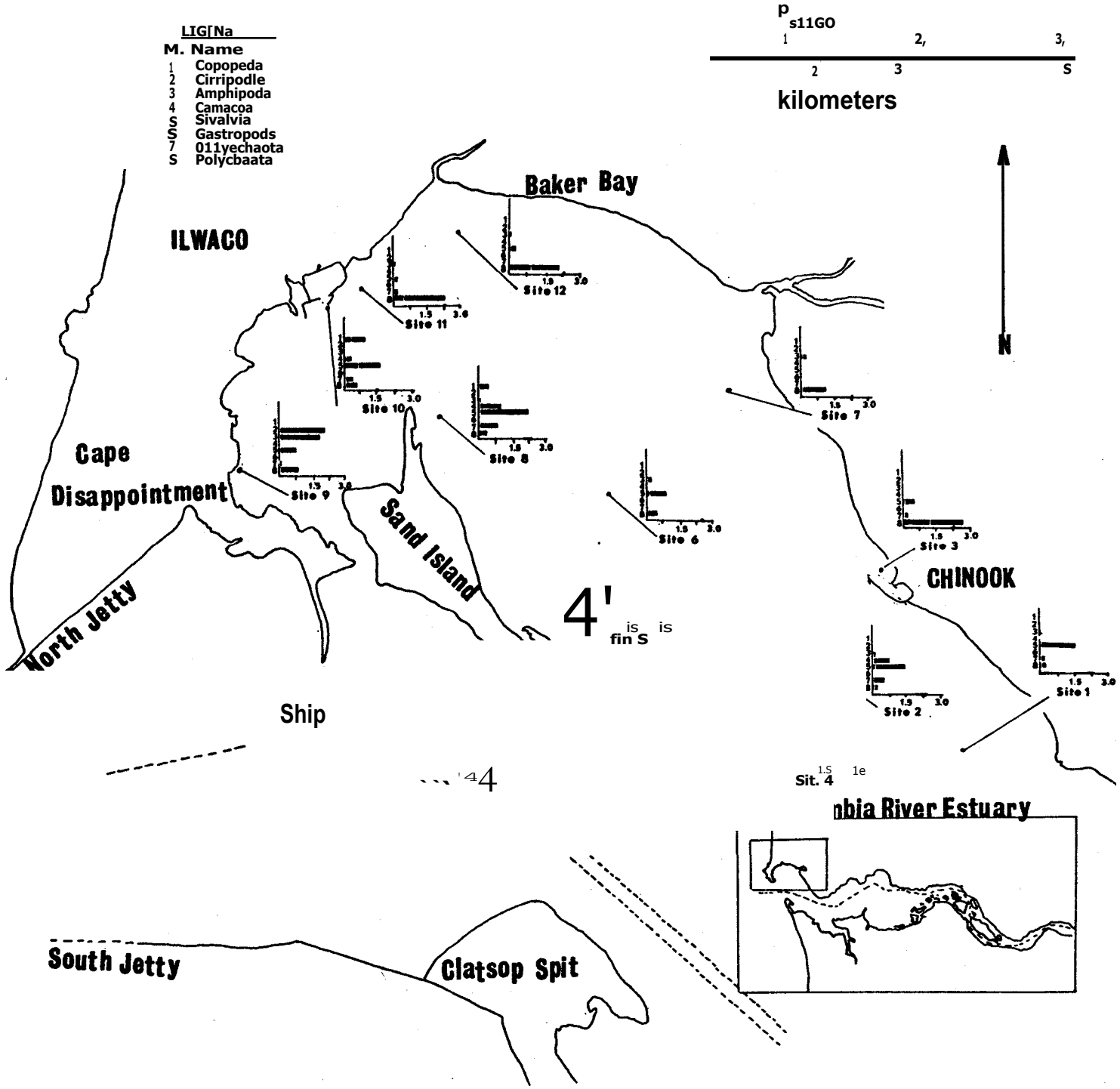

Figure 8.--Mean annual number of benthic invertebrates, expressed in thousands/m^2, at 12 Baker Bay sites.

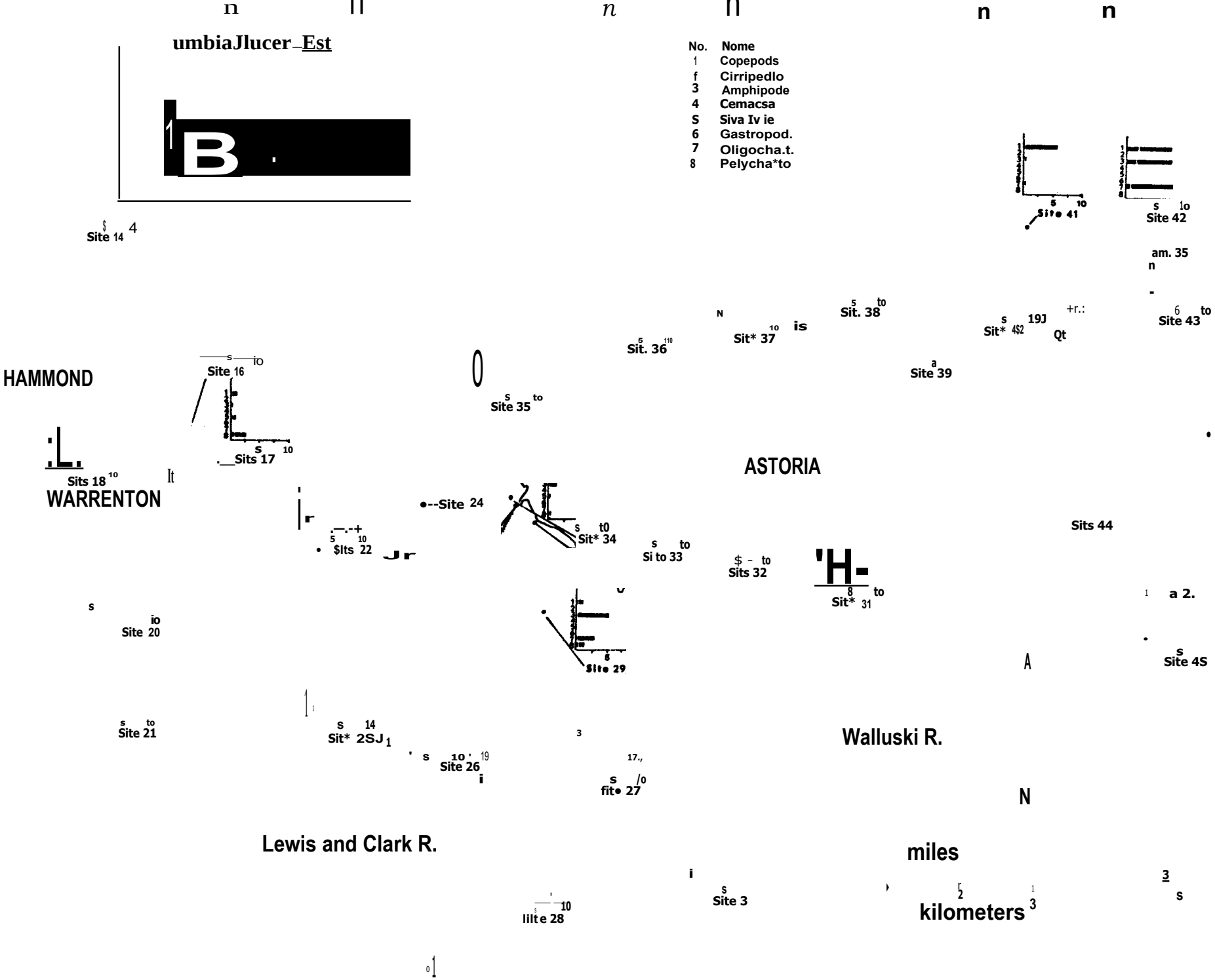

Figure 9.--Mean annual number of benthic invertebrates, expressed in thousands/m^2, at 33 sites in Youngs Bay and adjacent waters.

medium and fine grain sand substrate. Amphipods were common at Site 9 as were cirripedia. Other common benthic groups in Baker Bay were cumaceans, which occurred at Site 2 in Chinook Channel and Site 8 just north of Sand Island. Both sites had similar substrate.

Benthic invertebrate densities on the Oregon side were generally greater (Figure 9). The Oregon sites have either rich, diverse benthic invertebrate communities or sites with comparatively few organisms. Quantities of copepods were usually associated with low flow, and moderate salinities in the Skipanon River, Lewis and Clark River, Youngs River, Tongue Point, and several sites off Astoria. Copepods usually were associated with high numbers of amphipods and oligochaetes. Polychaeta, though common, were only numerically important at sites west of Astoria.

The densities of benthic invertebrates varied; the highest annual average was the 26,690 copepods/m^2 at Skipanon River Site 20. Site 27 at Youngs Bay had the highest average number of amphipods, 13,130/m^2. Whereas Sites 26 and 37 had comparable amphipod densities of 12,606/m^2 and 13,072/m^2, respectively. Bivalves occurred at every station, but the highest average number was 2,212/m^2 at Baker Bay Site 8. Polychaete densities average 10,596/m^2 at the Skipanon River Site 20 whereas gastropoda averaged 510/m^2 at Site 38. Oligochaeta densities were greatest (average 16,996/m^2) in Youngs Bay at Site 27. Nematoda did not appear in the graphs but occurred at all estuarine sites. Nematoda abundance was greatest in the Skipanon River, where they averaged 12,590/m^2.

Among all the 45 sampling sites, Skipanon River Site 20 with 58,150/m^2 had the highest mean density of all benthic invertebrates. Site 27 in Youngs Bay with 42,884/m^2 and Site 30 in Youngs River with 38,676/m^2 had the next greatest densities of invertebrates. The four Tongue Point sites had an average density exceeding 20,000/m^2. The lowest invertebrate density was 876/m^2 at Site 14 off Hammond. There were several other sites in Baker Bay and between Hammond and Warrenton with average densities below 2,000/m^2. These mean annual density levels, though useful for comparative purposes, tend to mask individual populations, particularly those that are high or low. For example, in June the greatest indicated single benthic density was at Skipanon River Site 20 where invertebrates numbering 131,280/m^2 were taken in one sample and 113,000/m^2 in a second. In contrast, invertebrate numbers of only 120/m^2 and 100/m^2 were found at Site 41 during the December survey.

Grouped Average Quantities

The annual mean densities for benthic invertebrates in similar geographic areas are shown as grouped data in Figure 10. The importance of specific groups can be associated with salinity levels or distance from the river mouth. Protected off-channel sites with fine sediment and slow water velocity can be factors adding significantly to enhancement of organisms such as copepods. Considerable variation in species richness and diversity exists between the geographic areas.

Seasonal Variation

Seasonal variation of invertebrates were examined at those five subareas where sediment texture changes were evaluated. The indicated seasonal trends are shown in Figure 11. Seasonal variation is apparent for amphipods, oligochaetes, and copepods. Sampling should be reinforced to

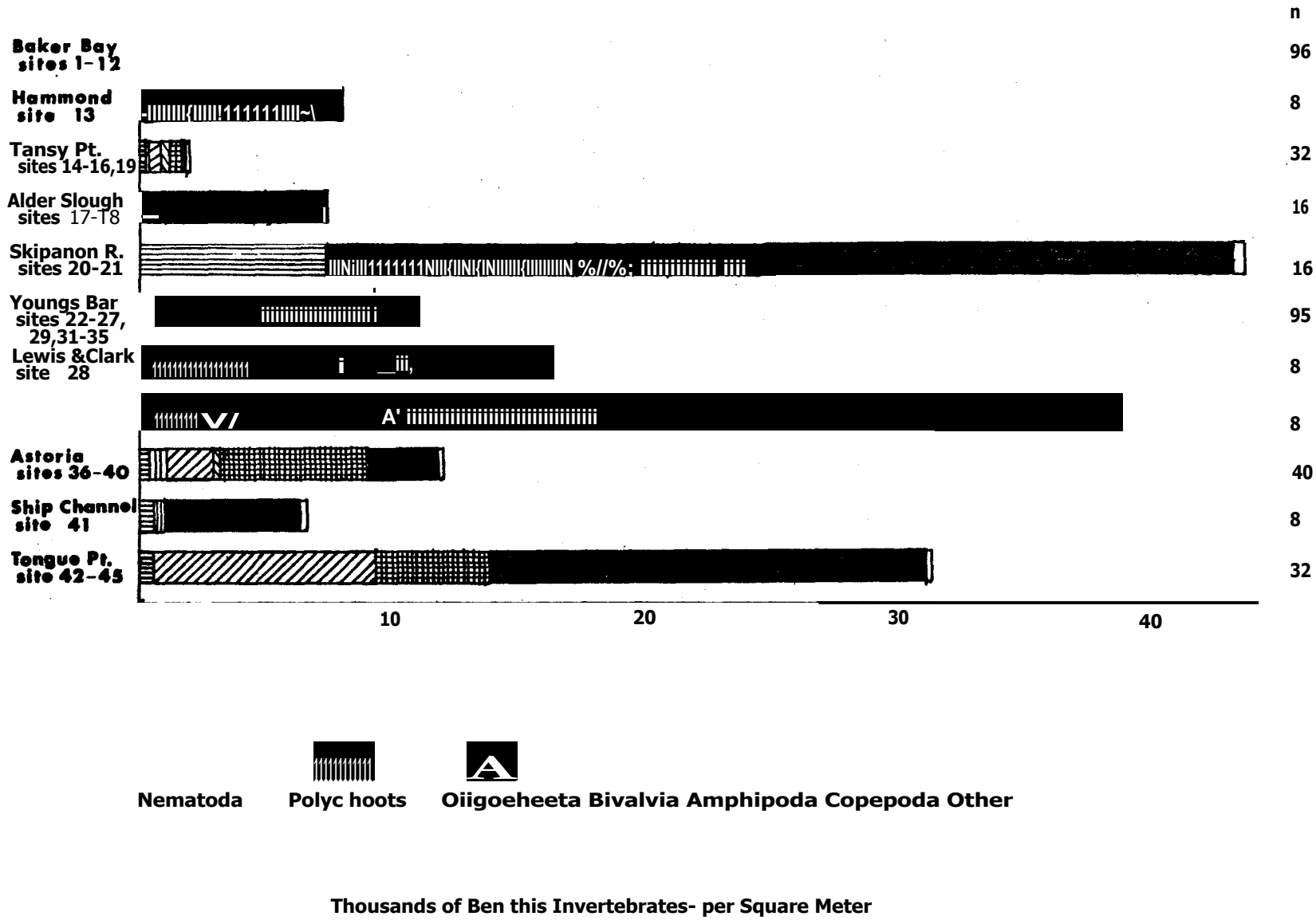

Figure 10.-- The average annual proportion of **different** benthic invertebrates found at groups of sites in similar geographic areas in the Columbia River estuary during June 1977 to March 1978.

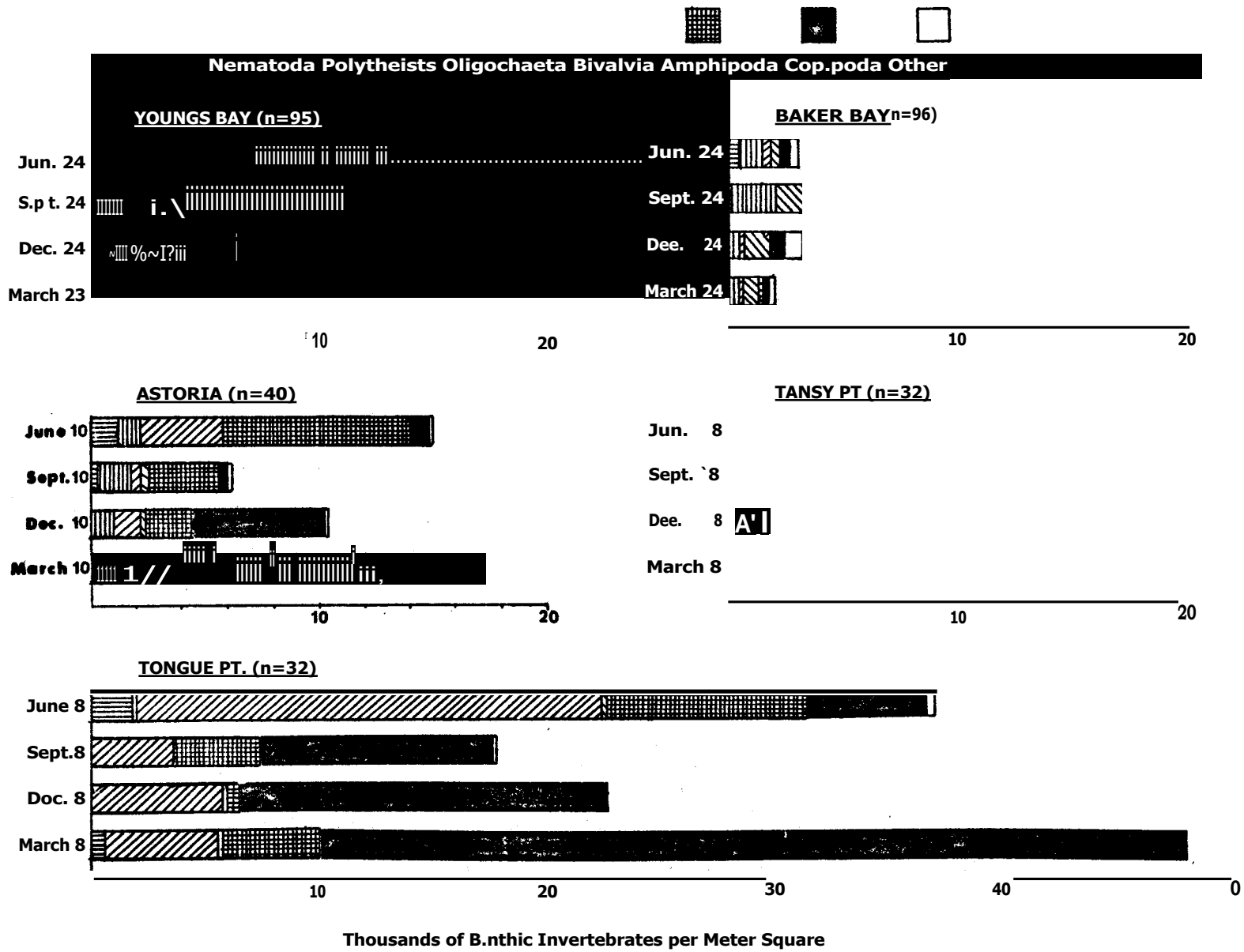

Figure 11.-- Seasonal composition and re[1] ative ab ndnnce of hen.*hic i.svertebrn*es **captured at five subareas** in the ^,oiunhtP [T]'i7er *par-a. -he .,„-g ber fnlio-aing the **month** indicates the number of samp[1] es for eaeh neri_o1.

statistically verify these seasonal changes and relate numerical shifts to geographic areas. The grouped data indicate that in specific areas examined, the total number of organisms, from low to high abundance cycles, resulted in a 100% increase. At the Astoria, Youngs Bay, and Tongue Point areas, a consistent pattern for amphipods and oligochaetes occurred. Both populations decreased after the June surveys, dropped lower during either September or December, and increased in March. Copepods increased at freshwater stations after June. Polychaetes and bivalves in Baker Bay were most frequent in the September survey.

Invertebrate Weights

The weight of an individual species, group, or entire sample provides an additional perspective of the benthic invertebrate community. The importance of numerical abundance may be countered by the relatively minor weight of a species or group. In addition, invertebrates such as bivalves may not numerically dominate a benthic community but may dominate its biomass. The shell weight of bivalves, gastropods, and cirripedias should be considered when assessing biomass, but different factors would be required for each species, and probably each age class. Amphipods, copepods, cladocerans, mysids, and cumaceans also have chitonous exoskeletons which could be considered extraneous weight. Oligochaetes, nematodes, and polychaetes are groups with no shell or exoskeleton. The various weight aspects are acknowledged; however, data in this report are simply overall weights.

Benthic invertebrate weights (g/m^2) in Baker Bay are shown in Figure 12. The importance of bivalvia (M. balthica) weight is obvious; cirripedia, polychaeta, and amphipoda groups provide the remaining weights.

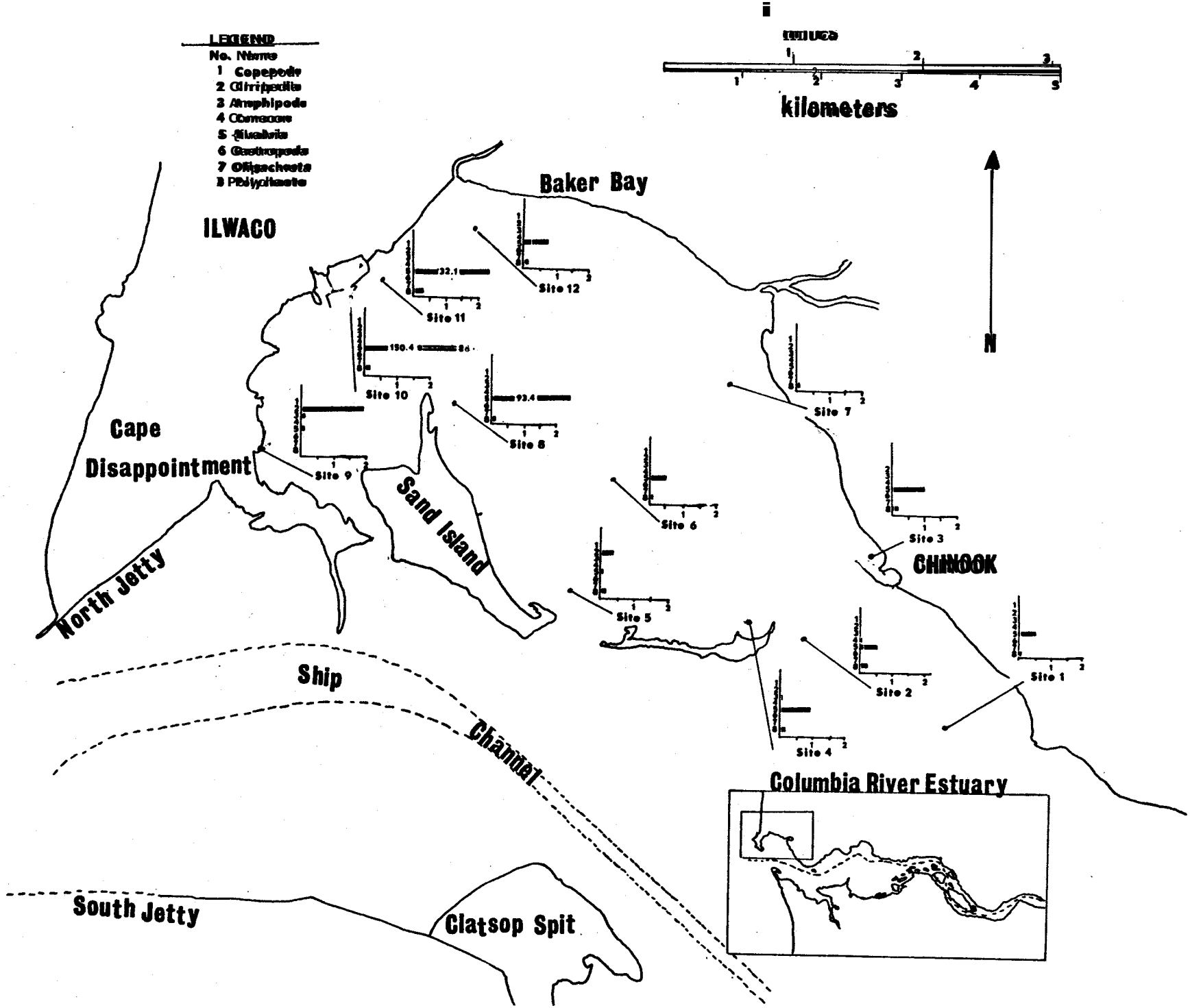

Figure 12.--Annual average weight (g/m^2) of eight benthic invertebrate groups occurring at 12 Baker Bay sites between June 1977 and March 1978.

The heaviest weight concentrations were found at Sites 8, 10, and 11 in the western portion of Baker Bay.

The average invertebrate weights (g/m^2) in Youngs Bay and adjacent Oregon sites are shown in Figure 13. Bivalvia and polychaeta groups were the major weight contributors at western sites; whereas, amphipoda, oligochaeta, bivalvia, and polychaeta accounted for nearly all Youngs Bay weights. Gastropoda, though numerically inconsequential at most sites, contributed substantially to the biomass found at Sites 37 and 38. Tongue Point sites reflected the importance of amphipoda and oligochaeta weights.

Grouped Average Weights

Sample weights from various sites were grouped to show the proportion of invertebrate weights associated with a particular area. These annual average weight components are compared in Figure 14. Bivalve weight dominance in Baker Bay is evident. Though having one of the lowest numerical densities of any study area, Baker Bay had the greatest average annual weight per square meter.

Seasonal Weight Variation

Seasonal weight comparison is presented in Figure 15 for geographically similar sites having 32 or more samples. Seasonal invertebrate weight trends in these areas follow the seasonal numerical trends at four of five sites. The exception was at Astoria where the lowest average weight occurred in June whereas the numerical low occurred in September.

SUMMARY

A study was conducted of benthic invertebrate communities and associated substrate texture at 45 sites in the Columbia River estuary. Replicate samples were made at each site every 3 months for 1 year.

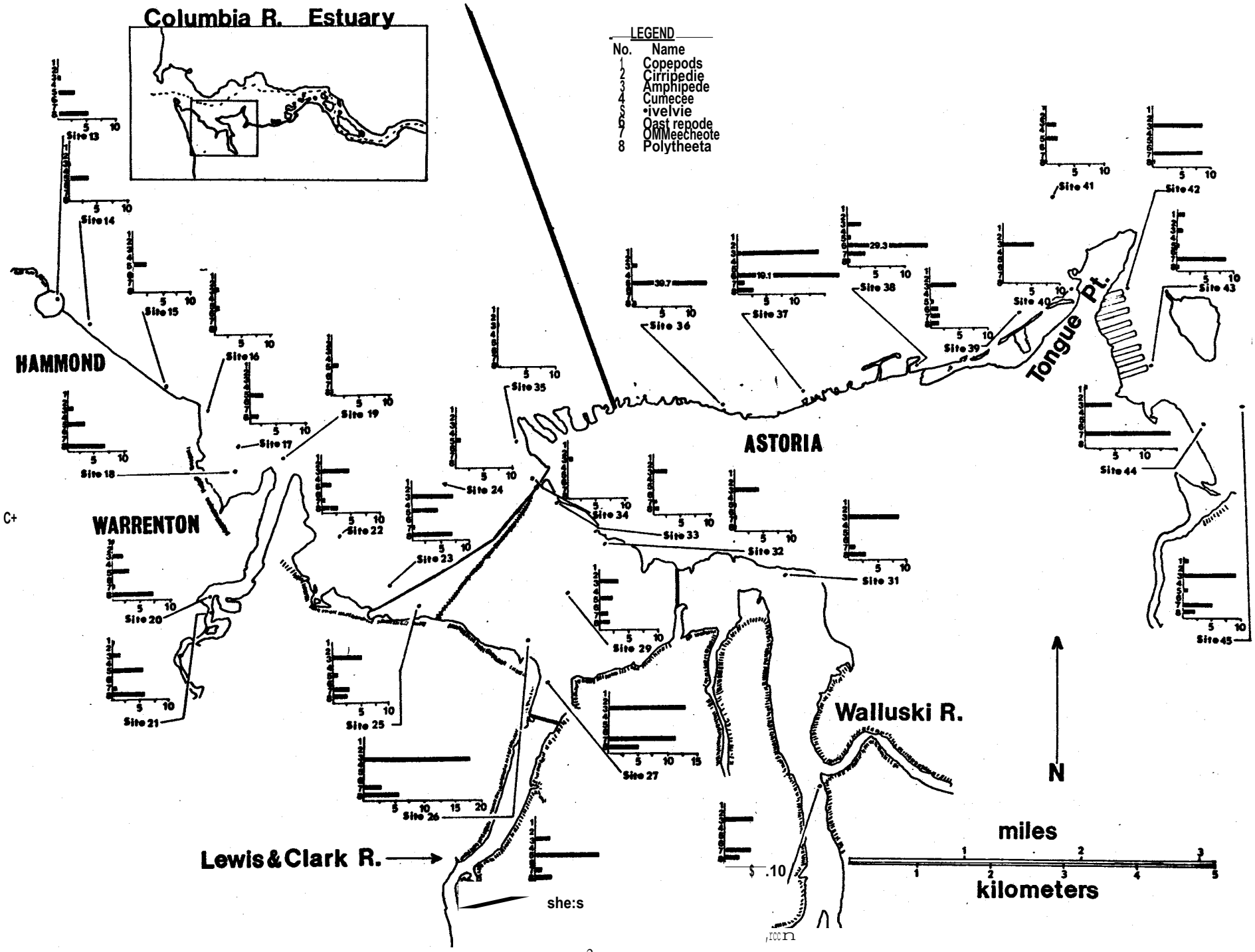

Figure 13.--Annual average weight (Om^2) of eight benthic invertebrate groups occurring at 33 Oregon sites between June 1977 and March 1978.

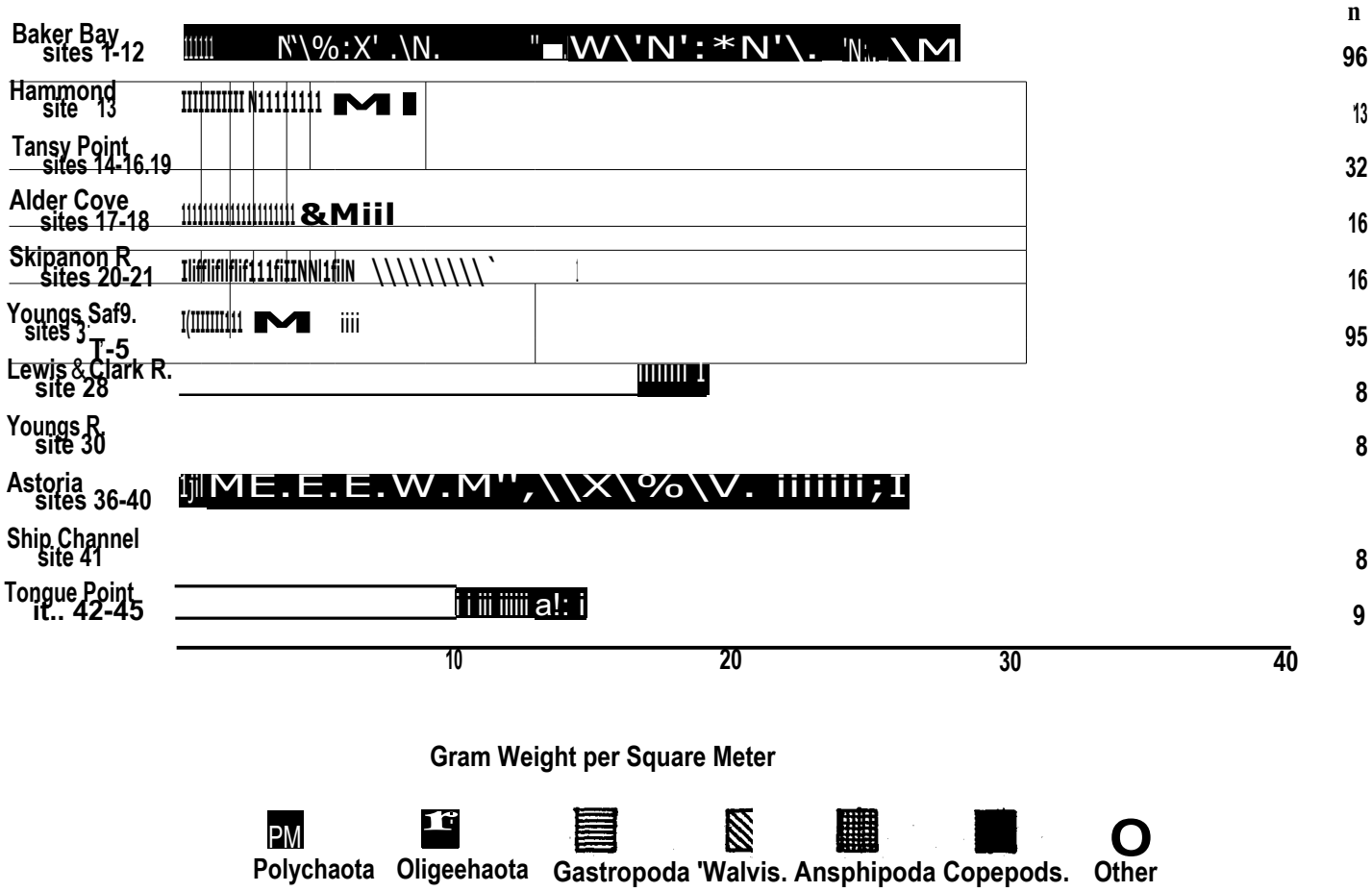

Figure 14.--The comparative weight (g/m^2) of various groups of benthic invertebrates at similar geographic sites. (n = number of samples.)

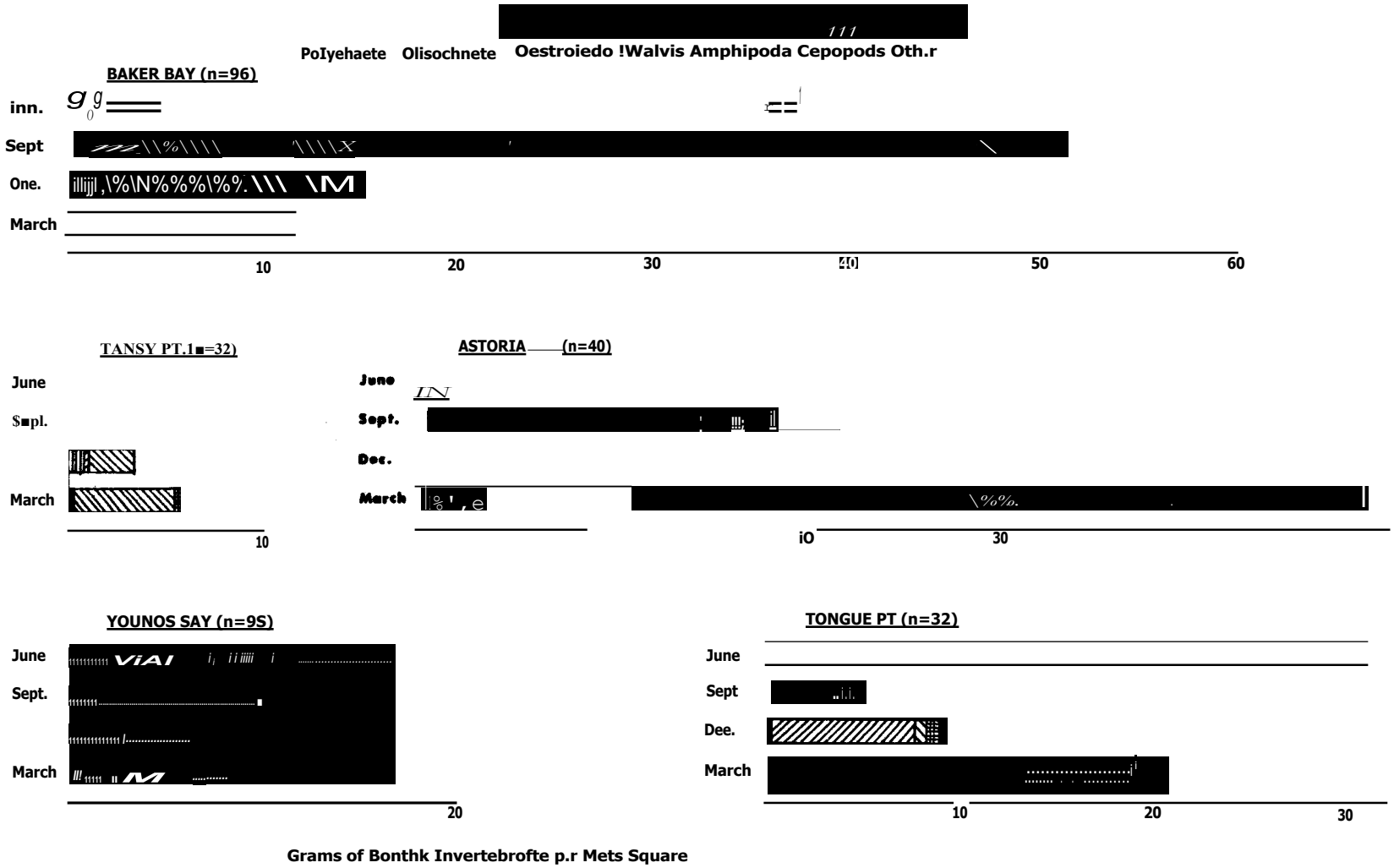

Figure 15.--Seasonal weight (g/m^2) comparison of selected groups of benthic invertebrates found at five subareas in the Columbia River estuary. (n = number of samples.)

Benthic invertebrate and substrate samples were taken with a 0.05 m^2 Ponar dredge. Water quality measurements were made just above the bottom and just below the surface in conjunction with the benthic sampling effort. Most sites were in estuarine embayments and in depths of less than 10 feet m1w.

The levels of water quality indicators measured were suitable for survival of aquatic estuarine species--ranges: salinity, 0.06 to 31.42 ppt; temperature, 5.1° to 19.8°C; O_2, 6.0 to 12.2 ppm; and pH, 6.45 to 9.0.

Sediment particle sizes were examined on an annual and seasonal basis. Annual averages indicated Baker Bay sites were primarily fine and medium grain sand, though proportions of very fine sand, silt, and clay did occur. Particle texture found at sites on the Oregon side varied considerably. Fine sand was a major component of sediments at Hammond, Tansy Point, Skipanon River, and northeastern Youngs Bay. Silt and very fine sand characterized the eastern and interior sites in Youngs Bay and Tongue Point. A mix of coarse and fine sediments occurred off Astoria. Areas with four or more sites revealed a gradual accumulation of fine grain material from June through March.

Examination of the organic content of sediments, expressed as percent volatile solids, indicated two areas., the Skipanon River and Lewis and Clark River, consistently exceeded EPA standards of 6%.

Benthic invertebrates collected were chiefly amphipods, oligochaetes, polychaetes, nematodes, bivalves, and copepods. Nemertea, gastropods, cirripedia, cumacea, and diptera were sporadically abundant at various sites but were geographically limited. The benthic infauna community at

Baker Bay sites was made up of polychaetes, bivalves, cumaceans, cirrepedias, and amphipods ranging in population from 1500 to 4000/m^2. On the Oregon side, the benthic community structure off Hammond was dominated by polychaetes, but the average quantities were below 5,000/m^2. Youngs Bay, Skipanon River, Youngs River, and Lewis and Clark River sites contained a diverse mix of amphipods, oligochaetes, polychaetes, copepods, and bivalves; the average population ranged from several thousand to over 58,000/m^2. Sites off Astoria were generally rich and diverse but varied in numbers and community structure. Tongue Point sites had benthic communities that exceeded an average of 20,000/m^2. Apparent seasonal differences in invertebrate numbers were noted based upon combined catches in specific areas. Seasonal abundance varied with the study area. Weights of bivalves and gastropoda dominated invertebrate weights at sites where they were numerous. Numerically important copepods provided only minor sample weight. Seasonal weight changes corresponded with numerical changes except at the Astoria group of stations.

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Nick Zorich and Roy Pettit operated and maintained our 12.2 m vessel. Lawrence Davis, Edward Keller, and Robert McConnell gathered all water quality measurements and helped verify benthic invertebrate counts. Travis Coley prepared charts and bibliographic data. Murray Amos provided statistical guidance and examined analysis of variance tests for applicability. Candace Van Dulcen, Sue Doumitt, Amy White, Linda Jennings, and Liam Antrim sorted, categorized, and counted benthic invertebrates. Nancy Ellifrit and Jack Kincheloe, FWS, Portland, guided site selection to obtain data to fit the habitat classification goal. Nancy Ellifrit; Duane Higley, OSU; and Karl Banse, University of Washington, provided expert identification of some troublesome invertebrates. Our sincere appreciation is offered to each of the individuals noted who worked with us on this study and to anyone we may have inadvertently neglected to mention.

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