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PUGET SOUND BASELINE PROGRAM

NEARSHORE FISH SURVEY

by

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FINAL REPORT
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INTRODUCTION

Since the inception of the Baseline Study Program[1] in July 1974, the Fisheries Research Institute (FRI) has conducted the Nearshore Fish Survey under contract to the Washington Department of Ecology (DOE). The objective of the baseline study was to document the seasonal occurrence, abundance, and distribution of the marine and estuarine fishes frequenting the shallow (< 20 m in depth) waters adjacent to the shoreline. This contributed to the DOE baseline studies which were designed to evaluate the potential and existing risks of environmental damage resulting from the introduction of oil and other known pollutants into Puget Sound. Emphasis was placed on nearshore biota because pollutant effects, especially those induced during oil spills, will probably be most pronounced there. In addition to the Nearshore Fish Survey, studies were also conducted by other investigators to document the oceanographic characteristics and invertebrate and fish assemblages in other nearshore areas of the region as well as the economic factors involved in the valuation of a healthy shoreline environment. This information would eventually contribute a valuable perspective to the economic and ecologic importance of the nearshore region and contribute to the assembly of a data base for future reference in the case of a nearshore pollution incident.

As emphasis was given to "those waters 1) in which the greatest risk of damage from oil spills exists; 2) which contain marine and freshwater life that is particularly sensitive to toxins contained in crude oil, oil products, and oil wastes; and 3) which are used or may be used for the harvesting, gathering, or production of food or food products,"[2] the area of study was located in northern Puget Sound because of the present and future transport of oil products through those waters, and because of the location of oil refineries in the area.

The first annual report of the Nearshore Fish Survey (Miller et al. 1976) presented the sampling design, methods, and results of the first 15 months of sampling. This report discusses the continuation of the previous sampling program, modifications to that sampling design, and expanded or new programs introduced with the 1975-76 survey. The tasks of the 1975-76 survey were: 1) continuation of the systematic fish survey in order to document annual variation in the occurrence, distribution, and abundance of nearshore fishes; 2) initiation of a nearshore

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[1] Chapters 30 and 39, Laws of 1973, 43rd Washington State Legislature, Second Extraordinary Session.

[2] Senate bill #2978.

ichthyoplankton survey to document temporal and spatial changes in the occurrence, distribution, and abundance of pelagic fish eggs and larvae in the nearshore plankton; 3) expansion of the nearshore food web investigations; and 4) preliminary sampling of nearshore epibenthic plankton as potential prey organisms available to fishes of the nearshore environment. This final report also presents the results, analysis, and discussion of all data collected during the Nearshore Fish Survey from 1974-1977.

Sampling with beach seine and townet and SCUBA transect observations decreased in scope and frequency during the second sampling period. The frequency of beach seine collections was reduced to every two months; townet collections continued to be made at monthly intervals through late winter and spring, during the peak occurrence of juvenile salmonids and baitfish larvae and juveniles, but were reduced to quarterly samples over the remainder of the year. SCUBA transect observations were also reduced to a quarterly sampling frequency except for the site at Point George, Shaw Island, in spring 1976 when monthly observations were made.

Analysis of the townet data from the first year of the Nearshore Fish Survey indicated substantial populations of larval fish present in the study area during some parts of the year. Consequently, in designing the 1975-76 continuation, we proposed a two-year study of the nearshore ichthyoplankton of the area to document temporal and spatial changes in the occurrence, distribution, and abundance of pelagic fish eggs and larvae present in the nearshore plankton. At the beginning of this study, it was understood that much of the first year work would be to develop field and laboratory techniques and to develop taxonomic ability, and that more detailed sampling and analysis would be carried out in the following year, 1976-77. Because the anticipated support for continuation of the nearshore ichthyoplankton survey in 1976-77 was not realized, it was not possible to satisfy the goals of the ichthyoplankton study. Our documentation of the composition, distribution, and abundance of nearshore ichthyoplankton will thus be limited by the incomplete series of samples obtained in 1976.

In addition to the stomach samples collected and analyzed by FRI during the Nearshore Fish Survey, stomach samples retained from beach seine catches collected by Western Washington State College (WWSC) along the eastern shore of Washington Sound and North Sound were forwarded to FRI for analysis. Thus, given a standardized analysis procedures applied to the stomach contents for nearshore fish from all baseline studies sites, it was possible to make direct comparisons between food habits of fishes from different regions.

Results from the quantitative analyses of the stomachs of nearshore fishes captured during the first year of study indicated that epibenthic plankton (primarily amphipods, mysids, and copepods) constituted important fish prey resources in the nearshore region of our study area. Unfortunately, the design of the Baseline Studies Program did not include sampling of these assemblages. We proposed that an objective of our continued Nearshore Fish Survey also include the preliminary sampling of epibenthic plankton coincident with our beach seine sampling, using a form of epibenthic suction pump previously shown to be an effective sampler of such organisms.

METHODS AND MATERIALS

Nearshore Study Habitats of North Puget Sound

In accordance with DOE Baseline Study guidelines, our sampling design was based on fish habitats thought to be representative of the physically and biologically diverse shoreline environments in north Puget Sound (Washington and North Sounds) from the United States-Canada border to the southern end of Rosario Strait (Fig. 1), namely: 1) Rocky/kelp bed--high gradient, exposed rocky shoreline with adjacent subtidal kelp (*Nereocystis*) beds; 2) cobble--high to moderate gradient, exposed beaches with substratum of large gravel to cobble; 3) gravel--moderate gradient, semi-protected gravel beaches (the typical "bivalve" beach); 4) sand/eelgrass--low gradient, protected sand beaches with eelgrass (*Zostera*) beds (usually a semi-enclosed embayment); and, 5) mud/eelgrass--low gradient, protected mud flats with eelgrass beds (usually a semi-enclosed embayment). It was not always possible to select sampling sites which conformed precisely with these definitions and some degree of compromise was necessary when the sites were chosen.

Study Sites

The study sites representing the five habitats (Fig. 1) were located in two regions. An "experimental" region subject to chronic pollution from existing oil refineries and potentially subject to acute oil pollution from oil loading and transportation mishaps was located along the eastern margin of north Puget Sound. A "control" region felt to be reasonably free from either present or future oil pollution was located along the western margin of the San Juan archipelago. Originally, 12 study sites were sampled in the experimental region and five in the control region in 1974-75; however, our sampling design for 1975-76 reduced the number of sites in the experimental region to eight while the five sites in the San Juan Island area were retained.

The distribution of study sites, by representative habitat, and the associated sampling techniques and sampling frequencies are described in Table 1.

The ichthyoplankton survey was designed to be coordinated with the nearshore townet sampling program. All the townet sites were initially sampled with surface ichthyoplankton hauls. After the first three months' of sampling, it was decided to reduce the field sampling plan in an attempt to sample more consistently and effectively within the limited boat-charter time. Eight of the 11 townet sites were incorporated in

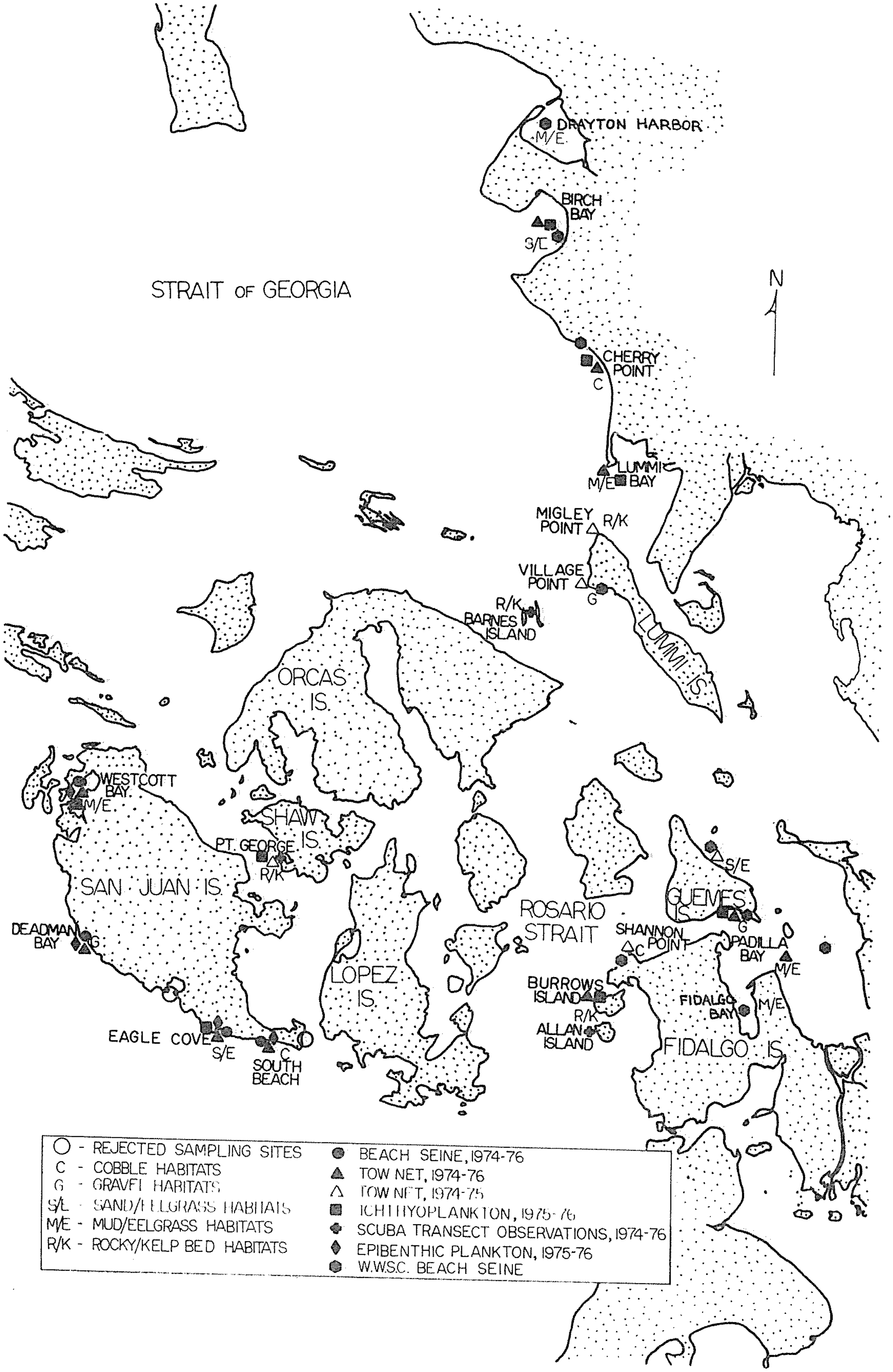


Fig. 1. Nearshore fish survey sampling sites in north Puget Sound, 1974-76.

Table 1. Nearshore Fish Survey Study sites, habitats, and sampling method and frequency 1974-76. M=monthly, B=bimonthly, Q=quarterly (seasonally), F=fall, W=winter, Sp=spring, S=summer. Refer to Fig. 1 for geographic location of sites

		1974-75				1975-76				
Habitat	Study site	Beach seine	Townet	Scuba transect observations	Trammel net	Beach seine	Townet	Scuba transect observations	Ichthyoplankton	Epibenthic plankton
Rocky/kelp bed, exposed	Pt. George, Shaw Island		M(Sp&S) B(F&W)	M			M(W&S) Q(S&F)	M(Sp&S) Q(F&W)	M(W-S)	
	Collins Cove San Juan Island				Q					
	Migley Pt., Lummi Island		M(Sp&S) B(F&W)		Q					
	Barnes Island			Q				Q		
	Burrows Island		M(Sp&S) B(F&W)				M(W&S) Q(S&F)		M(W-S)	
	Allan Island			M				Q		
Cobble, exposed	South Beach, San Juan Island	M	M(Sp&S) B(F&W)			B	M(W&S) Q(S&F)			Q
	Cherry Pt.		M(Sp&S) B(F&W)				M(W&S) Q(S&F)		M(W-S)	
	Shannon Pt. Fidalgo Island		M(Sp&S) B(F&W)							
Gravel, semi-exposed	Deadman Bay San Juan Island	M	M(Sp&S) B(F&W)			B	M(W&S) Q(S&F)			Q
	Village Pt., Lummi Island		M(SP&S) B(F&W)							
	Guemes Island, South side		M(Sp&S) B(F&W)				M(W&S) Q(S&F)		M(W-S)	
Sand/Eelgrass, protected	Eagle Cove, San Juan Island	M	M(SP&S) B(F&W)			B	M(W&S) Q(S&F)		M(W-S)	Q
	Birch Bay		M(SP&S) B(F&W)				M(W&S) Q(S&F)		M(W-S)	
	Guemes Island, East side		M(Sp&S) B(F&W)							
Mud/Eelgrass, protected	Westcott Bay San Juan Island	M	M(Sp&S) B(F&W)			B	M(W&S) Q(S&F)		M(W-S)	Q
	Lummi Bay		M(Sp&S) B(F&W)				M(W&S) Q(S&F)		M(W-S)	
	Padilla Bay		M(Sp&S) B(F&W)				M(W&S) Q(S&F)			

the new sampling design. All eight of these sites were sampled with surface ichthyoplankton tows and five of the same sites were also sampled with oblique ichthyoplankton hauls:

Birch Bay	surface	
Cherry Point	surface	oblique
Lummi Bay (Sandy Point)	surface	oblique
Guemes South	surface	oblique
Burrows Island	surface	
Westcott Bay	surface	
Eagle Cove	surface	oblique
Point George	surface	oblique

Sampling Methods

Beach Seine

Two 37-m (120-foot) beach seine nets equipped with 18 m (59 feet) long, 3-mm (1 1/8-inch) mesh wings, and a 0.6-m x 2.4-m x 2.3-m bag of 6-mm (1/4-inch) mesh (Appendix 1-A), were used to sample fishes in the nearshore waters of the cobble, gravel, sand/eelgrass, and mud/eelgrass type-habitat study sites on San Juan Island. One net was buoyant and swept the surface water layer over the nearshore region; the other, converted to a sinking net with the removal of several snap-on floats, sampled the bottom area. A modification was made to the nets prior to the 1975-76 sampling period. Substitution of the 113.4-g roller leads located at every second hanging of the lead line with 37 m of lead core line (of equivalent total weight) decreased the tendency of the beach seine to roll up when hauled through eelgrass and thus reduced the number of unsuccessful hauls.

A net was set 30 m out from the beach from the stern of a boat rowed parallel to shore and was retrieved to the beach by hand at approximately 10 m/minute. The lines attached to the poles at the end of each wing were initially hauled from positions 40 m apart until 20 m of line had been retrieved; the net was then closed down to a 12-m opening and the net retrieval completed. A conscious effort was made during the retrieval to keep the lead line portion of the wings in contact with the bottom at all times. Direct SCUBA observation confirmed that the nets were fishing properly. Once the net was completely retrieved to the beach, the collected fish were "worked" from the wings into the bag section of the net and the catch collected, labeled, and placed in plastic bags for later processing.

In the sand/eelgrass and mud/eelgrass habitats, only the sinking net was used because in these shallow areas the cork line (top margin of net) did not sink below the water's surface.

Both net samples were obtained in two replicate hauls during the lowest slack ebb tide period of each month. This involved nighttime samples from September to March, and daytime samples during the rest of the year. Typically, in the deeper water habitats, the first floating seine sample was made just before ebb slack, the two sinking seine replicates at the time of slack tide, and then the second replicate floating seine sample was obtained as the flood tide began. Usually, except in cases of low catches, at least 30 minutes elapsed between consecutive samples. At sites with sufficient beach area, the second haul was not fished over the same area as the first haul.

Townet

A townet is a large net towed at a relatively high speed along the surface of the water between two boats. The townet used in this study was 3 m x 6 m (10 x 20 feet), with mesh sizes grading from 76 mm (3 inches) at the opening to 6 mm (1/4 inch) at the bag (Appendix 1-B). The net was towed at 800 rpm (about 3.7 km/hour) between the 12-m (39-foot) FRI research vessel MALKA and a 2.8-m (12-foot) purse seine skiff. Two 10-minute tows were made at each of our sites. One tow was made with the prevailing tidal current along the shoreline, and the other tow was made in the opposite direction.

Sampling was conducted at night in order to minimize net avoidance by the larger pelagic species and to optimize sampling of pelagic species which migrate into nearshore surface waters after sunset. Whenever possible, sampling was carried out during periods of minimal tidal fluctuation and moonlight to minimize the effect of these variables.

The net was towed as close to the shoreline as possible. Often it was not possible to follow a consistent transect (i.e., same depth, distance from shore, and length) each month at each site because conditions such as tide, flotsam, and weather during sampling periods varied from month to month.

At the completion of each tow, the net was hauled onto the deck of the MALKA and the contents emptied into a bucket. Most catches were completely preserved in 10 percent formalin. Large catches were subsampled after being carefully sorted for the less common species. Subsampling was volumetric and the proportion subsampled was dependent on the magnitude of the catch. Intact stomachs were removed from selected samples of the more economically and ecologically important species of fish and preserved in 10 percent formalin. All samples were transported to Seattle for further processing.

SCUBA Transect Observations

Diving transects have been used increasingly to assess fish populations in areas which are difficult to sample with more traditional sampling methods. The use of SCUBA equipment for surveying fish populations was originally proposed by Brock (1954) and further evaluated by Bardach (1959). More recent studies include those by Quast (1968*a*, *b*), Burge and Schultz (1973) and Miller and Geibel (1973). Improvements were made in the methodology in order to more effectively meet the objectives of the present study. These improvements included: 1) The use of zigzag transects for a complete coverage of the 0- to 15-m depth range; 2) a measurement of horizontal visibility to more accurately determine the area surveyed; 3) the use of installed transect lines or marker floats released at transect leg corners to allow more bottom time for searching; and 4) a longer transect (250 m) to minimize the effect of patchiness in fish distribution.

Quantitative observations were made in rocky/kelp bed habitats by SCUBA-equipped divers swimming along zigzag transects. Two divers swam across shoreline depth contours at approximately a 45-degree angle to a depth of 15 m (Fig. 2), turned 90 degrees, and swam back up to the shoreline, repeating until approximately 250 m were surveyed.

It was necessary to make all dives on slack tides because of strong tidal currents in all study areas. A few dives were attempted between tidal exchanges, but the currents made it impossible to maintain position on the transect line or record data.

Two techniques were used for determining the exact distance of transects. Permanent measured transects were placed at Allan Island and Point George. Initially, these were 6 mm diameter, yellow polypropylene lines anchored with rock-climbing pitons; these were later changed to stainless steel cable when it was found that currents frayed the polypropylene line. Prior to placing the permanent transects, and for all dives at Barnes Island, temporary transects were used in which compass courses were followed. At the end of each transect leg an anchored marker was released for later surface measurement of the actual transect distance.

Data recorded for each fish sighted were fish species, fish length and/or weight, depth of sighting, time, and transect leg. Usually lengths were estimated for small fish and weights were estimated for larger fish. Sex was noted when obvious (e.g., sexually dimorphic species, obviously ripe females, male lingcod guarding nests). Horizontal visibility and temperature were measured at a depth of 7.5 m on the first transect leg by one diver holding the end of a measuring line and the recording board (30 x 35 cm white acrylic) against his chest, moving backward slowly until the other diver could no longer see the board. The point at which the board disappeared was recorded to the nearest 0.25 m. Since visibility of a white board is greater than the visibility of fishes, which are mostly dark-colored, "effective visibility" was defined as one-half the total visibility. This visibility correction seemed to be valid for most larger species but biased against smaller fishes. The smaller fishes were often seen only when in the immediate path of the diver, a path approximately 1.5 to 2 m wide. Since the two divers usually swam side by side, the width of the path surveyed for

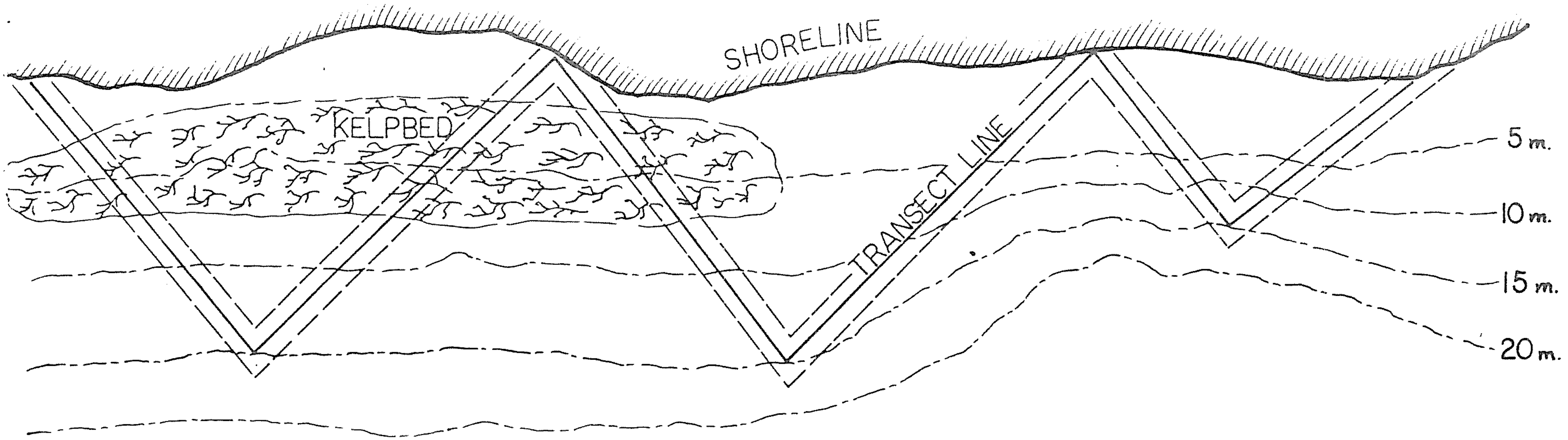


Fig. 2. Diagrammatic sketch of diving transects in rocky/kelp bed habitats. Width of transect determined by visibility of the water (not to scale).

smaller fish was approximately 3-4 m. This fact has not been corrected for in the calculations as no measurements were made to arrive at an accurate estimate of the path width for small fish. The only species affected by this correction in the present study would be the longfin sculpin as it was the only small species which occurred in large enough numbers to make density estimates.

Trammel Net

A trammel net is a vertically oriented setnet with a loosely hung small-mesh net panel between two tightly hung large-mesh panels. Fish encountering the net along the bottom continue through the large-mesh panel, forming a bag in the small-mesh netting. The trammel net used was a 45.7-m x 1.8-m (150- x 6-foot) net with two 51-cm (20-inch) large-mesh panels and a 5-cm (2-inch) small-mesh panel (Appendix 1-C). Two trammel nets were set parallel to each other and perpendicular to rocky/kelp bed habitats from dusk until daylight, at which time the fish were removed for later processing.

Problems were often encountered with the use of trammel nets primarily because the nets did not work effectively in areas of high current, a phenomenon common to the rocky/kelp bed habitats. The current would collapse the net, causing the mesh to entangle with rocks and with sea urchins. The rocky substrate also tore many holes in the net, leading to an inefficient set and time-consuming repairs. Retrieval of the net was difficult if not performed during slack time.

Bongo Net

A review of the literature and personal communication with several workers in the field indicated that a standardized sampling gear, the 60-cm bongo net, had been widely adopted for ichthyoplankton surveys. A standard aluminum bongo net frame was obtained and equipped with Nitex nets of 0.505-mm and 0.333-mm mesh having an open area to aspect ratio of 8:1. General Oceanics flowmeters were used to determine volume of water filtered by each haul and a BKG was used to determine the path of the gear during oblique hauls. All sampling was carried out from the research vessel MALKA.

The gear was attached to a steel cable which fed from the winch mounted on the boom of the vessel and passed through a meter wheel at the tip of the boom. The boom was lowered until it was parallel to the deck and located diagonally to the starboard side of the stern of the vessel.

Surface sampling was carried out by bringing the boat close to the shore and then turning perpendicular to the beach. Engine speed was set at 600 rpm and the gear was lowered to just below the surface. Tow duration varied from 3 to 10 minutes, depending upon net clogging observed in previous hauls and rate of depth dropoff.

At the completion of the tow, the gear was hauled from the water and carefully hosed down to concentrate organisms in the cod end buckets of the nets and prevent subsequent contamination. The contents of the cod end buckets were then transferred to 946-ml (32-ounce) sample jars and preserved with five percent buffered formalin. Flowmeter readings were recorded before and after each haul.

Oblique hauls were carried out upon completion of surface hauls. At the completion of the surface haul, the vessel was steered toward the shore at 600 rpm. The gear was released and 27.5 meters of wire was paid out quickly from the winch before being stopped (approximate depth, 15 m) and recovered at constant speed. Upon recovery the gear was cleaned and the sample processed in the same manner as the surface samples. Wire angle and amount of wire out were recorded at 15-second intervals during the haul and BKG traces were frequently made.

In the laboratory all samples were sorted under an illuminated magnifier and fish eggs and larvae were removed and placed in 4-ml vials with five percent buffered formalin. When this sorting was completed, the process of identification was begun. Eggs and larvae were identified and sorted into groups with a taxonomic resolution dependent upon sample condition, experience of laboratory personnel, and availability of taxonomic information.

Fieldwork began in late December 1975 and was continued through August 1976. After three months of sampling, during severe weather, in 1976 (February, March, and April), it was decided to reduce the number of sites sampled in an attempt to collect data consistently under the constraint of limited sea time.

The modified field sampling plan adopted in May 1976 was to sample eight stations in northern Puget Sound with surface hauls, and to carry out oblique hauls at five of the eight stations. This sampling plan was carried out during May, June, and August. The sampling plan was compromised on occasion as a result of weather conditions and the limited number of boat-charter days.

Epibenthic Plankton Pump

Many of the important prey of nearshore fishes are epibenthic organisms, i.e., those that live associated with, but not necessarily attached to or within, the bottom sediment. Unfortunately, they cannot be effectively sampled with the more traditional sampling techniques such as plankton net tows or with intertidal transect cores or quadrat sampling. In order to evaluate better these prey resources, we instituted preliminary epibenthic sampling using a suction pump plankton sampler (Fig. 3). The pump system consisted of a self-priming gasoline-powered 5.1-cm (2-inch) centrifugal pump which draws water and associated planktors in through a 25.4-cm (10-inch) conical expander into a 5.1-cm flexible plastic hose. Once through the pump, the water sample passes through a sealed-register, totalizing flowmeter into a double stainless

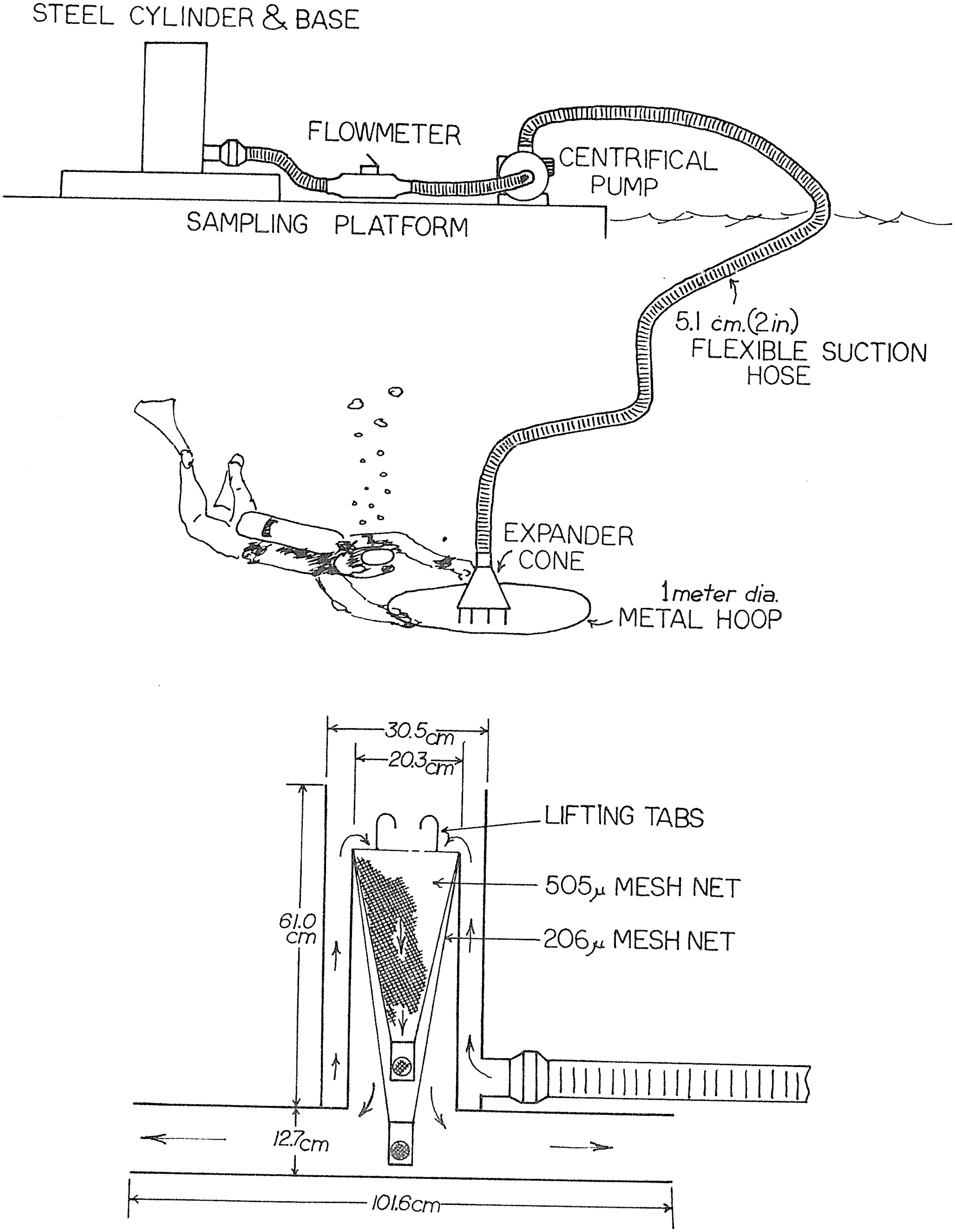


Figure 3. Overall system design and construction detail of epibenthic pump sampling system.

steel cylinder in which two nested conical nets were suspended. The nets were of 0.505-mm and 0.209-mm mesh sizes with open area to aspect rations of 1:2.54 and 1:5.3, respectively. The epibenthic organisms were retained in standard net buckets with window screen of appropriate mesh size.

The design of the epibenthic pump sampling was to filter a given volume of water over a standardized bottom surface area in the sublittoral region. In order to provide optimal correlation with the fish stomach contents data, the sampling sites chosen were the four beach seine sites on the west side of San Juan Island (Fig. 1). The general area involved in the epibenthic plankton sampling was thus approximately the same from which fish were procured for stomach samples. Epibenthic plankton sampling was also performed during a low tide series in order to correspond closely with the beach seine sampling design.

Pumping equipment was installed aboard a 9.1-m (26-foot) whaleboat. At the sampling site the boat was maneuvered within about 15 m of the beach and anchored. SCUBA-equipped divers then proceeded to place, at random, a 1-meter diameter metal hoop on the bottom. The pump was started and the suction hose end was passed to the divers who moved to the chosen sampling location. Upon a signal from the boat the diver located at the surface signaled the diver with the suction end on the bottom to begin sampling. He then began to move the expander cone about 10 cm above the bottom within the sampling hoop, "vacuuming" the epibenthic region. Four projecting bolts on the expander were used to stir the surface layer of the bottom. If, in this process a sediment cloud formed, the diver lifted the expander to sample the less dense perimeter of the cloud in order to prevent clogging of the filtering nets.

Several seconds after the diver had initiated the suction sampling, personnel aboard the whaleboat placed the two nested nets into place within the steel cylinder. This lag time ensures that water and organisms in the system at the starting time had passed through before the nets were in place and filtering. Three-hundred and seventy-eight liters (100 gallons) were pumped through this filtration system before the nets were removed and the divers signalled to halt sampling. Organisms were removed from the plankton net cups and preserved in five percent buffered formalin in labeled 946-ml (32-ounce) PVC jars. The sampling process was repeated for two replicates per study site.

In the laboratory the plankton samples were transferred to 70 percent isopropyl alcohol and stained with rose bengal dye, stirred, and allowed to sit for at least a week so that organisms would be completely stained. The organisms were then separated from the sediment and detritus in the sample, sorted to the lowest taxonomic level possible without extensive dissection (usually suborder or family), and total counts and weights (to nearest 0.01 g) obtained for each taxon.

Collection Information

Standardized collection, oceanographic, and other pertinent environmental information was recorded on computer-format forms (Appendix 2-A) for all sampling operations at the time of sampling. For each collection sample, these data included identification number, location, date, time, latitude and longitude, habitat and bottom type, depth of collection and bottom depth during collection, weather, and oceanographic conditions. Water depth was determined by direct measurement in shallow water and by fathometer recordings in deeper water.

Water samples were routinely collected from -1 m depth (except during SCUBA transect observations, which were at -7.5 m depth) using a hand-triggered Van Dorn water bottle. During beach seine, SCUBA transect observation, trammel net, and epibenthic plankton sampling, water temperature (°C) was determined from a thermometer and water sample retained in a magnesia bottle for salinity determination ($^{o}/_{oo}$) by the potentiometric method. During townet sampling, a Beckman temperature-salinity probe (RS5-3) was used to determine temperature and salinity at -1 m depth. For all sampling methods, water was retained in a dissolved oxygen bottle and immediately fixed according to the azide modification of the Winkler method. These samples were kept cool until titrated in the laboratory and the percentage oxygen supersaturation determined according to:

$$\text{Saturation level in mg/l} = \frac{475 - (2.65 \times \text{salinity in } ^{o}/_{oo})}{\text{Temperature } (^{o}\text{C}) + 33.5^{o}\text{C}}$$

$$\text{Percent saturation} = 100 \times \frac{\text{D.O. level in mg/l (titrated value)}}{\text{Calculated saturation level (mg/l)}}$$

Supplemental information, such as phase of moon, degree of bioluminescence, and sampling gear performance were also recorded at the time of sampling.

Biological Information

The catch obtained from each sample was bagged and labeled in its entirety for later processing. If the catch was excessively large, it was subsampled (see following section describing subsampling) and the numbers and total catch weight estimated from the proportional subsample. This applied to an excessively large catch of one species as well as the total catch. In the former instance, however, we attempted to remove all the other less abundant species from the catch before subsampling. Bagged samples from beach seine collections were refrigerated until processing could take place, approximately one-half hour to eight hours later, except for fish which were designated for stomach contents analysis, which were processed and preserved in 10 percent buffered formalin as soon as practical. Townet collections were retained in toto, or as a subsample of a large catch, and preserved in 10 percent buffered formalin. On occasion some processing of extremely large specimens was carried out in the field.

In the laboratory each sample of fish was sorted according to species and life history stage (larval, juvenile, adult), enumerated, and weighed as a total. For individual specimens, total length in millimeters, wet weight in grams to the learest 0.1 g (if greater than 0.1 g), and life history stage were recorded for all individuals of each species and life history stage or for a subsample. Where appropriate and possible, sex, age, maturity, evidence of external disease or parasites, and fin condition were also recorded.

At this time, whole specimens of species dominating in the catch were preserved for later stomach removal and analysis of the stomach contents. In the case of large specimens, the stomach was removed and preserved in 10 percent buffered formalin. In both cases, the specimen was tagged with a label giving the sample source and an individual specimen number.

All catch summary and fish examination data were recorded on computer coding forms (Appendices 2-B and 2-C). The principal taxonomic source for fish identification of nearshore fishes was Hart (1973).

Stomach Analyses

Whole fish specimens or intact stomach samples from selected samples of economically or ecologically important fishes were returned to the laboratory for detailed stomach analysis. Each specimen was identified according to the collection number, date of collection, and the individual specimen number.

Every stomach was examined according to a systematic standard procedure (Miller et al. 1976; Terry, in press) which describes the numerical and gravimetric composition of prey organisms contained in the stomach, the stage of digestion of the contents, and the degree of stomach fullness.

Prey identification was made to the lowest taxonomic level possible depending on the stage of digestion and the ability to identify the organism under a binocular microscope. At that time no attempt was made to further identify an organism which required dissection, mounting, staining, high magnification or other time-consuming techniques. The prey organisms were retained, however, for further identification and measurement should this become desirable in the future.

All stomach analysis data were recorded on special computer coding forms, with prey organisms assigned codes corresponding to the various phylogenetic levels identified (Appendices 2-D and 2-E).

Subsampling Procedures

Our sampling methods were designed to avoid subsampling, but there were occasions when catches were too excessive to be processed within the available time. In those cases an attempt was made to thoroughly mix the catch, and successive scoops (using a balance pan or similar container) were removed; every tenth scoop was retained to make a combined subsample of approximately 10 percent of the total. The total catch was then estimated from the subsample proportion of each species, each life history stage count, and weights. When an excessively large catch of one species was subsampled, a minimum of 50 (25 from each haul) of each life history stage was taken in a random manner. Any three data of: (1) total count, (2) total weight, (3) subsample count, and (4) subsample weight allowed the proportional estimation of the total number and biomass.

Sources of Sampling Error

The selection of any specific sampling technique or design is accompanied by biases which must be assumed to influence the collected data. This was especially true for certain aspects of our program where a variety of sampling techniques was used to try to assemble similar, comparable information. Each technique possessed a degree of selectivity for and against certain types of fish and by our chosen pattern of sampling we have often selected for and against dissimilar groups of fishes. For example, some of the characteristics of the sampling gear which influenced its selectivity included shape, mesh size, type of net material, and fishing configuration. Some fish characteristics which vary include shape, size, swimming behavior, and ability to perceive and avoid the gear. Selectivity was also an inherent aspect of sampling time and duration, since tidal stage, diel period, sun (or moon) light intensity and degree of bioluminescence are known to influence fish availability and catchability. Also, such variable environmental conditions as turbidity of water, bottom conditions, bioluminescence, and intensity and direction of current influenced effectiveness of the sampling techniques.

These potential biases are discussed in the appropriate sections later in the report.

Statistics

The Shannon-Wiener information statistic,

$$H' = -\Sigma \, Pi \log_2 Pi$$

where Pi is the proportion of the i^{th} species in the collection, was computed as an estimate of "species diversity" and, using the distribution of biomass among the species, to estimate the more trophically functional "biomass diversity" as suggested by Wihlm (1968).

H' incorporates both the number of species present and the evenness of distribution of individuals among those species; H' is relatively insensitive to sample size. H' is an appropriate measure of diversity if the collection can be considered a random sample of a very large population and includes all species found in the population (Pielou 1966*a*, *b*). In our case, H' was computed on the mean ot two beach seine hauls; two hauls were considered sufficient to catch essentially all of the species present, as suggested by DeLacy and English (1954). "Population" as defined for beach seine collections includes those fish subject to being captured by our beach seine within the standardized area and time criteria, i.e., within 30-40 m of the 0.0 tide line on the lowest tide series of the month, in the four habitat types. A slight bias was introduced because several beaches had configurations which prevented truly random sampling of the population.

A modification of the "Index of Relative Importance" (IRI) used in ranking prey organisms (Pinkas et al. 1971) has been utilized for describing a species' food habits, graphically, where sample sizes warrant it. Used in graphical form, the IRI diagram illustrates frequency of occurrence (that proportion of stomachs containing a specific prey organism) plotted on a horizontal axis and percentage of total abundance and percentage of total biomass plotted for each prey above and below the horizontal axis, respectively (e.g., Fig. 33, page 1). The prey have been arranged from left to right by decreasing frequency of occurrence. Prey organisms less than 5 percent frequency of occurrence or 1 percent of total abundance or biomass were not graphed. In all graphs, one division equals 10 percent. Prey taxa of differing stages of digestion (e.g., partly digested shrimp, "Natantia," as opposed to family "Pandalidae," or species, "*Pandalus borealis*," were graphed separately.

The numerical IRI value was computed as follows,

$$\text{IRI} = \text{percent frequency of occurrence}_i\ [\text{percent numerical composition}_i + \text{percent gravimetric composition}_i];$$

and is equivalent to the area encompassed by the bar for each prey category i composing the IRI diagrams. In order to normalize the IRI values when comparing stomach contents from unequal sample sizes, the overall contribution of each prey taxa has been discussed as a percentage of the total IRI (area) for the overall sample.

The IRI values represent a single, composite index of prey importance incorporating: 1) the frequency (percent) of occurrence; 2) the numerical percentage composition; and 3) the percentage composition by biomass for each prey taxa in a predator's prey spectrum.

Analysis Methods

Data recorded on coding forms were proofed, keypunched, and verified on 80-column computer cards. The accumulated data base was stored on magnetic tape and organized into a customized data manipulation and processing system called SSRP which facilitated: 1) screening of the data for unacceptable variable values; 2) sorting of fish data according to temporal, physical, or chemical variables associated with their collection; 3) retrieval of data subsets associated with a particular species, life history stage, or other fish characteristic; 4) interfacing of these data subsets with special processing programs providing statistical summarization; and 5) input of the summary values into programmed plotting routines or other available software for further statistical treatment (Simenstad and Gales, in press).

RESULTS AND DISCUSSION

Nearshore Demersal Fishes (Beach Seine): Results

Raw catch data are contained in a separate, accompanying data report (Miller et al. 1977).

Environmental Conditions

Physical-chemical conditions of surface water (0 to 1 m) show generally similar trends at all San Juan Island beach seine sites (Fig. 4). The protected mud/eelgrass site (Westcott Bay) exhibited more extreme local variations in environmental conditions than did the other, more exposed sites where there was more thorough mixing with offshore waters.

Trends in temperature at all beach seine sites were similar, with maximum temperatures occurring in midsummer and minima occurring in January-February (Fig. 4-A). The protected mud/eelgrass site exhibited maximum variation in temperature, ranging from 4.3°C in January 1975 to 17.5°C in August 1975. The more exposed beach seine sites exhibited a general 6°C annual fluctuation in surface temperatures. There was generally little variation in temperature trends between the two sampling years except for the December 1975 values in the gravel (Deadman Bay) and mud/eelgrass (Westcott Bay) habitats.

Salinities at the cobble and sand/eelgrass habitats were relatively constant, generally ranging from 29 $^{\circ}/_{\circ\circ}$ to 31 $^{\circ}/_{\circ\circ}$, with a slight depression in the winter (Fig. 4-B). Salinities at the gravel and mud/eelgrass sites fluctuated more widely, with large depressions occurring in the winter.

Dissolved oxygen values indicated generally well-saturated waters at all beach seine sites and showed similar seasonal trends at all

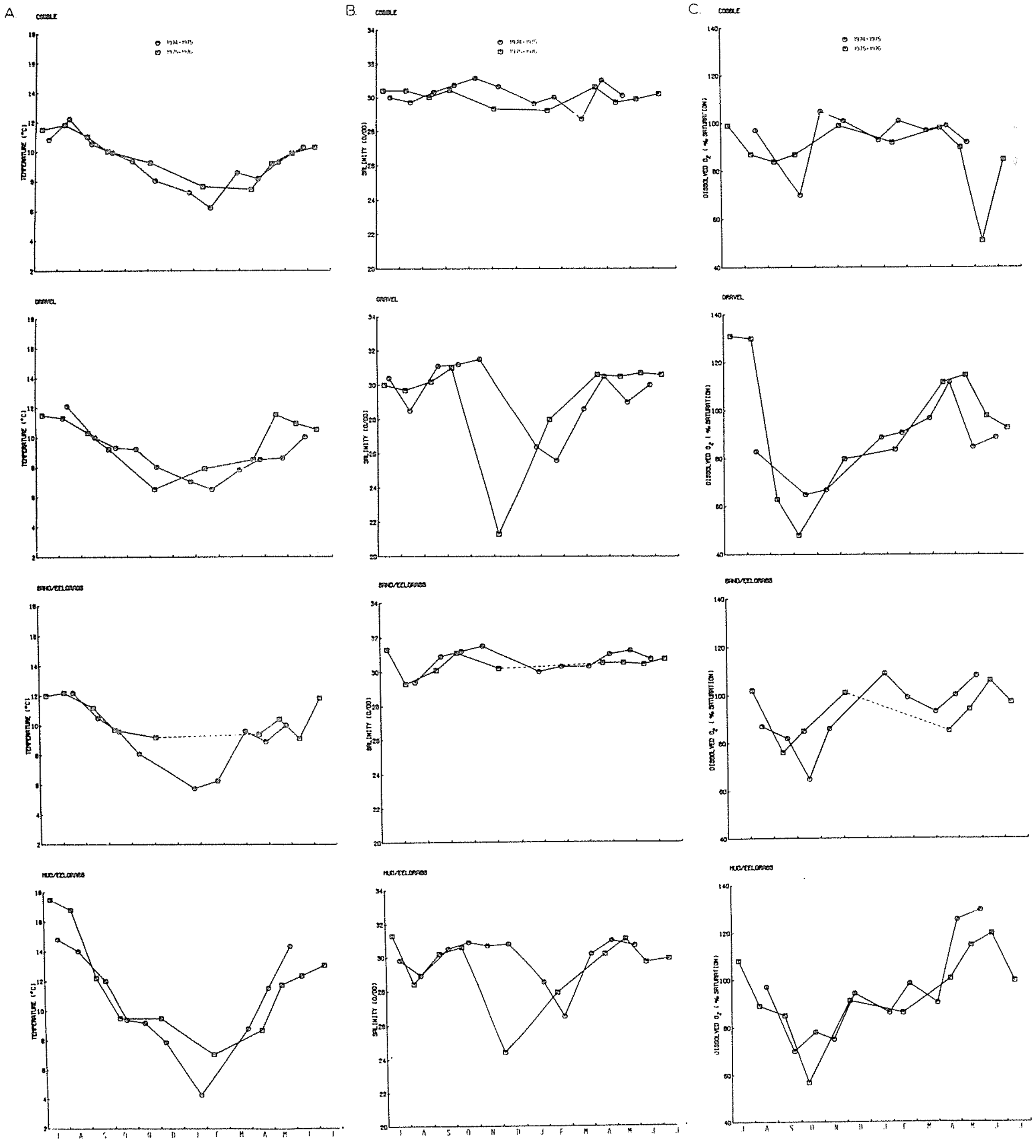


Fig. 4. Physiochemical conditions at north Puget Sound beach seine sites, 1974-1976.

sites, with low values occurring in the fall and then increasing through winter, spring, and summer (Fig. 4-C).

Species Occurrence

In the San Juan Island area, a total of 84 identified nearshore demersal species was captured during the two-year course of the survey, 75 species in 1974-75 and 73 species in 1975-76, with an additional three to four unverified species (Table 2). These species comprised a combined total catch of 85,855 fish, weighing 632 kg. Twenty-three species comprised the ten most common species when ranked according to frequency of occurrence, total abundance, and total biomass in the two years (Table 3). The consistently dominant species from 1974-76 were English sole (juveniles), Pacific staghorn sculpin, and surf smelt by frequency of occurrence; Pacific herring (juveniles), shiner perch, and Pacific sand lance by total abundance; and Pacific herring (juveniles), shiner perch, and Pacific staghorn sculpin by total biomass.

Species richness, the number of species per beach seine collection, was plotted against month (Fig. 5). In the sinking beach seine collections (Fig. 5-A), the gravel habitat had the greatest species richness, followed by the mud/eelgrass and sand/eelgrass habitats. The cobble habitat generally displayed the least number of species. Floating beach seine samples in the gravel and cobble habitats (Fig. 5-B) had fewer species than the sinking beach seines in those habitats and showed more seasonal and annual variability, presumably due to the periodic influx of neritic species.

Seasonal patterns of species richness showed little variation between the two years, and ranged from a maximum of 23 species to a minimum of 0 for two replicate hauls. The coefficient of variation, defined as $(s \sqrt{\frac{}{x}}) \cdot 100$ percent, where s is the standard deviation and $\bar{x}$ is the mean of collections of the same month between the two years sampled, provides an estimate of the variability between years. The monthly coefficient of variation for species richness between the two years was relatively low, usually below 50 percent (Fig. 6-A). The two years sampled showed the greatest similarity in number of species present during the spring when species richness was lowest in all habitats. Floating beach seines (Fig. 6-B) generally had higher coefficients of variation than sinking beach seines.

In the cobble habitat, maximum numbers of species in the sinking beach seine occurred in early summer (June-July) and fall (September-October), with numbers declining through the winter until very few or no species were present in March and April. This habitat is the only one of the four sampled to show an absence of fish at any time. Species richness of the floating beach seine collections in the cobble habitat showed the same general pattern, but with greater variability. In the gravel habitat, species richness was higher in all seasons and was generally less variable. Maximum numbers of species were again seen in the fall and declined through the winter to reach a minimum in March and

Table 2a. Species of nearshore demersal fishes captured in the first year, July 1974 through June 1975

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Squalus acanthias	spiny dogfish	2	4	23,850.0
Raja binoculata	big skate	3	3	207.8
Hydrolagus colliei	ratfish	7	31	15,740.4
Clupea harengus pallasi	Pacific herring	50	23,054	86,824.8
Oncorhynchus gorbuscha	pink salmon	2	2	8.3
O. keta	chum salmon	16	1,151	1,833.0
O. kisutch	coho salmon	14	194	9,281.5
Salmo clarki	cutthroat trout	1	1	380.0
Hypomesus pretiosus	surf smelt	56	1,453	34,420.9
Mallotus villosus	capelin	4	29	143.5
Gobiesox maeandricus	northern clingfish	4	4	12.3
Gadus macrocephalus	Pacific cod	2	5	8.0
Microgadus proximus	Pacific tomcod	39	504	2,706.5
Theragra chalcogramma	walleye pollock	17	41	886.1
Lycodes brevipes	shortfin eelpout	2	2	1.4
L. palearis	wattled eelpout	4	9	137.3
Lycodopsis pacifica	blackbelly eelpout	2	2	0.3
Aulorhynchus flavidus	tubesnout	44	2,059	7,049.8
Gasterosteus aculeatus	threespine stickleback	35	110	156.5
Syngnathus griseolineatus	bay pipefish	16	42	30.9
Brachyistius frenatus	kelp perch	2	2	48.4
Cymatogaster aggregata	shiner perch	52	3,024	39,214.0
Embiotoca lateralis	striped seaperch	1	4	1,890.0
Rhacochilus vacca	pile perch	7	16	2,307.0
Trichodon trichodon	Pacific sandfish	5	9	6.7
Anoplarchus purpurescens	high cockscomb	2	2	3.2
Lumpenus sagitta	snake prickleback	16	436	1,098.3
Phytichthys chirus	ribbon prickleback	1	1	--
Apodichthys flavidus	penpoint gunnel	19	94	2,330.8
Pholis laeta	crescent gunnel	17	58	320.9
P. ornata	saddleback gunnel	17	23	120.1
Ammodytes hexapterus	Pacific sand lance	27	3,466	23,831.8
Clevelandia ios	arrow goby	1	1	0.3

Table 2a. Species of nearshore demersal fishes captured in the first year, July 1974 through June 1975 - Continued

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Lepidogobius lepidus	bay goby	1	1	11.4
Sebastes auriculatus	brown rockfish	1	4	235.5
S. caurinus	copper rockfish	36	202	9,764.1
S. flavidus	yellowtail rockfish	1	3	142.0
S. maliger	quillback rockfish	1	1	338.0
S. melanops	black rockfish	5	48	6,173.0
Hexagrammos decagrammus	kelp greenling	16	35	20,814.9
H. stelleri	whitespotted greenling	15	25	2,539.2
Ophiodon elongatus	lingcod	1	1	939.6
Artedius fenestralis	padded sculpin	43	321	1,090.6
A. harringtoni	scalyhead sculpin	4	4	5.6
A. lateralis	smoothhead sculpin	12	33	189.9
Ascelichthys rhodorus	rosylip sculpin	10	19	21.2
Blepsias cirrhosus	silverspotted sculpin	34	216	1,210.9
Clinocottus acuticeps	sharpnose sculpin	34	161	150.4
Enophrys bison	buffalo sculpin	44	218	1,311.7
Hemilepidotus hemilepidotus	red Irish lord	4	6	3,037.8
Leptocottus armatus	Pacific staghorn sculpin	56	2,900	30,766.5
Myoxocephalus polyacanthocephalus	great sculpin	15	33	1,653.3
Nautichthys oculofasciatus	sailfin sculpin	2	2	2.0
Oligocottus maculosus	tidepool sculpin	35	787	988.9
Psychrolutes paradoxus	tadpole sculpin	8	8	9.5
Rhamphocottus richardsoni	grunt sculpin	1	1	2.0
Scorpaenichthys marmoratus	cabezon	7	11	137.7
Synchirus gilli	manacled sculpin	5	13	12.8
Agonus acipenserinus	sturgeon poacher	23	67	185.0
Pallasina barbata	tubenose poacher	17	42	26.2
Eumicrotremus orbis	Pacific spiny lumpsucker	21	66	305.2
Liparis callyodon	spotted snailfish	14	42	83.8
L. cyclopus	ribbon snailfish	2	2	28.4
L. florae	tidepool snailfish	8	11	119.5
L. mucosus	slimy sculpin	1	1	37.0
L. pulchellus	showy snailfish	2	2	15.8
L. rutteri	ringtail snailfish	9	14	27.5
Nectoliparis pelagicus	snailfish	1	1	0.1
Citharichthys stigmaeus	speckled sanddab	3	6	256.6

Table 2a. Species of nearshore demersal fishes captured in the first year, July 1974 through June 1975, continued

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Isopsetta isolepis	butter sole	1	1	4.7
Lepidopsetta bilineata	rock sole	12	20	4,876.6
Parophrys vetulus	English sole	61	1,218	9,478.1
Platichthys stellatus	starry flounder	40	174	24,541.4
Pleuronichthys coenosus	C-O sole	6	7	1,147.4
Psettichthys melanostictus	sand sole	20	70	478.5
Pholidae	gunnel	1	1	--
Scorpaenidae	rockfish	1	4	0.4
Sebastes sp.	rockfish	2	4	0.3
Cottidae	sculpin	1	1	0.1
Liparis sp.	snailfish	1	1	14.3
Total 75 species		1,125	42,644	378,026.2

Table 2b. Species of nearshore demersal fishes captured in the second year, July 1975 through July 1976

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Squalus acanthias	spiny dogfish	2	3	11,685.0
Raja binoculata	big skate	3	3	430.2
Hydrolagus colliei	ratfish	4	16	7,190.0
Clupea harengus pallasi	Pacific herring	36	22,944	88,931.0
Engraulis mordax	northern anchovy	1	1	17.0
Oncorhynchus gorbuscha	pink salmon	6	545	1,530.1
O. keta	chum salmon	4	16	98.8
O. kisutch	coho salmon	4	12	723.4
O. tshawytscha	chinook salmon	2	2	4,790.0
Hypomesus pretiosus	surf smelt	34	209	2,240.2
Mallotus villosus	capelin	1	1	14.0
Gobiesox maeandricus	northern clingfish	5	7	9.9
Gadus macrocephalus	Pacific cod	3	7	8.1
Merluccius productus	Pacific hake	1	6	4.3
Microgadus proximus	Pacific tomcod	22	976	3,382.9
Theragra chalcogramma	walleye pollock	33	473	2,733.6
Lycodes brevipes	shortfin eelpout	2	3	27.6
L. palearis	wattled eelpout	1	1	43.7
Aulorhynchus flavidus	tubesnout	22	3,027	14,398.5
Gasterosteus aculeatus	threespine stickleback	34	175	192.3
Syngnathus griseolineatus	bay pipefish	22	54	33.4
Brachyistius frenatus	kelp perch	2	4	32.3
Cymatogaster aggregata	shiner perch	31	5,173	43,383.3
Embiotoca lateralis	striped perch	3	4	65.0
Rhacochilus vacca	pile perch	3	3	1,559.8
Trichodon trichodon	Pacific sandfish	2	12	1.5
Anoplarchus purpurescens	high cockscomb	1	1	5.7
Lumpenus sagitta	snake prickleback	12	695	1,883.2
Poroclinus rothrocki	whitebarred prickleback	1	1	0.3
Apodichthys flavidus	penpoint gunnel	28	108	1,894.8
Pholis clemensi	longfin gunnel	1	1	2.7
P. laeta	crescent gunnel	21	92	566.6
P. ornata	saddleback gunnel	12	29	96.5

Table 2b. Species of nearshore demersal fishes captured in the second year, July 1975 through July 1976 - Continued

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Anarrichthys ocellatus	wolf eel	1	5	13.8
Ammodytes hexapterus	Pacific sand lance	30	3,092	7,885.4
Sebastes caurinus	copper rockfish	9	67	2,635.9
S. melanops	black rockfish	2	2	202.1
Hexagrammos decagrammus	kelp greenling	18	44	4,590.8
H. stelleri	whitespotted greenling	13	21	1,263.3
Ophiodon elongatus	lingcod	2	2	608.9
Artedius fenestralis	padded sculpin	31	112	378.6
A. harringtoni	scalyhead sculpin	6	72	23.2
A. lateralis	smoothhead sculpin	5	5	35.3
Ascelichthys rhodorus	rosylip sculpin	11	162	136.0
Blepsias cirrhosus	silverspotted sculpin	40	242	936.1
Clinocottus acuticeps	sharpnose sculpin	33	80	27.1
Enophrys bison	buffalo sculpin	39	234	567.8
Gilbertidia sigalutes	soft sculpin	1	1	0.6
Hemilepidotus hemilepidotus	red Irish lord	2	3	1,029.4
Leptocottus armatus	Pacific staghorn sculpin	48	1,774	21,610.3
Myoxocephalus polyacanthocephalus	great sculpin	27	93	1,212.2
Nautichthys oculofasciatus	sailfin sculpin	1	1	3.1
Oligocottus maculosus	tidepool sculpin	28	542	662.5
Psychrolutes paradoxus	tadpole sculpin	12	58	69.6
Scorpaenichthys marmoratus	cabezon	1	1	2.0
Synchirus gilli	manacled sculpin	2	2	0.8
Agonus acipenserinus	sturgeon poacher	24	63	63.0
Anoplagonus inermis	smooth alligator fish	2	2	1.2
Pallasina barbata	tubenose poacher	22	100	34.4
Eumicrotremus orbis	Pacific spiny lumpsucker	18	42	161.7
Liparis callyodon	spotted snailfish	4	8	1,159.5
L. cyclopus	ribbon snailfish	4	9	107.4
L. florae	tidepool snailfish	5	6	31.8
Lepidopsetta bilineata	rock sole	8	9	703.8
Parophrys vetulus	English sole	51	1,369	10,282.2
Platichthys stellatus	starry flounder	28	67	8,122.6
Pleuronichthys coenosus	C-O sole	5	5	338.8

Table 2b. Species of nearshore demersal fishes captured in the second year, July 1975 through July 1976 - Continued

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Psettichthys melanostictus	sand sole	17	72	1,454.0
Liparis rutteri	ringtail snailfish	9	20	28.9
L. mucosus	slimy snailfish	1	1	2.6
Osmeridae	smelt	7	56	11.0
Scorpaenidae	rockfish	2	31	2.9
Sebastes sp.	rockfish	19	114	97.7
Hexagrammidae	greenling	7	8	1.7
Cottidae	sculpin	2	2	0.1
Careproctus sp.	snailfish	1	1	1.2
Liparis sp.	snailfish	1	1	0.2
Pleuronectidae	righteye flounder	2	4	0.1
Total 73 species		955	43,209	254,477

Table 3. The ten most common species encountered in beach seine collections in the San Juan Islands, 1974-1976, ranked according to frequency of occurrence, total abundance, and total biomass.

Species	1974-1975			1975-1976		
	Occurrence	Abundance	Biomass	Occurrence	Abundance	Biomass
English sole juveniles	1	7		1	6	6
Pacific staghorn sculpin juveniles	2	4	4	2	5	3
Surf smelt larvae to adults	2	6	3	6		
Shiner perch juveniles, adults	4	3	2	8	2	2
Pacific herring juveniles, larvae	5	1	1	5	1	1
Tubesnout juveniles, adults	6	5			4	4
Buffalo sculpin juveniles, adults	6			4		
Padded sculpin juveniles, adults	8			8		
Starry flounder juveniles, adults	9		5			7
Copper rockfish juveniles, adults	9		10			
Pacific tomcod juveniles	10	10			7	
Threespine stickleback adults, juveniles				6		
Tidepool sculpin juveniles, adults		9			10	
Silverspotted sculpin juveniles, adults				3		
Sharpnose sculpin juveniles, adults				8		
Pacific sand lance adults, juveniles		2	7	10	3	8
Chum salmon juveniles		8				
Spiny dogfish immature adults			6			5
Kelp greenling adults			8			
Ratfish adults			9			9
Snake prickleback juveniles, adults					8	
Pink salmon juveniles					9	
Chinook salmon adults						10

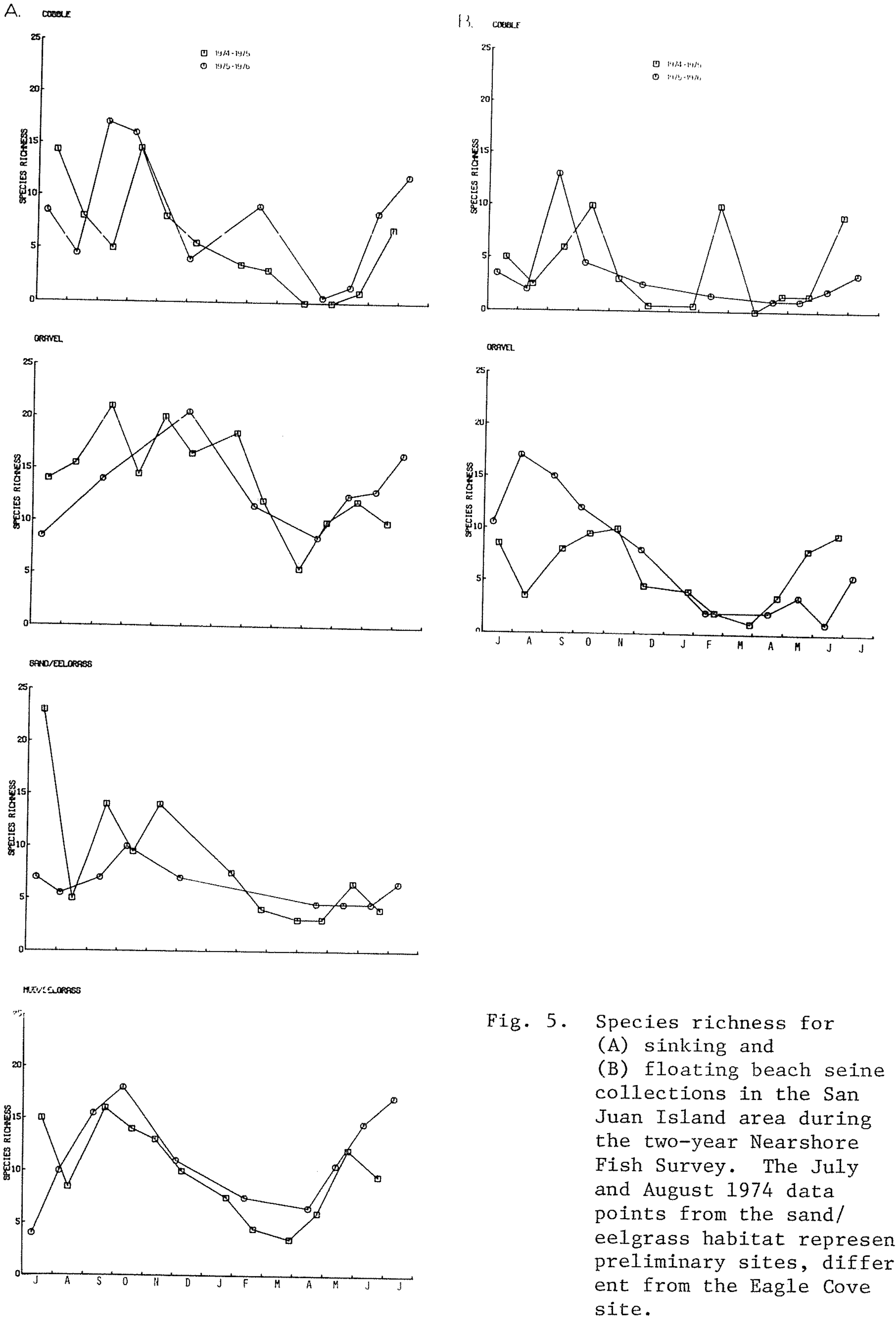


Fig. 5. Species richness for (A) sinking and (B) floating beach seine collections in the San Juan Island area during the two-year Nearshore Fish Survey. The July and August 1974 data points from the sand/eelgrass habitat represent preliminary sites, different from the Eagle Cove site.

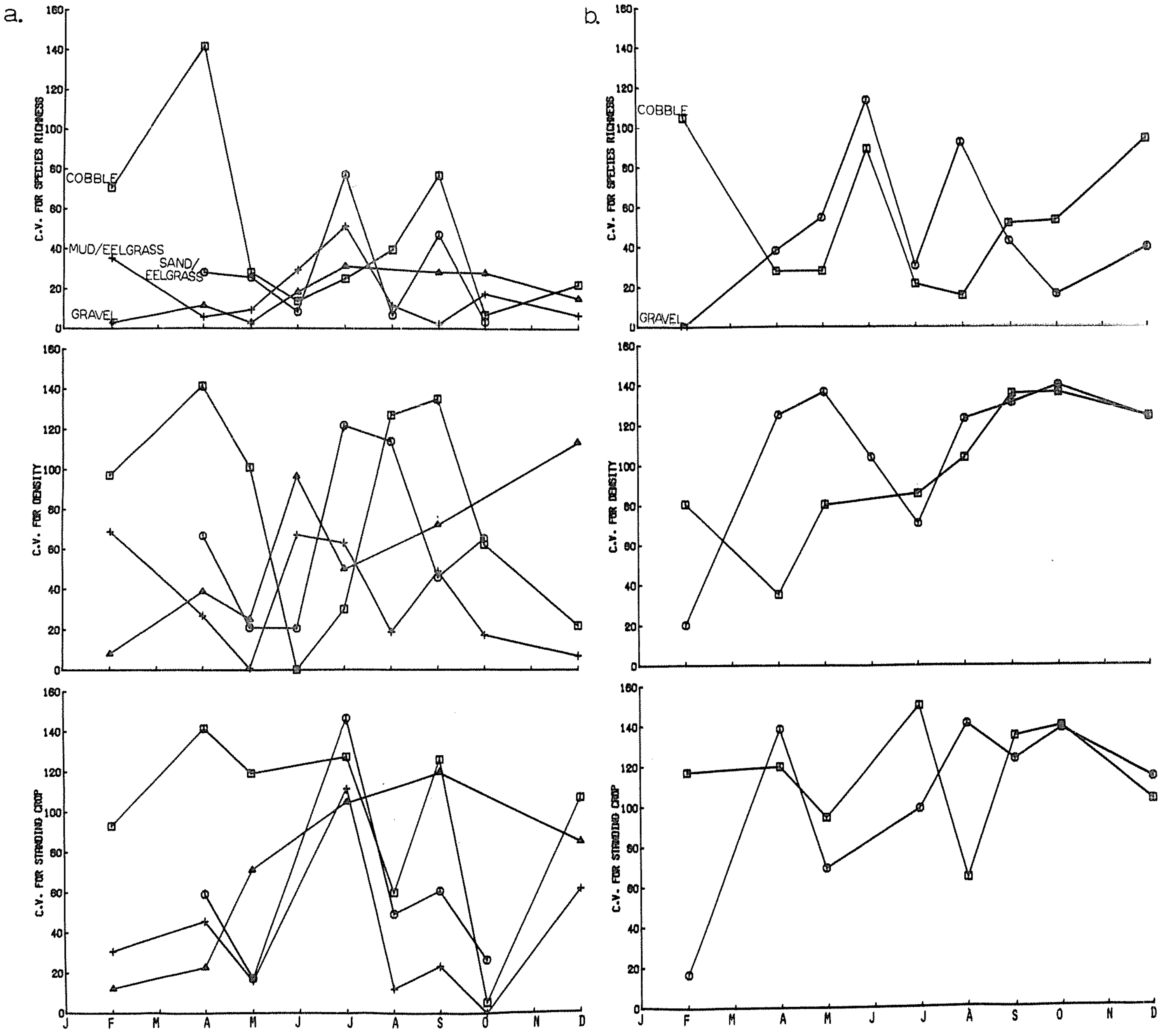


Fig. 6. Annual (between years) coefficient of variation (C.V.) for species richness, density, and standing crop of (A) sinking and (B) floating beach seine catches, 1974-1976.

April. Numbers of species collected in floating beach seines in the gravel habitat were much lower, ranging from 13 to 0, but showed the same seasonal trends. The number of species collected in the sand/eelgrass habitat was much more constant over the year. Maximum numbers of species occurred in the fall and minimum numbers in March and April. The unusually high species richness (23 species) of July 1974 occurred at a preliminary sand/eelgrass site (False Bay). Subsequent sampling in sand/eelgrass habitats was shifted to the Eagle Cove site which produced a maximum of 14 species. In the mud/eelgrass habitat, numbers of species again reached a fall maximum and declined steadily through March in both years sampled.

At the eastern shore beach seine sites sampled by WWSC, 75 species were captured over the 2 years of the survey, 58 in 1974-1975 and 70 in 1975-1976. The combined total catch of these species was 36,016 fish with a catch weight of 161 kg for 1975-1976. The species comprising the 10 most common species when ranked according to frequency of occurrence, total abundance and total biomass are listed in Table 4 for the 2 years sampled.

Species richness (Fig. 7) for sinking beach seine collections at WWSC sites appears to be higher in the cobble and gravel habitats than in the sand or mud/eelgrass habitats. As in the San Juan area, the floating beach seine samples had fewer species than the sinking beach seines in the same habitat.

The cobble and gravel habitats showed the same overall pattern of species richness in the sinking beach seines with maximum numbers of species occurring in September-October, declining steadily to a minimum in March and April. In the sand/eelgrass and mud/eelgrass habitats, maximum numbers of species occurred in May-June and then declined to an early spring minimum.

Density

Abundance data, converted to fish density (fish per m^2) was plotted against beach seine collection month for sites in the San Juan Island area (Fig. 8). Overall fish densities determined from sinking beach seine collections (Fig. 8-A) were highest in the gravel habitat, followed by the mud/eelgrass, sand/ eelgrass, and cobble habitats. Fish densities in the floating beach seine samples (Fig. 8-B) were greater in the gravel than in the cobble habitat although both were generally more variable than the sinking beach seine samples. Coefficient of variation for density in the sinking beach seines was relatively high, frequently exceeding 100 percent, and fluctuated widely in the four habitats (Fig. 6-A). The low coefficient of variation for density found in the spring reflected the low fish densities found at that time in all habitats. Floating beach seines (Fig. 6-B) showed an increasing trend through the year.

Table 4. The ten most common species encountered in beach seine collections in the eastern shore area, 1974-1976, ranked according to frequency of occurrence, total abundance, and total biomass. Biomass information was not available for 1974-1975.

	1974-1975		1975-1976		
Species	Occurrence	Abundance	Occurrence	Abundance	Biomass
Pacific staghorn sculpin juveniles, adults	1	4	1	8	1
Shiner perch juveniles, adults	2	1	3	4	5
Tubesnout juveniles, adults	3	2	9	1	8
Threespine stickleback adults, juveniles	4	5	6	9	
Buffalo sculpin juveniles, adults	5		2		
Surf smelt larvae to adults	7	6	4	5	6
Starry flounder juveniles, adults	8				
English sole juveniles	9	7	9		
Chinook salmon juveniles, adults	10	10			
Padded sculpin juveniles, adults	10		5		
Pacific herring juveniles, larvae		3	7	3	9
Crescent gunnel juveniles, adults			8		
Pile perch juveniles, adults					2
Spiny dogfish immature adults					3
Cabezon juveniles, adults					4
Pacific tomcod juveniles	5			6	7
Striped seaperch juveniles, adults					10
Tadpole sculpin juveniles				2	
Pacific sand lance juveniles, adults		8			
Sockeye salmon juveniles		9			
Tidepool sculpin juveniles, adults				7	

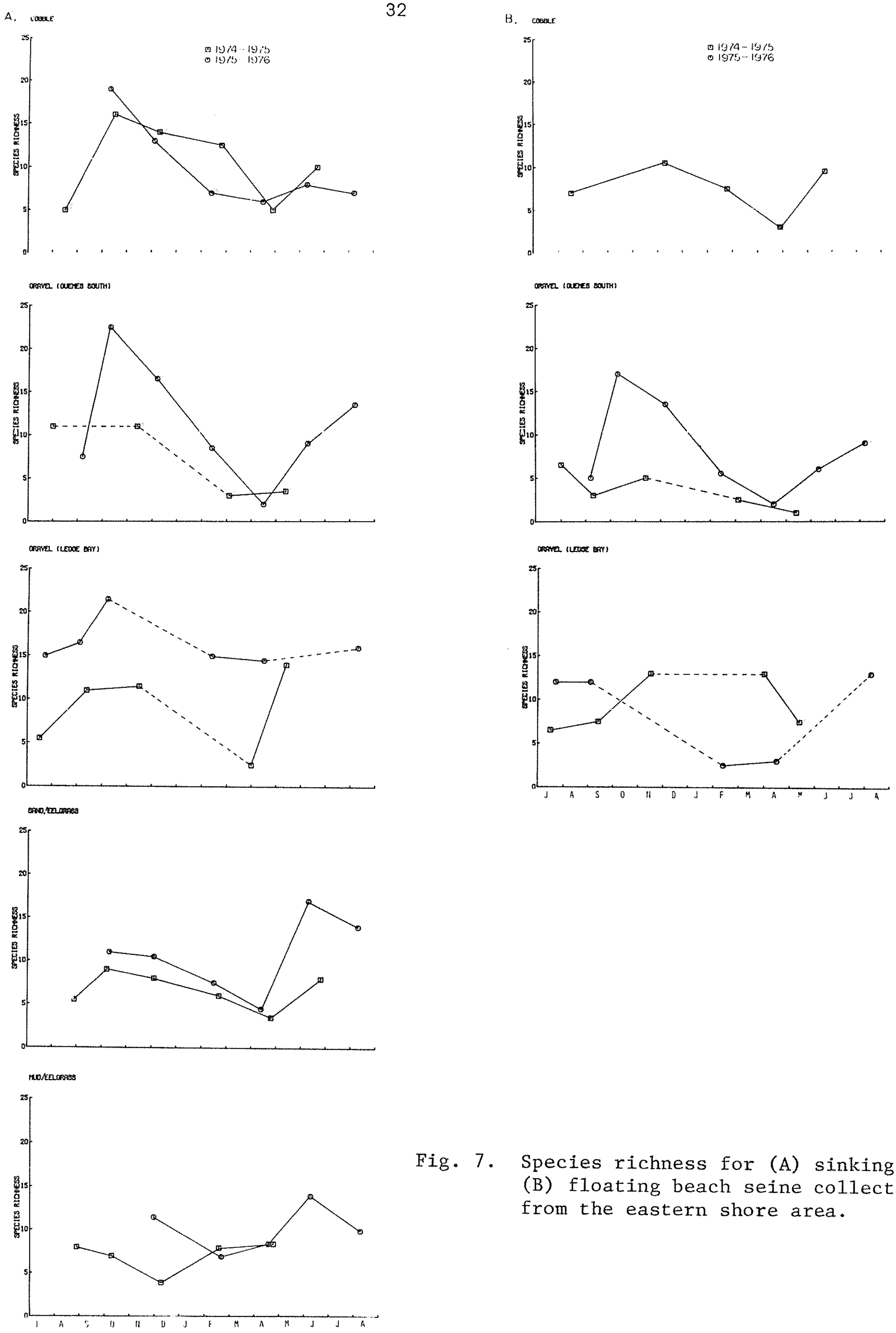


Fig. 7. Species richness for (A) sinking and (B) floating beach seine collections from the eastern shore area.

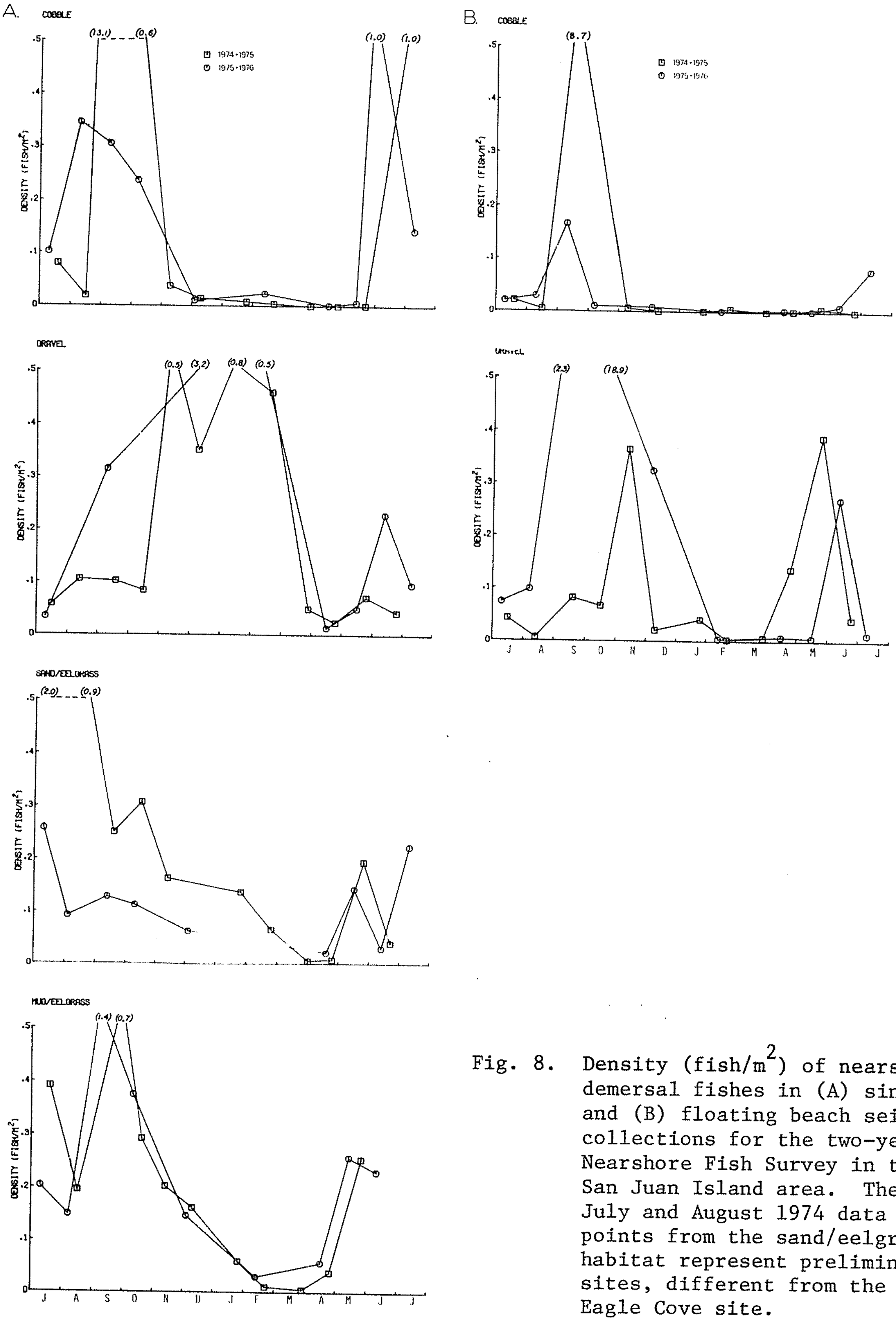


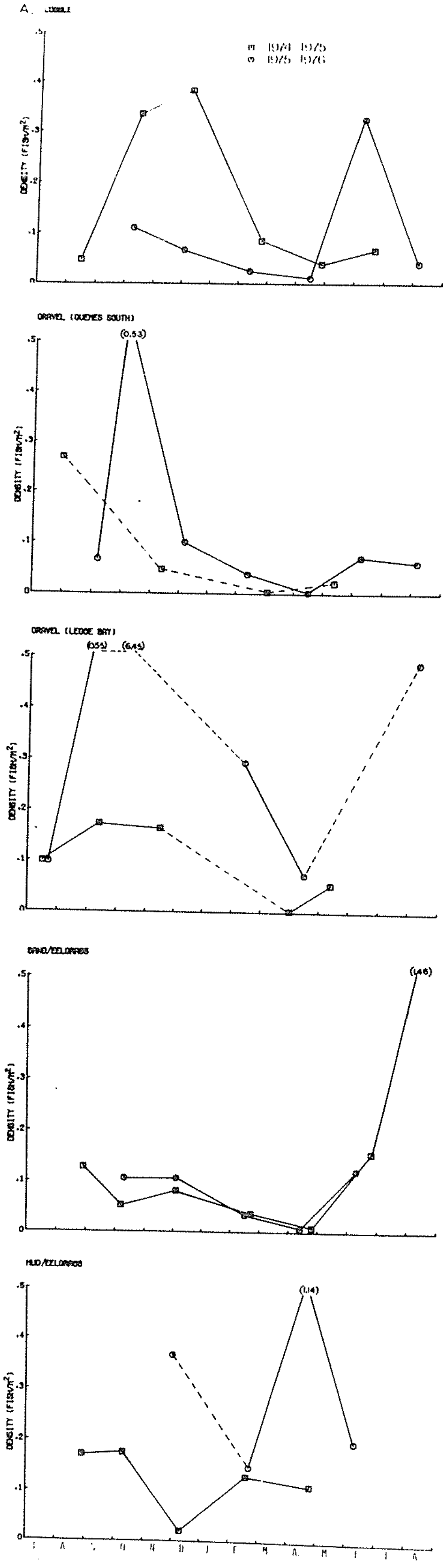
Fig. 8. Density (fish/m^2) of nearshore demersal fishes in (A) sinking and (B) floating beach seine collections for the two-year Nearshore Fish Survey in the San Juan Island area. The July and August 1974 data points from the sand/eelgrass habitat represent preliminary sites, different from the Eagle Cove site.

High seasonal peaks in fish densities in the spring and fall were observed in both floating and sinking beach seine catches in the cobble habitat in both years. The gravel habitat, as sampled by the sinking beach seine, displayed a different seasonal trend with maximum densities occurring in the winter. Densities declined through late spring, with small increases during the summer, before rising sharply in late fall. The floating beach seine in the gravel habitat showed maximum densities in spring and fall due to influxes of neritic species, principally Pacific sand lance and juvenile chum salmon in the spring and juvenile Pacific herring in the fall. Fish densities in the sand/eelgrass habitat showed less seasonal variability, having higher densities of resident demersal fish and less influence from neritic species. Densities in July and August 1974 represent collections from preliminary sand/eelgrass habitat sites at False Bay and Cattle Point. Eagle Cove was later chosen as a more representative sand/eelgrass site and was used for subsequent sampling. Fish densities at Eagle Cove were highest in the late spring and declined steadily to very low levels by the following April. In the mud/eelgrass habitat, densities were moderately high through the summer with a sharp peak occurring in September. Densities declined through autumn and winter and reached very low levels in February and March. Seasonal trends in the mud/eelgrass habitat varied little between the 2 years sampled.

Overall fish densities at the eastern shore (WWSC) sites were highest at the gravel (Legoe Bay) and cobble sites followed by the mud/eelgrass, gravel (Guemes South) and sand/eelgrass sites, respectively (Fig. 9).

Sinking beach seines in the cobble and gravel (Legoe Bay) habitats show high seasonal peaks in fish densities in spring and fall with minima occurring in the winter months (Fig. 9-A). The gravel habitat at Guemes South exhibited a similar density peak in fall with densities remaining below 0.1 fish/m^2 at other times of the year. In the sand/eelgrass habitat, maximum density occurred in June-July with minimum densities near zero in March-April. Densities remained fairly constant at around 0.1 fish/m^2 in the remaining months. Densities in the mud/eelgrass habitat fluctuated widely throughout the year, ranging from a minimum of 0.02 fish/m^2 in December 1974 to a maximum of 0.65 fish/m^2 in April 1976. In most cases, the large density peaks were due to influxes of neritic species, chiefly juvenile Pacific herring, tube-snouts, and shiner perch in fall and surf smelt, juvenile Pacific herring, and Pacific sand lance in spring.

The floating beach seines (Fig. 9-B) in the cobble and gravel habitats displayed trends similar to the sinking beach seines in those habitats but with more variability owing to their sampling bias toward the sporadically occurring neritic species.



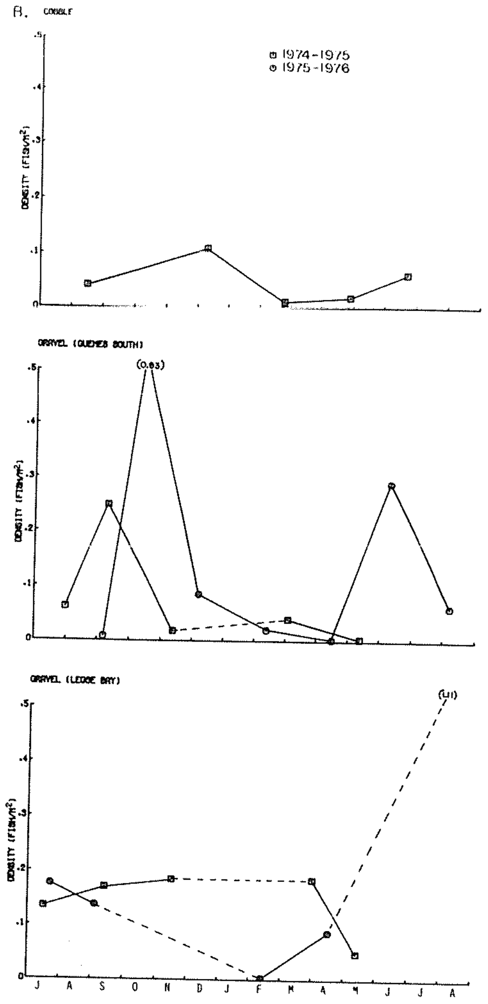


Fig. 9. Density (fish/m^2) of nearshore demersal fishes in (A) sinking and (B) floating beach seine collections from the eastern shore area.

Standing Crop

Catch weights were converted to standing crop in g/m^2 and were plotted against beach seine collection months for sites in the San Juan Island area (Fig. 10).

Fish standing crop, like fish density, was highest in the gravel habitat. Standing crops at the other three sites were about equal, although higher standing crop maxima occurred at the cobble habitat, mostly because of an occasional seasonal influx of neritic species. The coefficient of variation for standing crop in the sinking beach seine fluctuated from 0 to 140 percent (Fig. 6-A). Variation between the two years sampled appeared to be greatest in the summer months when the coefficient of variation exceeded 100 percent in all habitats sampled. Again, floating beach seines (Fig. 6-B) showed higher values (more variation) than the respective sinking beach seines. Intermittently abundant neritic species account for much of the high variability in the data.

Except for large numbers of juvenile Pacific herring in the fall and a large catch of Pacific sand lance in early summer, standing crop in the cobble habitat was relatively low. The floating beach seine pattern was similar to the sinking beach seine, showing the large influxes of neritic species and extremely low standing crop the rest of the year.

Standing crop of the sinking beach seine in the gravel habitat, unlike the other sites, was greatest during the winter. Influences from neritic species can be seen in the smaller standing crop peaks in spring and fall. The floating beach seine in the gravel habitat indicated low standing crops in the upper nearshore water column, except for the fall influx of juvenile herring which provided the only significant variability between the two sampling years. In the sand/eelgrass habitat at Eagle Cove, standing crop was high through the summer reaching a maximum in September in both years sampled, and declined to low levels in March and April just prior to settlement by young-of-the-year demersal species. In the mud/eelgrass habitat, fish standing crop was high in summer and low in February, March, and April. Seasonal trends in standing crop in the mud/eelgrass habitat were similar in the two years sampled, except during June 1976 when an abundance of shiner perch dominated the catches.

At the eastern shore sites sampled by WWSC, standing crop data are available only for the second year of sampling, July 1975-August 1976 (Fig. 11). Insufficient weight data for all species were collected during the first year of sampling at these sites to allow standing crop values to be calculated.

Standing crop trends were heavily influenced by sporadic catches of a few large individuals. The majority of the peaks in Fig. 11 were due to catches of this nature, consisting principally of large individuals of spiny dogfish, cabezon, pile perch, and whitespotted greenling.

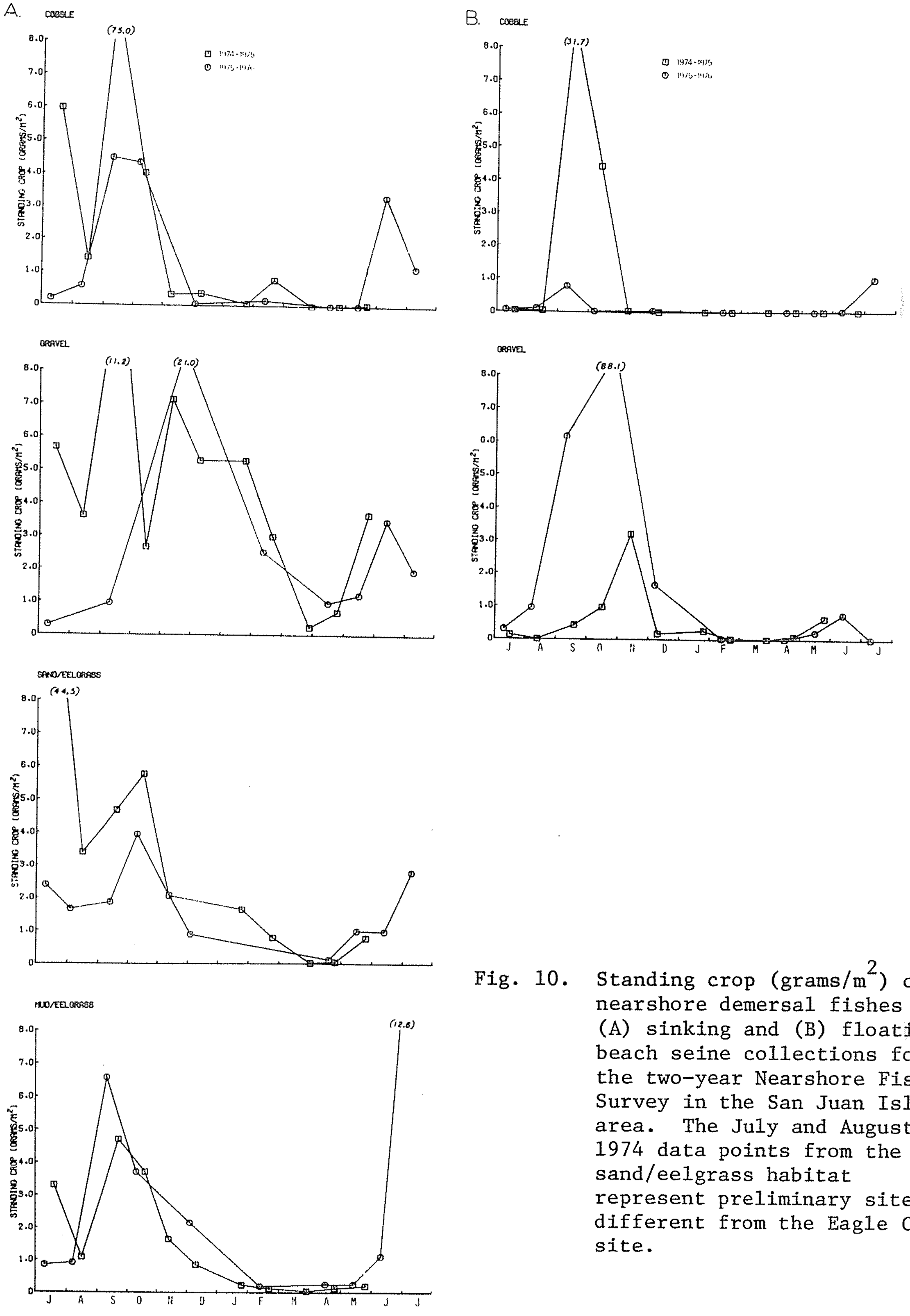
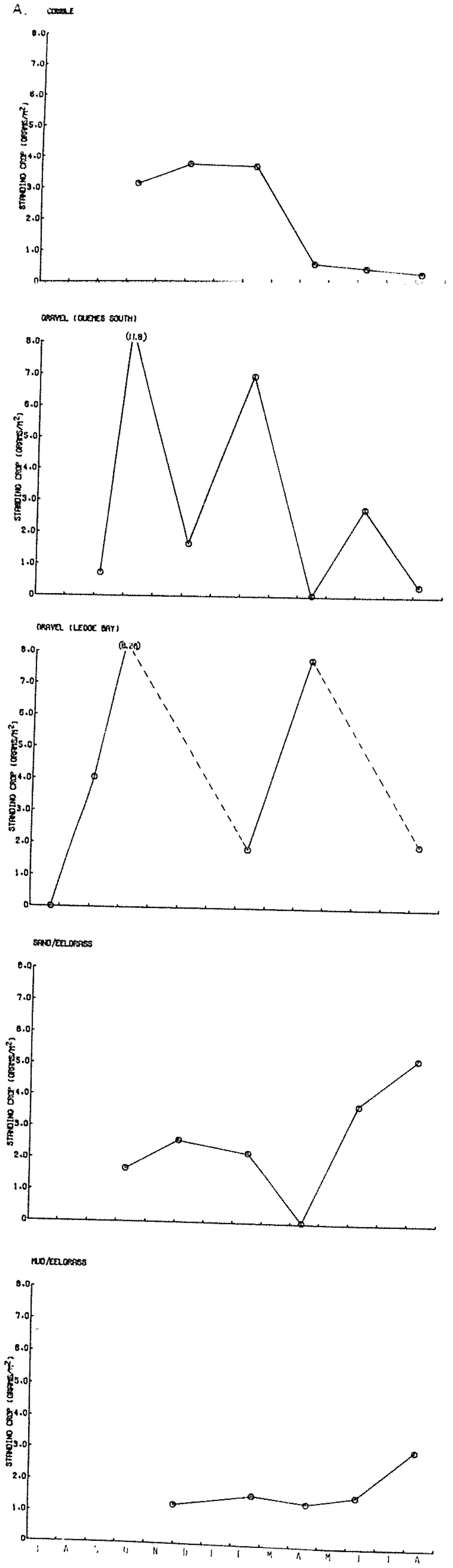


Fig. 10. Standing crop (grams/m^2) of nearshore demersal fishes in (A) sinking and (B) floating beach seine collections for the two-year Nearshore Fish Survey in the San Juan Island area. The July and August 1974 data points from the sand/eelgrass habitat represent preliminary sites, different from the Eagle Cove site.

A.



B.

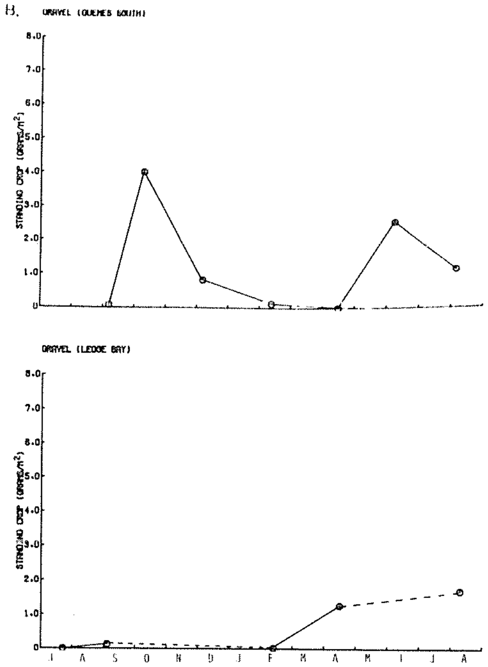


Fig. 11. Standing crop (grams/m^2) of nearshore demersal fishes in (A) sinking and (B) floating beach seine collections from the eastern shore area.

In the sinking beach seines (Fig. 11-A) at the cobble and gravel (Guemes South and Legoe Bay) sites, biomass peaks were entirely due to sporadic catches of these large individuals with the exception of the October 1975 sample from the Legoe Bay site which was composed of large numbers of juvenile tubesnout. Biomass peaks due to catches of large individuals appear mostly during the winter months when sampling occurred at night and these species may have been more accessible to the beach seine.

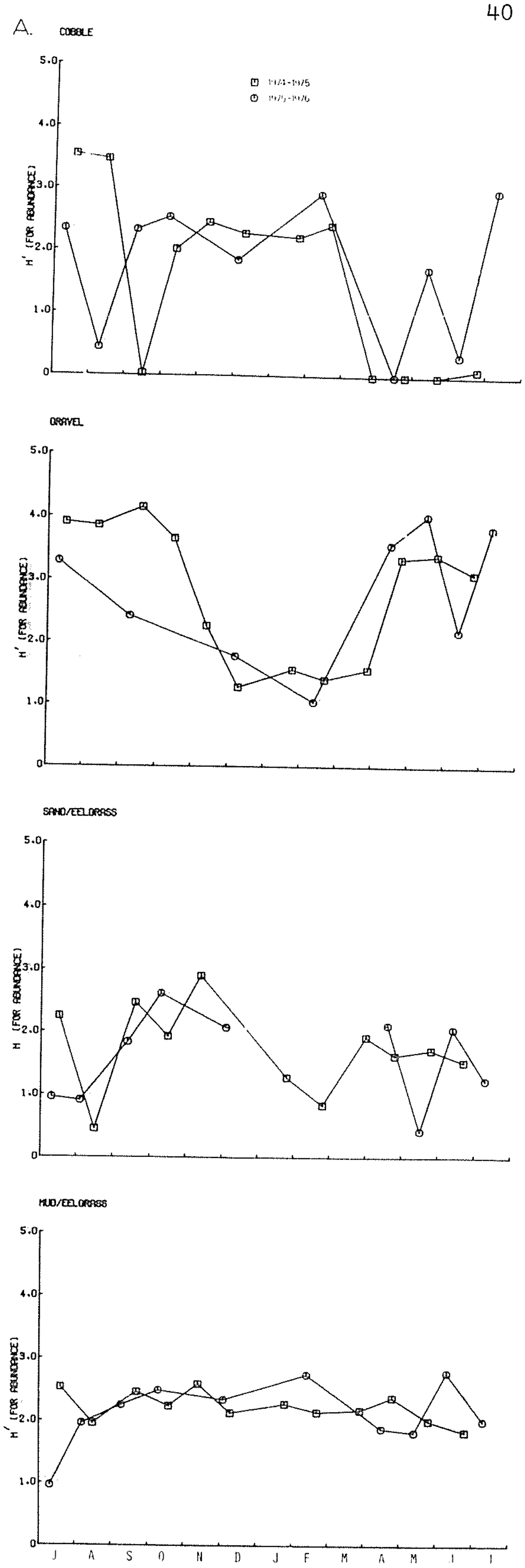
In the sand/eelgrass and mud/eelgrass sites, standing crop peaked in August with large catches of juvenile shiner perch. The mud/eelgrass site exhibited the most stable standing crop levels, ranging between 1 and 2 g/m^2 for all months except for the August catches of shiner perch juveniles.

Diversity

The Shannon-Weiner diversity indices for abundance and biomass at the San Juan Island sites were plotted for the sinking and floating beach seine collections (Fig. 12).

In sinking beach seines in the cobble habitat, species and biomass diversity fluctuated widely over the year. Species diversity tended to fluctuate with greater amplitude than did biomass diversity since the source of the variation was the periodic catches of large numbers of relatively small schooling species. Species and biomass diversity were suprisingly high in the winter, given the few species present, implying high evenness among the species present. As expected, both indices fell to very low levels during large catches of single neritic species in the spring and fall. Floating beach seine H' values were generally low and variable, being influenced by infrequent large catches of very few schooling species. Much of the diversity apparent in the floating beach seine collections was due to occurrences of benthic species captured as the floating gear contacted the bottom at the end of a haul.

The sinking beach seine collections in the gravel habitat generally had the highest species and biomass diversities of the four habitats during spring, summer, and fall, and fell to somewhat lower levels during the winter. Species richness decreased only slightly during this period while density and standing crop increased, so that most of the decline in diversity may be attributed to decreased evenness in the distribution of abundance and standing crop among the species present. Biomass diversity tended to be somewhat lower, relative to the other habitats, than species diversity, owing to the occurrence in most collections of a few large individuals (e.g., rockfish, greenling, lingcod) probably associated with nearby kelp beds. As in the cobble habitat, diversity in the floating beach seine collections in the gravel habitat was quite variable. Species and biomass diversity values again reflect the occurrence of benthic species in most collections and fall to very low levels during large catches of neritic species.



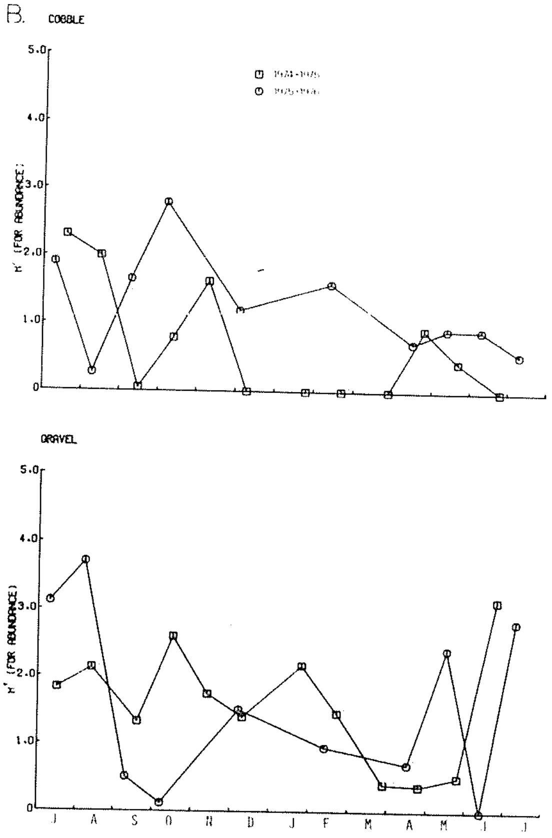


Fig. 12-A. Species diversity in (A) sinking and (B) floating beach seine collections in the San Juan Island area during the two-year Nearshore Fish Survey, 1974-75 and 1975-76.

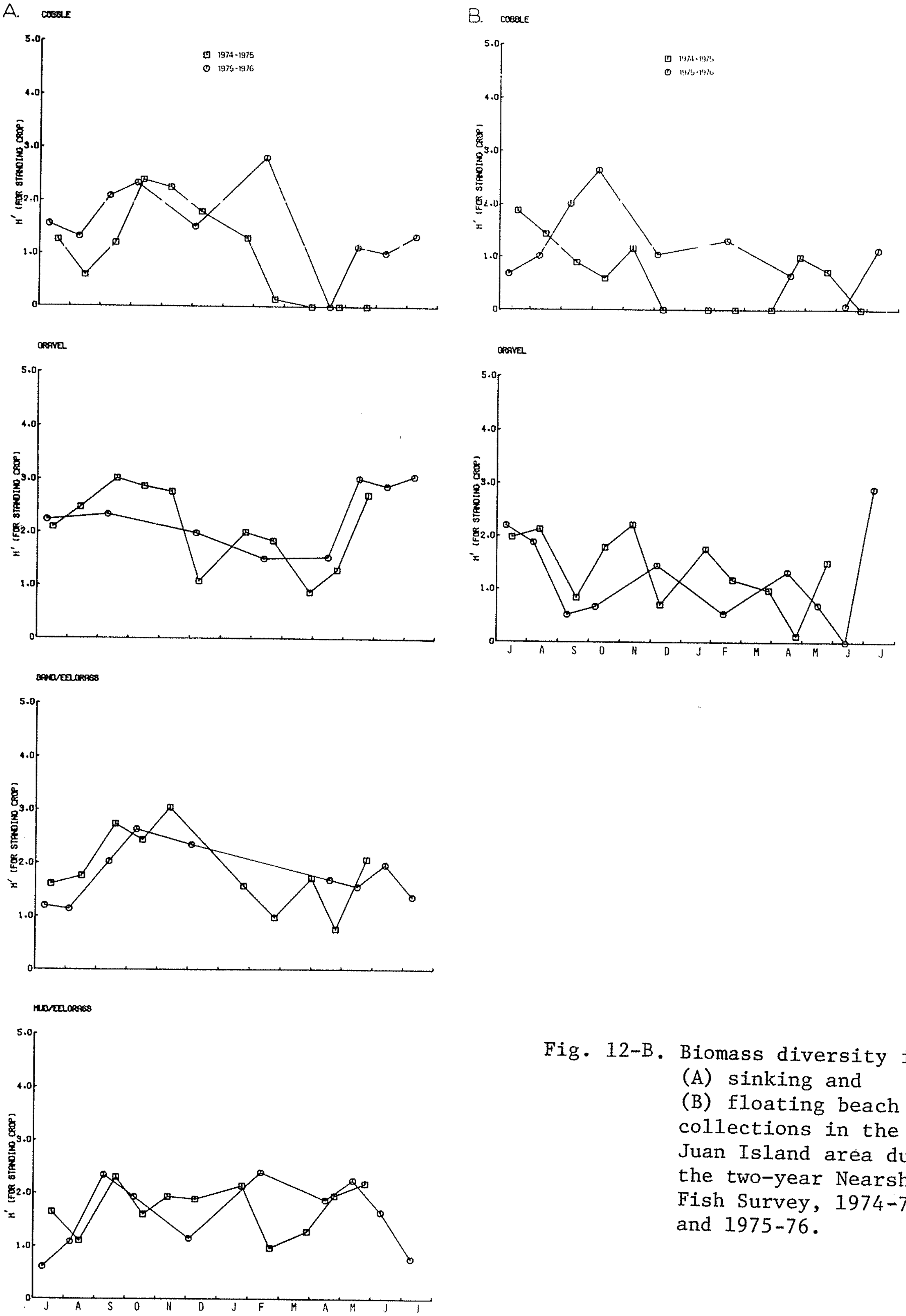


Fig. 12-B. Biomass diversity in (A) sinking and (B) floating beach seine collections in the San Juan Island area during the two-year Nearshore Fish Survey, 1974-75 and 1975-76.

The sand/eelgrass habitat displayed a somewhat lower overall species diversity than the other habitats, while biomass diversity was similar to that found in the gravel and cobble habitats. Values for both species and biomass diversity declined only slightly from fall through spring, following the trend of species richness.

A different trend was seen in the mud/eelgrass habitat as biomass, and particularly species diversities, remained constant, while species richness, density, and standing crop fluctuated considerably, all being greatest in the fall and reaching minimum values in the spring. Shifts in the evenness of the distribution of biomass, and particularly abundance, among the component species apparently compensated for the fluctuations in species richness, so that the H' values remained relatively constant.

Species diversity at WWSC's eastern shore sites in sinking beach seine collections fluctuated widely between 1.0 and 4.0 (Fig. 13-A). However, the diversity of collections from the mud/eelgrass site dropped to considerably lower levels during February-April. Trends in species diversity through time were similar for both years sampled, indicating little between-year variation. Floating beach seines (Fig. 13-B) fluctuated more widely as sporadic large catches of neritic species caused the indices to drop to low levels.

Biomass diversity (Fig. 13-B) appeared to be similar in the sinking beach seine collections at the cobble, sand/eelgrass, and mud/eelgrass sites. At the gravel (Guemes South) site, biomass diversity fluctuated more widely and reached low levels in February. Floating beach seines in the cobble and gravel (Legoe Bay) habitats followed trends similar to those seen in the respective sinking beach seines.

Nearshore Demersal Fish Assemblages: Discussion

Cobble

The dominant environmental factor influencing fish assemblages in the nearshore cobble habitat was physical stress due to the high degree of wave exposure. The effects of direct exposure were generally strongest during fall and spring when wave forces tended to keep the beach substrate unstable. As a result, most resident demersal species disappeared from the habitat with the onset of the fall storm period.

In the San Juan Island area, the cobble habitat was characterized by the lowest densities of resident demersal fishes, but was periodically utilized by schooling neritic species, resulting in the large amount of variability evident in species richness, density, and standing crop. During the spring months, few or no fish were caught at this site.

In the eastern shore area, the cobble site does not appear to be significantly lower in species richness, density, or standing crop than

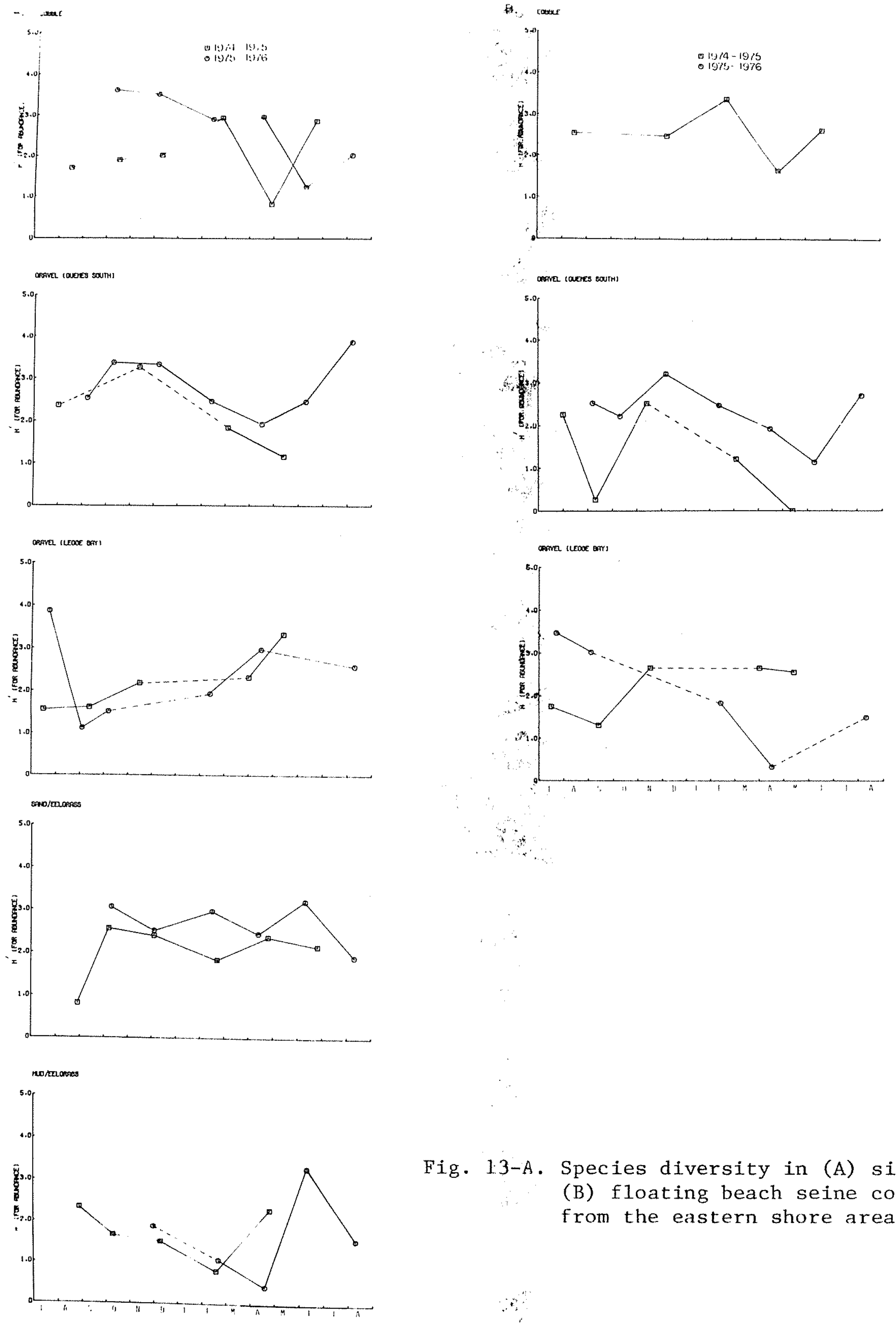
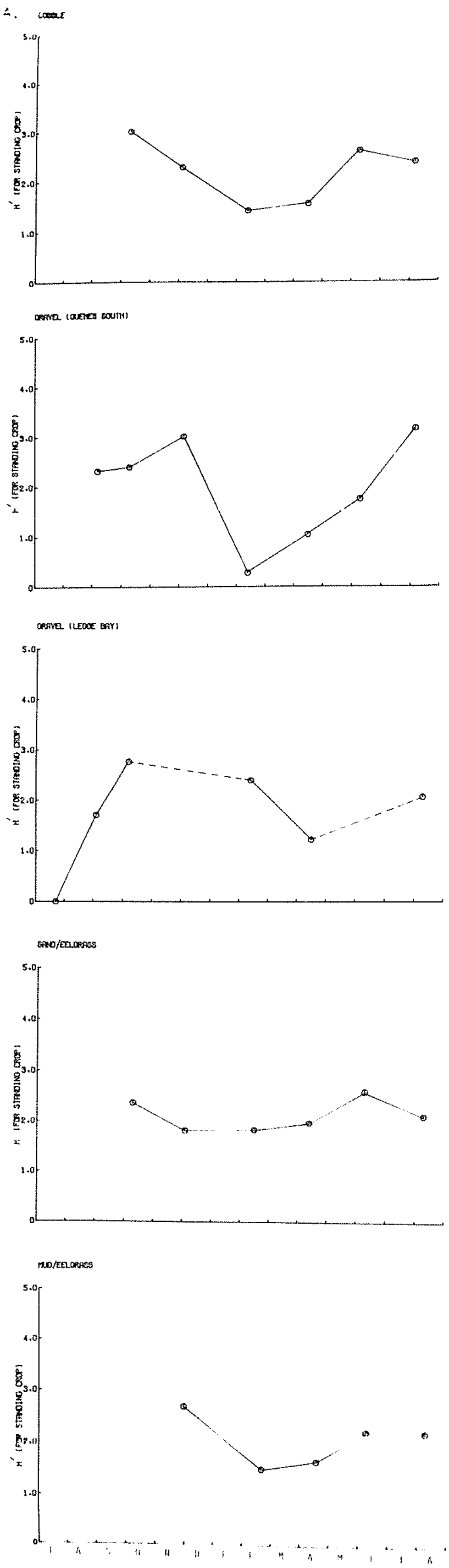


Fig. 13-A. Species diversity in (A) sinking an
(B) floating beach seine collection
from the eastern shore area.



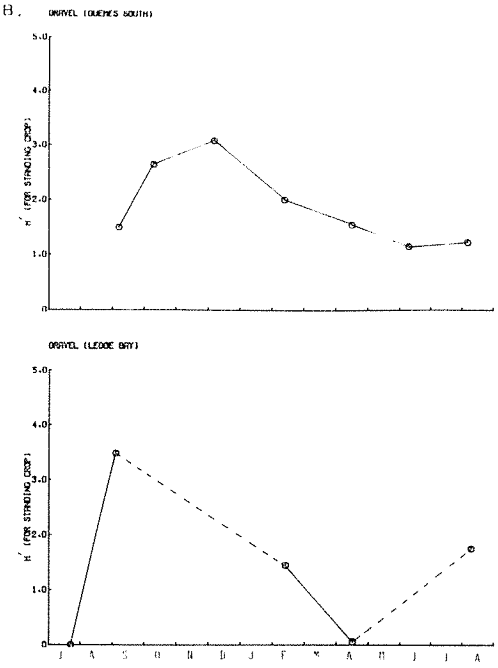


Fig. 13-B. Biomass diversity in (A) sinking and (B) floating beach seine collections from the eastern shore area.

the other sites. There appears to be less influence from neritic species in the eastern area as no extremely large catches of these species were reported.

In the San Juan Island area, the high seasonal peaks in fish density and standing crop were, in part, a result of the high abundance of larval Pacific herring and Pacific sand lance in the spring and juvenile Pacific herring, tubesnout, and to a lesser extent, juvenile tomcod in the fall. Schools of these neritic species appeared in the eastern shore habitats in spring and fall with the additional appearance of large numbers of shiner perch in the fall. The appearance of shiner perch in this area may be due to the eelgrass beds known to occur adjacent to the eastern shore cobble site. Much less eelgrass occurs at the San Juan Island cobble site.

The late summer-early fall (September-October) increases in species richness, density, and standing crop may, in part, be a reflection of the sampling design. At that time of the year the maximum low tide series began occurring at night and the sampling schedule was changed from daytime to nighttime collections. This phenomenon is particularly evident in standing crop since large demersal species such as ratfish, dogfish, and large hexagrammids and cottids appeared to move into shallower water and become accessible to beach seining gear at night. Diel differences in the distributions of species in the nearshore region have been recognized at other locations in Puget Sound (Miller et al. 1975; Cooney 1967; Zebold 1970), usually indicating a tendency to greater abundance and species richness at night.

Predominant demersal species include the sharpnose sculpin, padded sculpin, ringtail snailfish, and juvenile buffalo and great sculpins. Young-of-the-year of several of these species, particularly buffalo sculpin, entered the habitat in May and apparently moved out of the habitat, perhaps into deeper water, by March of the following year. Species typical of the adjacent offshore sand bottom habitat, such as juvenile rock sole and English sole and adult starry flounder, occasionally were present in the collections.

Gravel

Fish assemblages of the gravel habitat in the San Juan Island area showed the influence of adjacent habitat types. Fish associated with nearby rocky kelp beds, cobble areas, and offshore sand/eelgrass beds were also captured at this site; however, as the Deadman Bay site is typical of the narrow gravel (pocket) beaches of the San Juan archipelago, the fish fauna can be considered characteristic of this habitat.

Mean species richness, density, and standing crop were all higher in this habitat than in any other in the San Juan Island area, perhaps because of the habitat's diversity. Predominant demersal species were juvenile copper rockfish, kelp greenling, silverspotted sculpin, buffalo sculpin, whitespotted greenling, padded sculpin, staghorn sculpin, juvenile English sole, tidepool sculpin, crescent and penpoint gunnels, great sculpin, smoothhead sculpin, spiny lumpsucker, threespine stickleback, and bay pipefish, in descending order of abundance.

Demersal fish densities were highest in the early summer and declined through the winter. While most of the predominant demersal species were absent during the winter, some species such as kelp greenling, buffalo sculpin, and padded sculpin maintained stable populations through the winter. As in the cobble habitat, patterns of fish species richness, density, and standing crop may reflect, in part, the changes from daylight to nighttime sampling of fish assemblages with differing diel distributions.

Large numbers of neritic species occurred periodically in the gravel habitat, particularly during early winter, causing the overall fish densities and standing crops to be highest at this time, unlike the other habitats. Pacific herring were abundant in the autumn; tubesnouts and shiner perch frequented the habitat during the winter; and outmigrating juvenile pink and chum salmon appeared in early summer. The maximum fish density (18.9 fish/m^2) and standing crop (88.1 g/m^2) were recorded in the shallow neritic waters of this habitat in October 1975.

Of the two gravel habitats sampled in the eastern shore area, the Legoe Bay site showed the most similarity to the San Juan area gravel habitat. The demersal fish fauna was generally quite similar, although slightly less species rich. Silverspotted sculpins were rare in this habitat and tadpole and padded sculpins were much more common than at the San Juan site. Very few flatfish were present. The neritic component of the assemblage was principally composed of tube-snouts, which along with tadpole sculpin dominated the collections in fall. Small numbers of juvenile herring and tomcod were also encountered in fall. Much smaller numbers of shiner perch entered this habitat over the winter months than at the Deadman Bay site. As at the Deadman Bay site, juvenile tubesnouts dominated spring collections.

The Guemes Island South gravel site exhibited many dissimilarities compared to the other two gravel sites, perhaps due to its finer and more homogeneous substrate. The substrate at this site graded from gravel and pebbles intertidally to a medium sand subtidally with no patches of boulders and rocky kelp bed as were present at the other gravel sites. The assemblage was less species rich and had a large flatfish component, chiefly juvenile English sole, but with rock sole, sand sole, and C-O sole also present. Large staghorn sculpins were frequently encountered, as in the sand/eelgrass habitats. Other cottids typical of the other gravel sites were also present, such as padded, smoothhead, buffalo, tadpole, and great sculpins. As at the other eastern shore gravel site, silverspotted sculpins were rare. Crescent and penpoint gunnel densities were lower than either the Deadman Bay or Legoe Bay sites and a third pholid, the saddleback gunnel, was encountered at about the same densities.

The neritic component of the Guemes South assemblage was much smaller than the other two gravel habitats and appeared to be absent in the spring collections. The fall collections were chiefly comprised of juvenile herring and stickleback in August and herring and tadpole sculpin in October. The winter increase in density and standing crop due to an influx of neritic species was not seen at this site.

Sand/Eelgrass

While the sand/eelgrass habitats were protected from the most direct wave exposure, heavy surf conditions were not uncommon. Environmental conditions in this habitat were often characterized by well-mixed and periodically turbulent water.

In the San Juan Island area, the sand/eelgrass habitat supported large numbers of resident demersal fishes and exhibited little influence from neritic schooling species and typically had the lowest species richness. During both years, large numbers of young-of-the-year English sole had begun settling out on the sand/eelgrass habitat by April. Earlier settlement was probable, but because of the relatively large mesh of the net wings, settled English sole did not appear in the collections until they had attained a somewhat larger size. The abundance of English sole juveniles declined through the summer and fall, and the young-of-the-year fish had completely disappeared from the habitat by the following March. Adult staghorn sculpin were a constant member of this assemblage from May to February, occurring at low densities ranging from 0.001 to 0.017 fish/m^2. Juvenile sand sole were also constant members of the assemblage, occurring in every collection in densities of 0.001 to 0.01 fish/m^2. Juvenile sturgeon poacher and larger starry flounder were rare members of the assemblage from May through December. Small schools of Pacific sand lance and juvenile chum salmon were found in early summer, and schools of juvenile tomcod and coho salmon entered the habitat in late summer. Surf smelt schools frequented the habitat at night during the fall and winter and were particularly dense during their January-February spawning period. Again, patterns of species richness, density, and standing crop may reflect, in part, the change in sampling procedures from daylight to nighttime sampling.

The fish assemblage at this site, while the least species rich among the San Juan Island area habitats sampled, maintained the most stable density and standing crop over the year. This apparent stability is partly due to equivalent shifts in dominant species composition--while resident demersal fish densities declined in the fall, an influx of tomcod and surf smelt at this time kept densities and standing crop at relatively stable levels.

At the eastern sand/eelgrass site, the fish assemblage was generally similar to the San Juan area. However, English sole were less common, and schools of shiner perch were encountered much more frequently. These differences may be due to the denser eelgrass beds at the eastern shore site. Adult staghorn sculpins and starry flounder were present at similar densities as in the San Juan habitat. The flatfish assemblage was slightly different, with sand sole encountered less frequently and rock sole and C-O sole encountered as rare members of the assemblage. Neritic species were very similar to those occurring in the San Juan habitat, with Pacific sand lance encountered in the spring, shiner perch in the fall, and surf smelt in winter and spring. A very small number of tomcod were reported in only one collection in December 1975.

Mud/Eelgrass

While this was the most protected habitat with respect to wave exposure, physiochemical fluctuations, particularly temperature, were of the greatest seasonal amplitude of the four habitats sampled.

At the San Juan area mud/eelgrass site, this habitat was characterized by a diverse assemblage of resident young-of-the-year demersal species. Snake prickleback, staghorn sculpin, and tidepool sculpin were the consistently abundant members of this assemblage with lesser numbers of English sole, sharpnose sculpin, and larger starry flounders present. Young-of-the-year staghorn sculpin entered the habitat in May and always were more abundant than tidepool sculpin which did not appear in abundance until July. Snake prickleback and English sole entered the habitat in April while sharpnose sculpins did not appear until July. Almost all demersal species had left the habitat by January as densities fell close to zero at this time.

At the San Juan site, seasonal spawning influxes of several neritic species, followed later by pulses of their recruits, caused considerable variability in fish density and standing crop between seasons. However, the extremely close agreeement in species richness, fish density, and standing crop between the two years indicates that these fluctuations are a predictable phenomenon. Shiner perch were the predominant schooling species utilizing this habitat. Adults appeared in great numbers and females were observed to be in fecund condition in July of both years sampled. New recruits were present in abundance in September. Since shiner perch are viviparous, the new recruits must either have been too small for the beach seine mesh size or have been unavailable in the shallow subtidal area during August. An influx of Pacific herring appeared at the San Juan site in late summer of both years, reaching maximum abundance in September. Smaller numbers of adult surf smelt appeared in the fall and the young-of-the-year appeared the following spring.

Seasonal documentation was not as complete for the eastern shore mud/eelgrass site. Demersal species appeared to follow the same seasonal patterns as in the San Juan area, but the assemblage of young-of-the-year demersal species appeared to be less diverse. Sharpnose sculpin and snake prickleback were essentially absent from the assemblage and while tidepool sculpin occurred in the same densities as at the San Juan site, staghorn sculpins appeared to be much less abundant. English sole appeared in much lower numbers in April and May and left the habitat in

December. As in the San Juan area, densities of demersal species fell to very low levels in eary spring. However, the influx of surf smelt at this time kept the overall density from dropping to low levels. Surf smelt appeared in this habitat earlier in the spring than in the San Juan area and the fall influx of herring appeared to be much less dense. As at the San Juan site, shiner perch utilized the habitat during the summer months, although apparently in lesser densities.

Summary

1. Demersal fishes in two regions (San Juan Island and eastern shore vicinities) of northern Puget Sound were sampled by beach seine over a 25-month study period from 1974-1976. Four shoreline habitats--cobble, gravel, sand/eelgrass, and mud/eelgrass--were selected for study.

2. A total of 84 species was identified in these nearshore fish assemblages, with English sole (juveniles), Pacific staghorn sculpin, and surf smelt being the dominant species by frequency-of-occurrence; Pacific herring (juveniles), shiner perch and Pacific sand lance were dominant by total abundance; and Pacific herring (juveniles), shiner perch, and Pacific staghorn sculpin dominated by total biomass.

3. Mean species richness, fish density, and standing crop were highest in the fish assemblages characterizing the gravel habitat, particularly in the San Juan Island area, followed by the assemblages in the mud/eelgrass, sand/eelgrass and cobble habitats.

4. Seasonal trends were evident in the occurrence and abundance of nearshore demersal fishes, with maxima occurring in September and October and minima in February and March.

5. Species richness values averaged between 10 to 15 (maximum of 23 species in a beach seine set), densities between 0.2 and 0.3 fish/m^2 (maximum of 13.1 fish/m^2), and standing crop between 3.0 and 4.0 grams/m^2 (maximum of 75.0 grams/m^2).

6. Species diversity and biomass diversity (H' of Shannon-Weiner) varied according to habitat with obvious seasonal fluctuations in all but the mud/eelgrass habitat assemblage. Species diversity averaged from 2.0 to 3.0, reaching a maximum of 4.2 in the gravel habitat in the San Juan Island area assemblage during the summer; biomass diversity averaged between 1.5 and 2.5 with a maximum of 2.8 in winter months.

7. Between-year variation in the composition, density, and standing crop of the nearshore demersal fish assemblages was least among the mud/eelgrass habitat fishes and generally greatest among the cobble and gravel habitat assemblages, and was principally due to the occurrence of neritic fishes in these habitats in the fall and winter months.

8. Fish assemblages in corresponding habitat types in the San Juan Island and eastern shore areas were generally similar. The major differences appeared to be related to differences in substrate adjacent to and offshore from the sampling sites.

Neritic Fishes (Townet): Results

Raw catch data are contained in a separate, accompanying data report (Miller et al. 1977).

Environmental Conditions

Temperature, salinity, and dissolved oxygen data obtained during the 19 townet trips, 1974-76, enabled us to document the nearshore surface water conditions corresponding to fish collections at each site (Fig. 14). While the sampling was too infrequent to permit conclusions about surface water oceanography, the data do provide indications of seasonal and annual trends of nearshore environmental conditions in the different habitats and geographic areas.

Sites in all three areas exhibited temperature trends of minimums of around 6°C in the winter followed by increases during spring and early summer, reaching maximum levels around 13°C in late summer and early fall (Fig. 14-A). Shallower embayments, typically sand/eelgrass and mud/eelgrass habitats, such as Birch Bay and Westcott Bay, were more variable and exhibited higher summer maxima than more exposed sites such as Cherry Point (cobble) and Eagle Cove (sand/eelgrass).

Salinity values ranged between 18.8 $^{o}/_{oo}$ and 32.8 $^{o}/_{oo}$ with most values occurring between 28.8 $^{o}/_{oo}$ and 32.0 $^{o}/_{oo}$ (Fig. 14-B). Low salinities generally were characteristic of fall while highs were characteristic of spring and summer. Values from the San Juan Island area were on the average slightly higher and less variable than values from eastern sites.

Dissolved oxygen data (Fig. 14-C) are less complete than the other physiochemical data because quantitative measures of dissolved oxygen were not obtained until after the December 1974 collection. Our dissolved oxygen data were highly variable, exhibiting no consistent geographic, habitat, or exposure-related trends.

Species Occurrence

Over the 25-month study period, 234 townet collections resulted in the capture of 403,000 individuals and 801 kg of 71 identified species of fish from 15 sites representing five nearshore habitats (Table 5). The ten most common species were ranked by frequency of occurrence, abundance, and biomass (Table 6). These ranks illustrate that the schooling Pacific herring dominate the neritic fish assemblage in northern

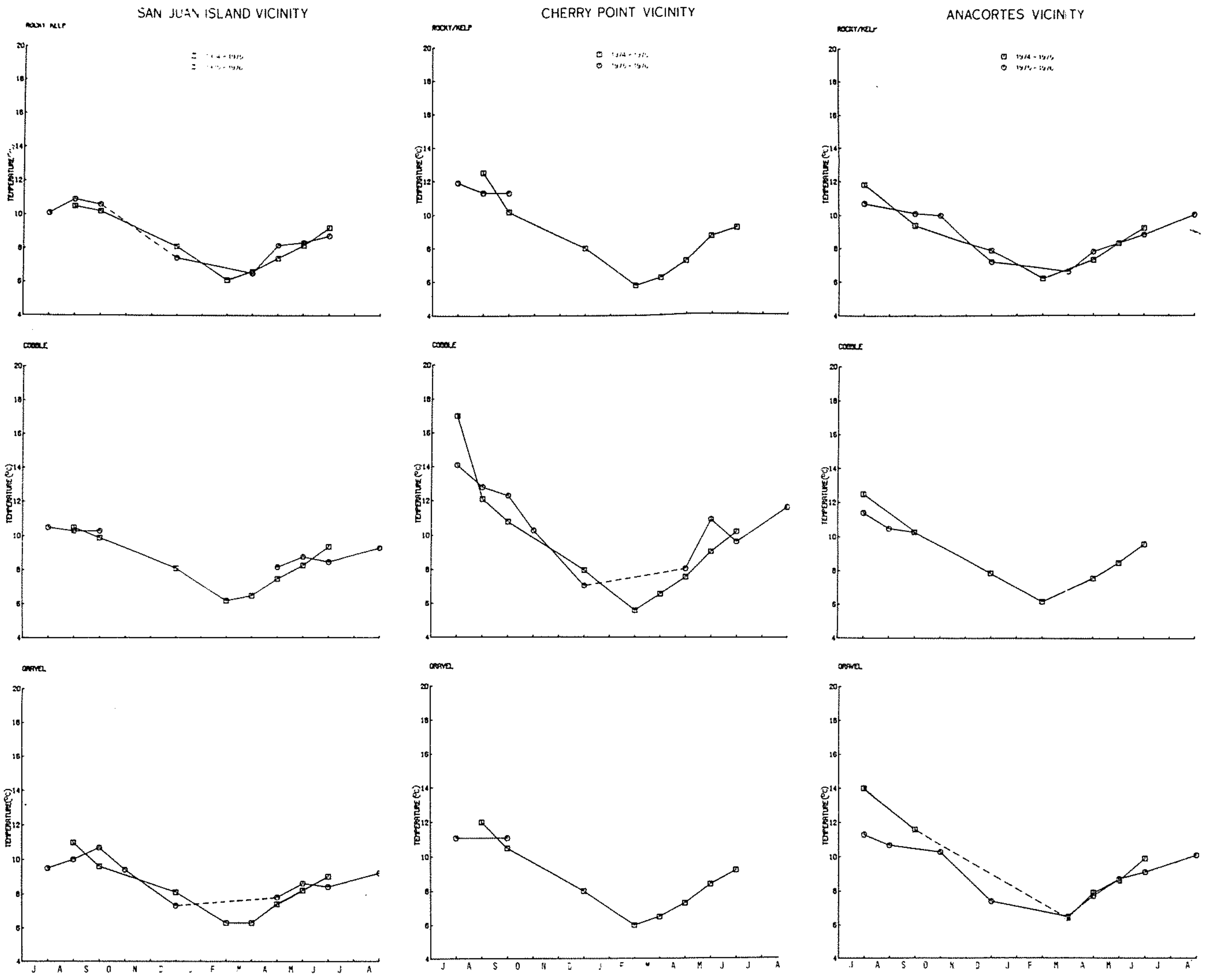


Fig. 14-A. Temperature (°C) values for neritic waters in five northern Puget Sound habitats sampled by tow net during the two years of the Nearshore Fish Survey, 1974-1976.

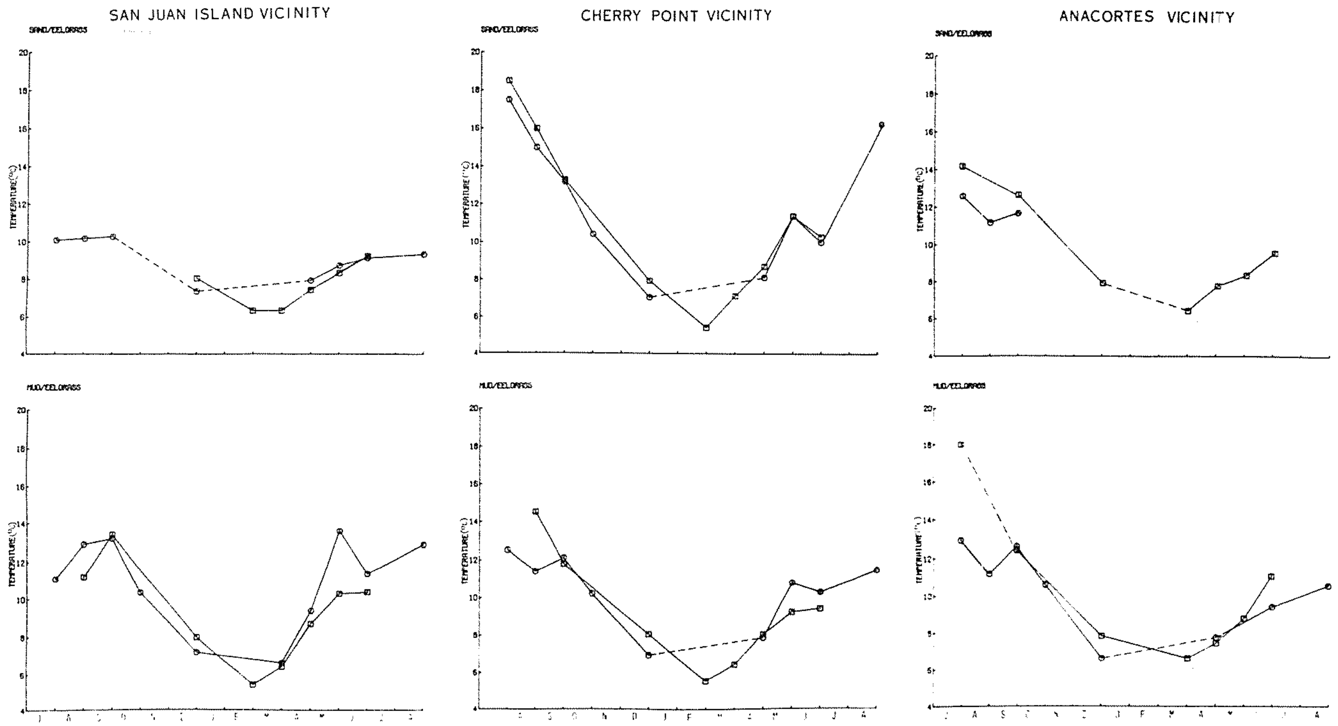


Fig. 14-A.cont'd

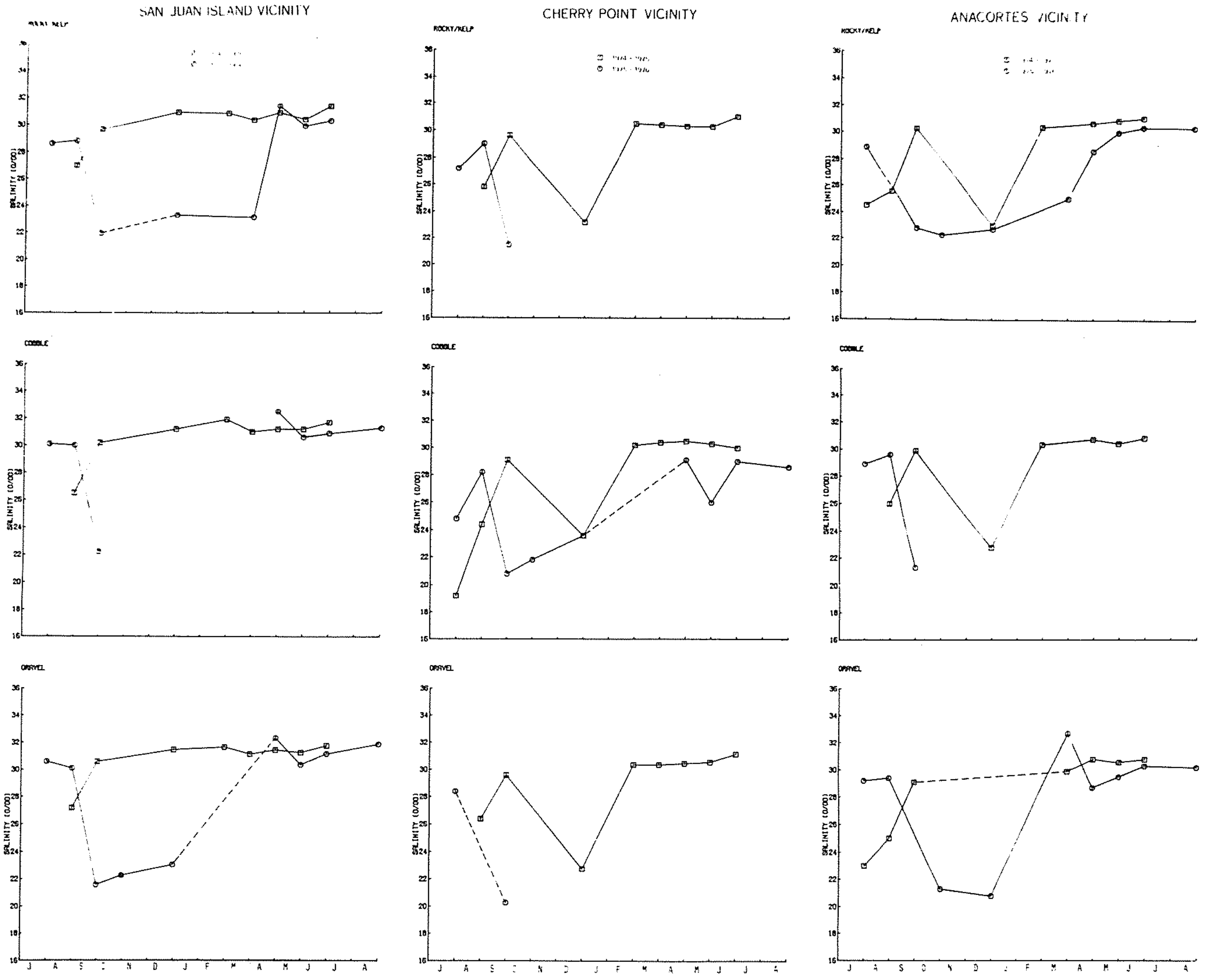


Fig. 14-B. Salinity (°/∘∘) values for neritic waters in five northern Puget Sound habitats sampled by tow net during the two years of the Nearshore Fish Survey, 1974-1976.

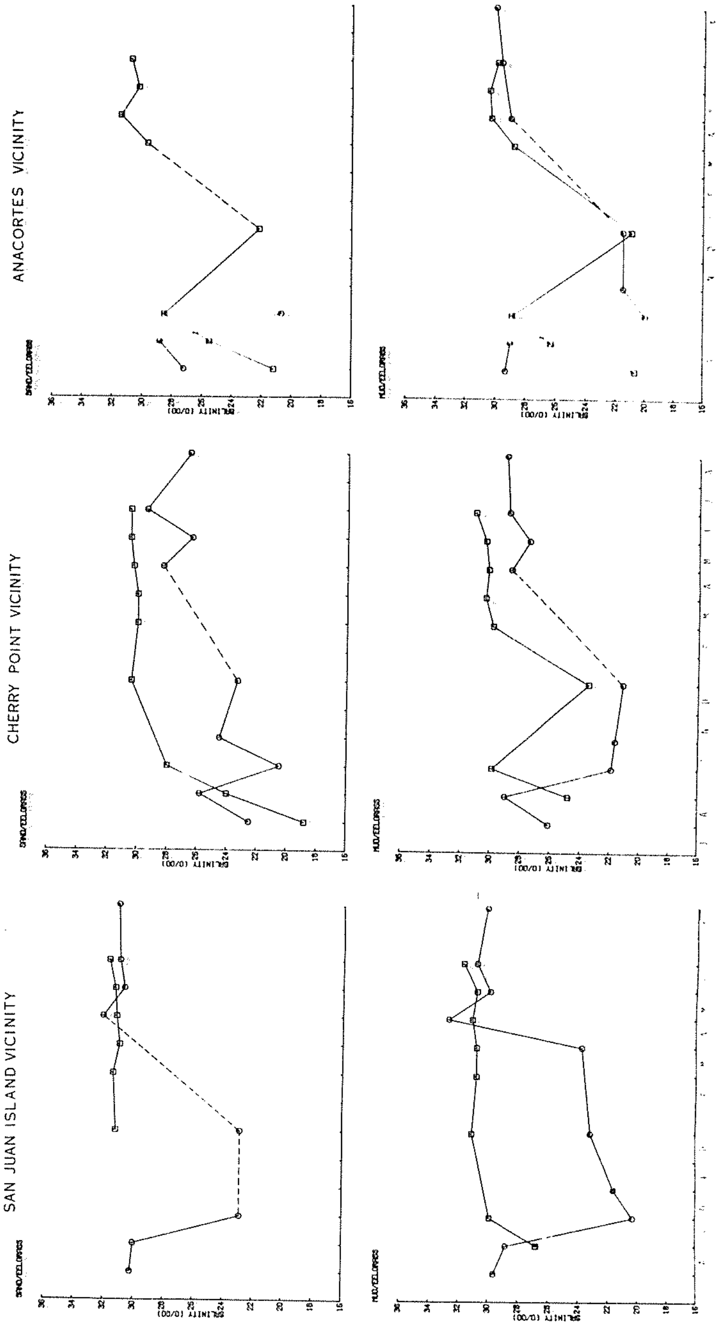


Fig. 14-B. cont'd

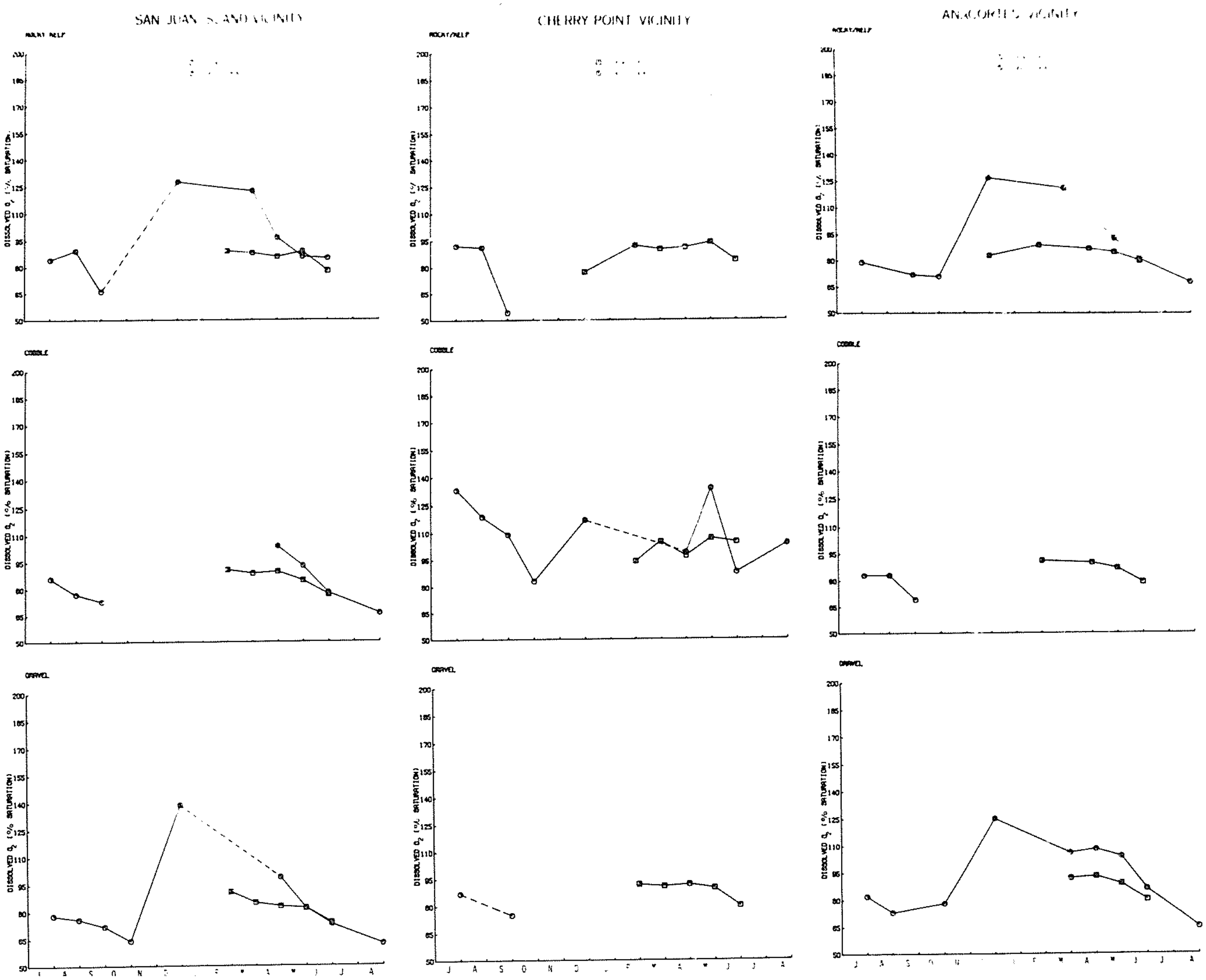


Fig. 14-C. Dissolved oxygen (% saturation) values for neritic waters in five northern Puget Sound habitats sampled by tow net during the two years of the Nearshore Fish Survey, 1974-1976.

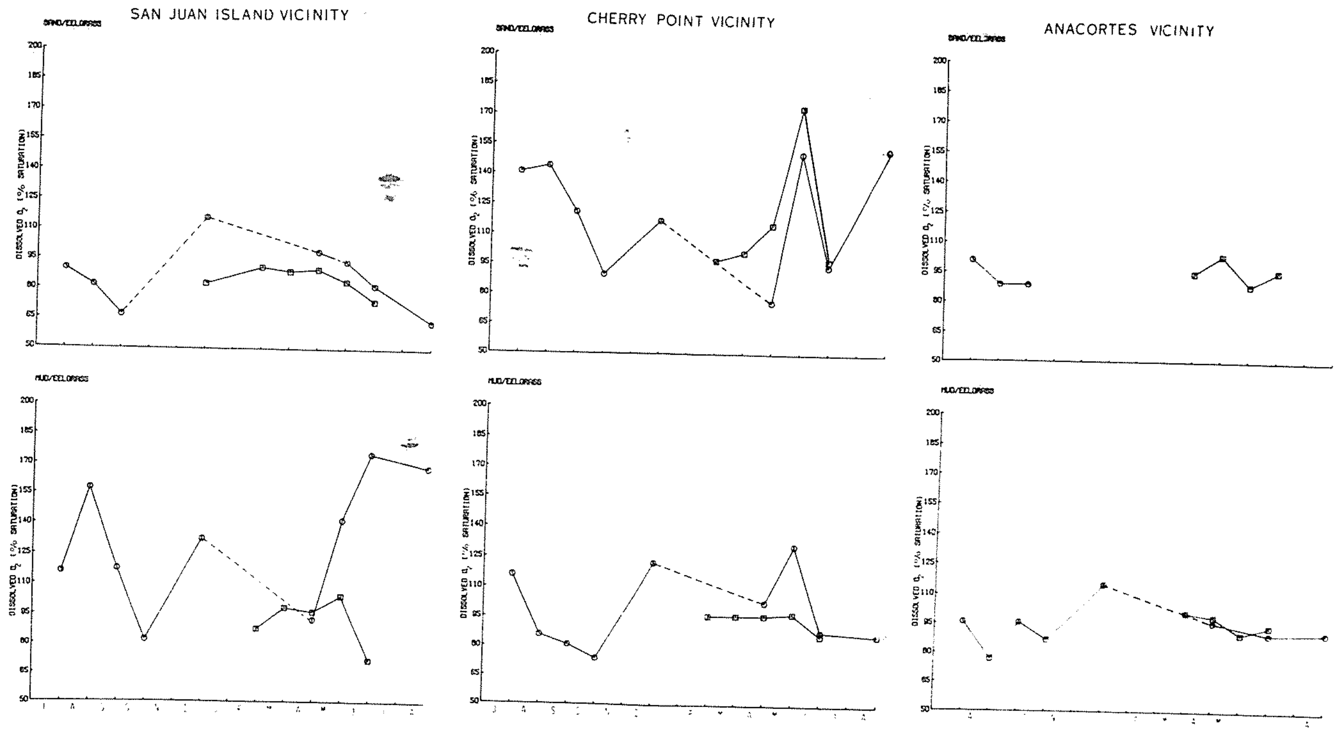


Fig. 14-C.cont'd

Table 5a. Species of neritic fishes captured during the first year, July 1974 through June 1975

Species	Common Name	Number of occurrences	Abundance	Biomass (grams)
Entosphenus tridentatus	Pacific lamprey	1	3	25.0
Lampetra ayresi	river lamprey	3	3	17.0
Squalus acanthias	spiny dogfish	14	30	17,897.0
Hydrolagus colliei	ratfish	1	1	5.6
Clupea harengus pallasi	Pacific herring	235	130,700	210,900.0
Engraulis mordax	northern anchovy	9	31	150.8
Oncorhynchus gorbuscha	pink salmon	13	23	267.0
O. keta	chum salmon	33	112	1,470.9
O. kisutch	coho salmon	30	102	1,883.6
O. nerka	sockeye salmon	7	29	377.0
O. tshawytscha	chinook salmon	58	240	5,194.4
Hypomesus pretiosus	surf smelt	86	940	4,434.7
Spirinchus thaleichthys	longfin smelt	47	269	1,372.9
Stenobrachius leucopsarus	northern lampfish	1	1	0.3
Porichthys notatus	plainfin midshipman	1	1	13.0
Microgadus proximus	Pacific tomcod	13	290	1,641.0
Lycodopsis pacifica	blackbelly eelpout	4	22	1.6
Aulorhynchus flavidus	tube-snout	10	58	112.6
Gasterosteus aculeatus	threespine stickleback	186	11,361	12,985.1
Syngnathus griseolineatus	bay pipefish	14	24	22.7
Cymatogaster aggregata	shiner perch	22	877	7,025.0
Embiotoca lateralis	striped seaperch	1	1	10.0
Rhacochilus vacca	pile perch	1	16	289.0
Trichodon trichodon	Pacific sandfish	4	7	346.7
Lumpenus sagitta	snake prickleback	22	100	126.3
Poroclinus rothrocki	whitebarred prickleback	1	1	24.0
Apodichthys flavidus	penpoint gunnel	1	2	12.0
Pholis clemensi	longfin gunnel	1	3	0.6
P. laeta	crescent gunnel	16	30	109.6
P. ornata	saddleback gunnel	20	22	136.0
Lyconectes aleutensis	dwarf wrymouth	4	23	1.8
Ammodytes hexapterus	Pacific sand lance	108	9,918	4,642.1
Clevelandia ios	arrow goby	1	1	0.5
Lepidogobius lepidus	bay goby	4	15	16.4

Table 5a. Species of neritic fishes captured during the first year, July 1974 through June 1975 - Continued

Species	Common Name	Number of occurrences	Abundance	Biomass (grams)
Sebastes caurinus	copper rockfish	1	1	1.0
Hexagrammos decagrammus	kelp greenling	14	72	212.0
Ophiodon elongatus	lingcod	2	2	5.3
Artedius lateralis	smoothhead sculpin	1	1	5.0
Blepsias cirrhosus	silverspotted sculpin	3	4	5.1
Gilbertidia sigalutes	soft sculpin	32	112	67.1
Leptocottus armatus	Pacific staghorn sculpin	60	254	8,262.0
Nautichthys oculofasciatus	sailfin sculpin	2	2	0.2
Oligocottus rimensis	saddleback sculpin	1	3	10.0
Psychrolutes paradoxus	tadpole sculpin	49	1,892	205.0
Radulinus boleoides	darter sculpin	2	101	7.3
Rhamphocottus richardsoni	grunt sculpin	8	13	1.0
Scorpaenichthys marmoratus	cabezon	1	1	1.0
Agonopsis emmelane	northern spearnose poacher	1	1	0.0
Agonus acipenserinus	sturgeon poacher	5	6	97.8
Odontopyxis trispinosa	pygmy poacher	1	1	0.2
Pallasina barbata	tubenose poacher	6	6	15.0
Xeneretmus latifrons	blacktip poacher	2	2	1.0
X. triacanthus	bluespotted poacher	1	1	0.0
Eumicrotremus orbis	Pacific spiny lumpsucker	2	3	14.0
Liparis callyodon	spotted snailfish	2	3	21.0
L. fucensis	slipskin snailfish	1	1	0.8
Liparis rutteri	ringtail snailfish	1	1	3.0
Isopsetta isolepis	butter sole	1	1	0.0
Lepidopsetta bilineata	rock sole	1	1	505.0
Microstomus pacificus	Dover sole	4	4	4.1
Parophrys vetulus	English sole	16	24	458.4
Platichthys stellatus	starry flounder	17	28	10,943.0
Psettichthys melanostictus	sand sole	1	4	0.2
Unidentified species		175	540	86.1
Total 63 species		1,385	158,341	292,500.3

Table 5b. Species of neritic fishes captured during the second year, July 1975 through August 1976

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Lampetra ayresi	river lamprey	2	2	40.0
Squalus acanthias	spiny dogfish	13	59	55,205.0
Clupea harengus pallasi	Pacific herring	161	199,000	360,000.0
Engraulis mordax	northern anchovy	38	176	1,431.7
Oncorhynchus gorbuscha	pink salmon	30	104	773.3
O. keta	chum salmon	23	37	352.9
O. kisutch	coho salmon	33	100	2,999.7
O. nerka	sockeye salmon	3	29	255.5
O. tshawytscha	chinook salmon	40	260	3,910.4
Hypomesus pretiosus	surf smelt	62	1,780	1,339.6
Mallotus villosus	capelin	1	1	5.2
Spirinchus thaleichthys	longfin smelt	59	2,092	3,640.2
Thaleichthys pacificus	eulachon	1	1	11.5
Porichthys notatus	plainfin midshipman	3	11	63.7
Microgadus proximus	Pacific tomcod	16	372	416.9
Theragra chalcogramma	walleye pollock	15	74	52.5
Aulorhynchus flavidus	tubesnout	7	16	13.2
Gasterosteus aculeatus	threespine stickleback	120	3,525	3,447.1
Syngnathus griseolineatus	bay pipefish	12	34	41.4
Cymatogaster aggregata	shiner perch	20	190	1,410.3
Embiotoca lateralis	striped seaperch	1	1	4.6
Trichodon trichodon	Pacific sandfish	9	17	230.0
Lumpenus maculatus	daubed shanny	1	2	4.7
L. sagitta	snake prickleback	28	605	510.8
Plectobranchus evides	bluebarred prickleback	1	1	1.8
Apodichthys flavidus	penpoint gunnel	1	1	0.8
Pholis laeta	crescent gunnel	7	8	29.2
P. ornata	saddleback gunnel	13	15	50.3
Ammodytes hexapterus	Pacific sandlance	77	23,707	27,143.4
Clevelandia ios	arrow goby	1	1	0.2
Lepidogobius lepidus	bay goby	3	3	12.1
Ophiodon elongatus	lingcod	2	3	3.7
Blepsias cirrhosus	silverspotted sculpin	6	10	25.5
Gilbertidia sigalutes	soft sculpin	21	189	141.5

Table 5b. Species of neritic fishes captured during the second year, July 1975 through August 1976 - Continued

Species	Common name	Number of occurrences	Abundance	Biomass (grams)
Hemilepidotus hemilepidotus	red Irish lord	1	1	20.3
Leptocottus armatus	Pacific staghorn sculpin	50	149	7,463.4
Psychrolutes paradoxus	tadpole sculpin	32	383	126.3
Rhamphocottus richardsoni	grunt sculpin	5	8	0.4
Agonus acipenserinus	sturgeon poacher	3	3	29.7
Asterotheca alascana	gray starsnout	1	1	5.1
Pallasina barbata	tubenose poacher	4	5	12.5
Eumicrotremus orbis	Pacific spiny lumpsucker	3	4	23.4
Liparis florae	tidepool snailfish	1	1	0.6
L. fucensis	slipskin snailfish	1	2	0.6
Lepidopsetta bilineata	rock sole	1	1	9.6
Parophrys vetulus	English sole	14	58	27.9
Platichthys stellatus	starry flounder	14	42	25,995.4
Unidentified		51	113	6.5
Total 47 species		1,008	238,197	497,290.4

Table 6. The ten most common neritic fishes of northern Puget Sound ranked according to occurrence, abundance, and biomass, 1974-1976.

	1974-1975			1975-1976		
Species	Occurrence	Abundance	Biomass	Occurrence	Abundance	Biomass
Pacific herring juveniles, larvae	1	1	1	1	1	1
Threespine stickleback adults, juveniles	2	2	3	2	3	8
Pacific sand lance larvae to adults	3	3	8	3	2	3
Surf smelt larvae to adults	4	5	9	4	5	
Pacific staghorn sculpin juveniles, adults	5	7	5	6		5
Chinook salmon juveniles	6	10	7	7	9	6
Tadpole sculpin larvae to adults	7	4		10	7	
Longfin smelt juveniles, adults	8	9		5	4	7
Chum salmon juveniles	9					
Soft sculpin larvae to adults	10					
Shiner perch juveniles, adults		6	6		10	
Pacific tomcod juveniles		8			8	
Spiny dogfish immature adults			2			2
Starry flounder juveniles, adults			4			4
Coho salmon juveniles			10	9		9
Northern anchovy adults				8		10
Snake prickleback juveniles, adults					6	

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*Shared rank

Puget Sound, followed by threespine stickleback (although not by biomass), and Pacific sand lance. Spiny dogfish and starry flounder ranked high in total biomass but relatively lower in occurrence and abundance. Juvenile salmonids, smelt, and neritic cottids also ranked high in these assemblages.

The species richness for the collections was plotted against collection month (Fig. 15) and summarized by habitat and geographical area (Table 7).

All habitats seemed to follow the same trends in species richness. Maximum number of species occurred during the late spring and summer, followed by a gradual reduction in the fall with minimum species richness in the winter. The eelgrass and cobble habitats were consistently the most species-rich and most variable, while the gravel and rocky/kelp bed habitats were the least species-rich and least variable. Significant geographical variation was also apparent from the data. Eastside habitats were usually more species-rich and more variable while the San Juan Island habitats were lower in species richness with less variation.

Density

The relative densities (fish/m^3) of neritic fishes in the nearshore habitats were plotted (Fig. 16) and summarized (Table 7). Consistent patterns of density were evident in all habitats studied. Lowest densities occurred in the winter when a 10-minute tow often yielded less than 0.01 fish/m^3 (30 fish). A moderate increase in catches was observed in early spring, caused by the abundance of the larvae of some pelagic species (mostly Pacific herring, Pacific sand lance, and surf smelt). This increase was more substantial in the more protected eelgrass habitats. In middle to late spring a greater increase was observed, primarily due to the appearance of larval and juvenile Pacific herring and juvenile and adult threespine stickleback. Peak densities (as high as 2.62 fish/m^3) occurred during the late summer with juvenile Pacific herring, adult threespine stickleback, and juvenile Pacific sand lance being the most prominent species. Juvenile salmonids and juvenile and adult smelt were also consistently well-represented in late summer catches. Density then decreased during the fall to the low winter levels.

The mud/eelgrass habitat generally exhibited a wider range of densities than the other habitats. In the winter, levels of density were similar to those observed in other habitats; however, during other periods maximum densities were typically higher in the mud/eelgrass habitat than the other habitats. In all the mud/eelgrass sites and in the Birch Bay sand/eelgrass site, the fall decrease to winter lows occurred later in the fall than at other sites.

Substantial differences in density occurred between sites of the same habitat type in three of our study habitats--rocky/kelp bed, cobble, and sand/eelgrass. At rocky/kelp bed sites, large, infrequent catches of Pacific herring and Pacific sand lance occurred during the summer at

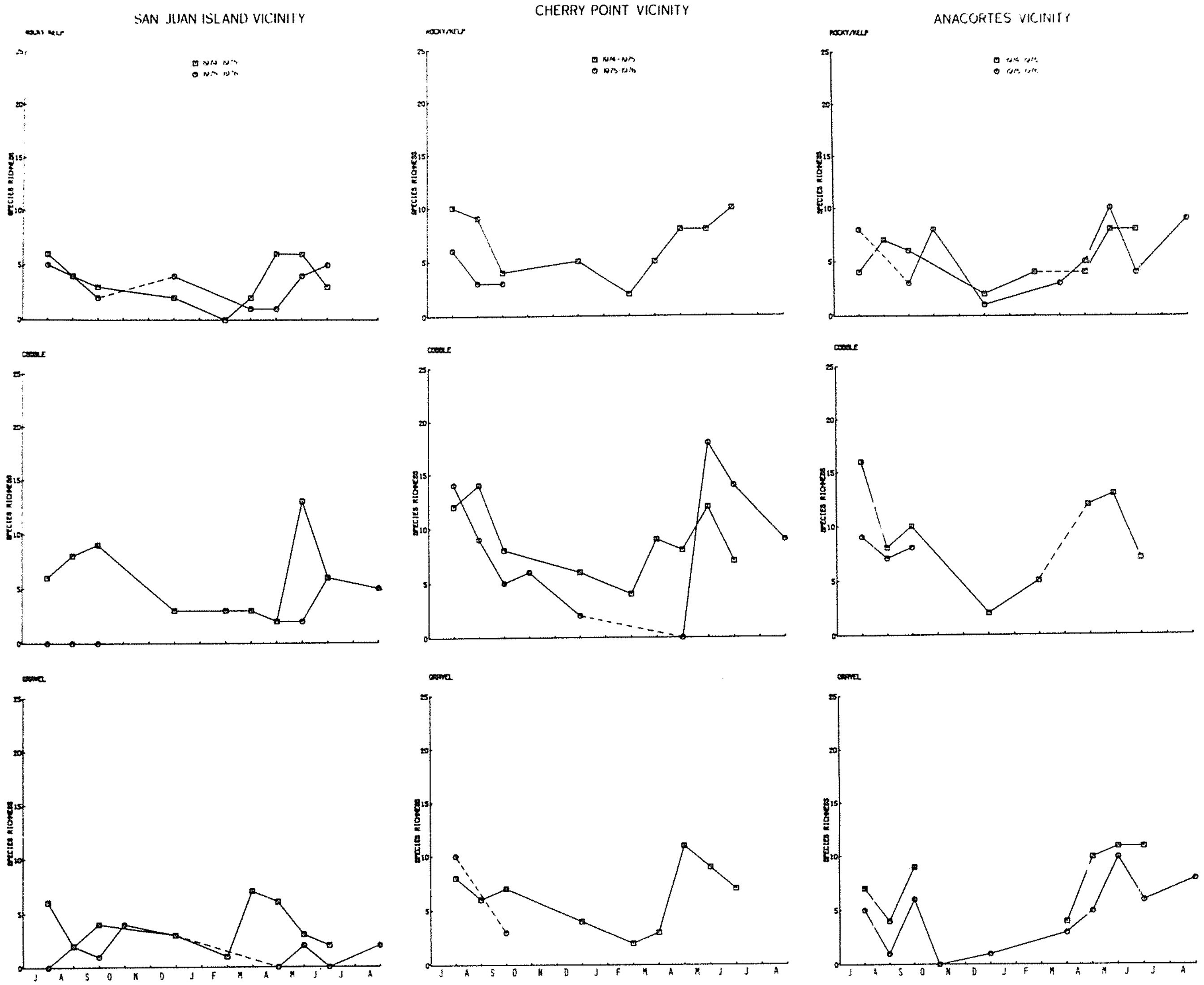

Fig. 15. Species richness of neritic fishes in tow net collections for the two years of the Nearshore Fish Survey, 1974-1976.

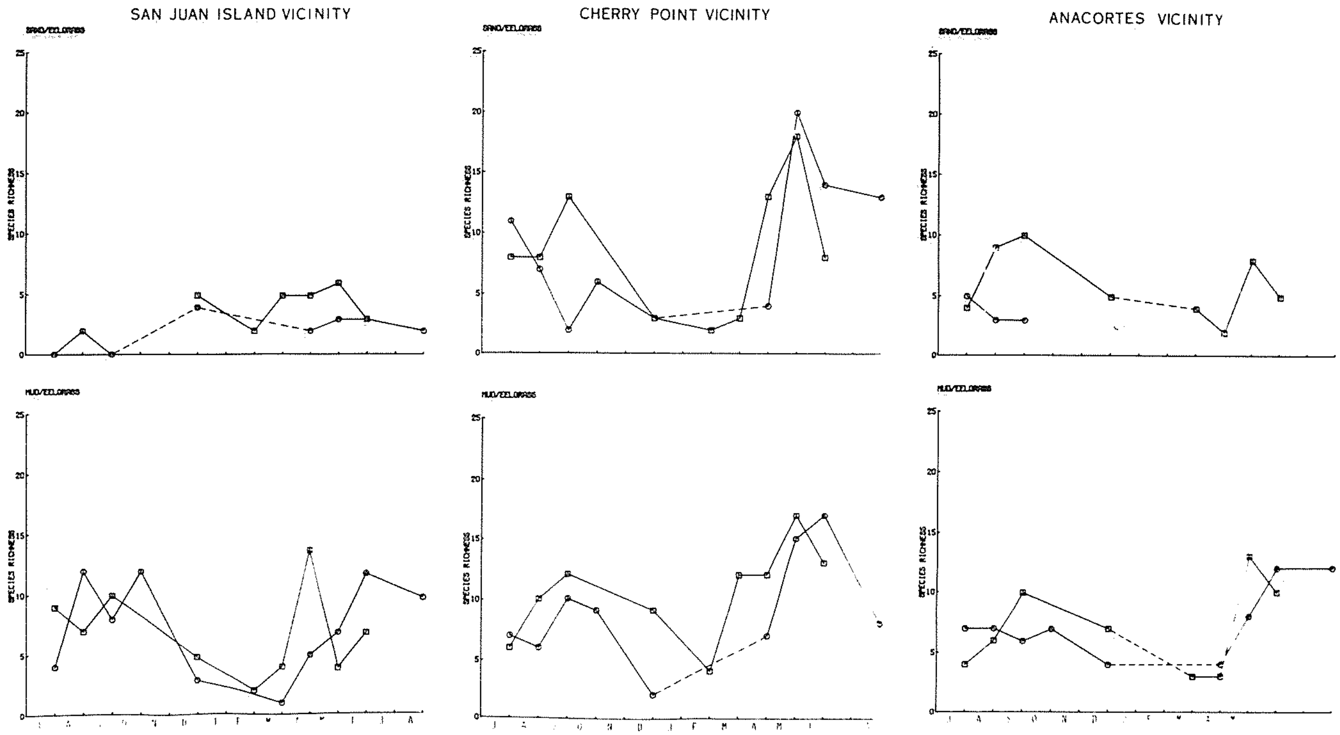
SAN JUAN ISLAND VICINITY
CHERRY POINT VICINITY
ANACORTES VICINITY
SAND/EELGRASS
MUD/EELGRASS
SPECIES RICHNESS
0
5
10
15
20
25
J
A
S
O
N
D
J
F
M
A
M
J
J
A

Fig. 15, cont'd

Table 7. Mean catch data for 1974-1976 tow net collections: (a) By site, (b) summarized by habitat, and (c) summarized by geographical area.

Habitat	Site	Sample size, n	Mean species richness	Mean density (fish/m^3)	Mean standing crop(gr/m^3)
Rocky/ kelp bed	Pt. George, San Juan Is.	17	3.4	0.29	0.14
	Pt. Migley, Lummi Is.	12	6.1	0.01	0.03
	Burrows Island	17	5.5	$<$ 0.01	0.01
Cobble	South Beach, San Juan Is.	16	4.3	$<$ 0.01	0.01
	Cherry Pt.	18	8.7	0.05	0.13
	Shannon Pt., Fidalgo Is.	11	8.8	0.02	0.04
Gravel	Deadman Bay, San Juan Is.	18	2.7	$<$ 0.01	0.01
	Village Pt., Lummi Is.	11	6.4	0.01	0.03
	Guemes Island, South	17	5.9	0.01	0.04
Sand/ eelgrass	Eagle Cove, San Juan Is.	14	3.1	$<$ 0.01	$<$ 0.01
	Birch Bay	18	8.7	0.32	0.69
	Guemes Island, East	11	5.3	0.02	0.08
Mud/ eelgrass	Westcott Bay, San Juan Is.	19	7.2	0.12	0.33
	Lummi Bay	18	9.8	0.10	0.26
	Padilla Bay	17	7.2	0.03	0.23
	Total	234			

Habitat	Sample size n	Mean species richness	Mean density (fish/m^3)	Mean standing crop(gr/m^3)
Rocky/kelp bed	46	4.9	0.11	0.06
Cobble	45	7.2	0.03	0.07
Gravel	46	4.8	0.01	0.03
Sand/eelgrass	43	6.0	0.14	0.31
Mud/eelgrass	54	8.1	0.09	0.27

Geographic area (vicinity)	Sample size n	Mean species richness	Mean density (fish/m^3)	Mean standing crop(gr/m^3)
San Juan Is.	84	4.2	0.09	0.11
Cherry Pt.	77	8.2	0.12	0.26
Anacortes	73	6.5	0.01	0.09

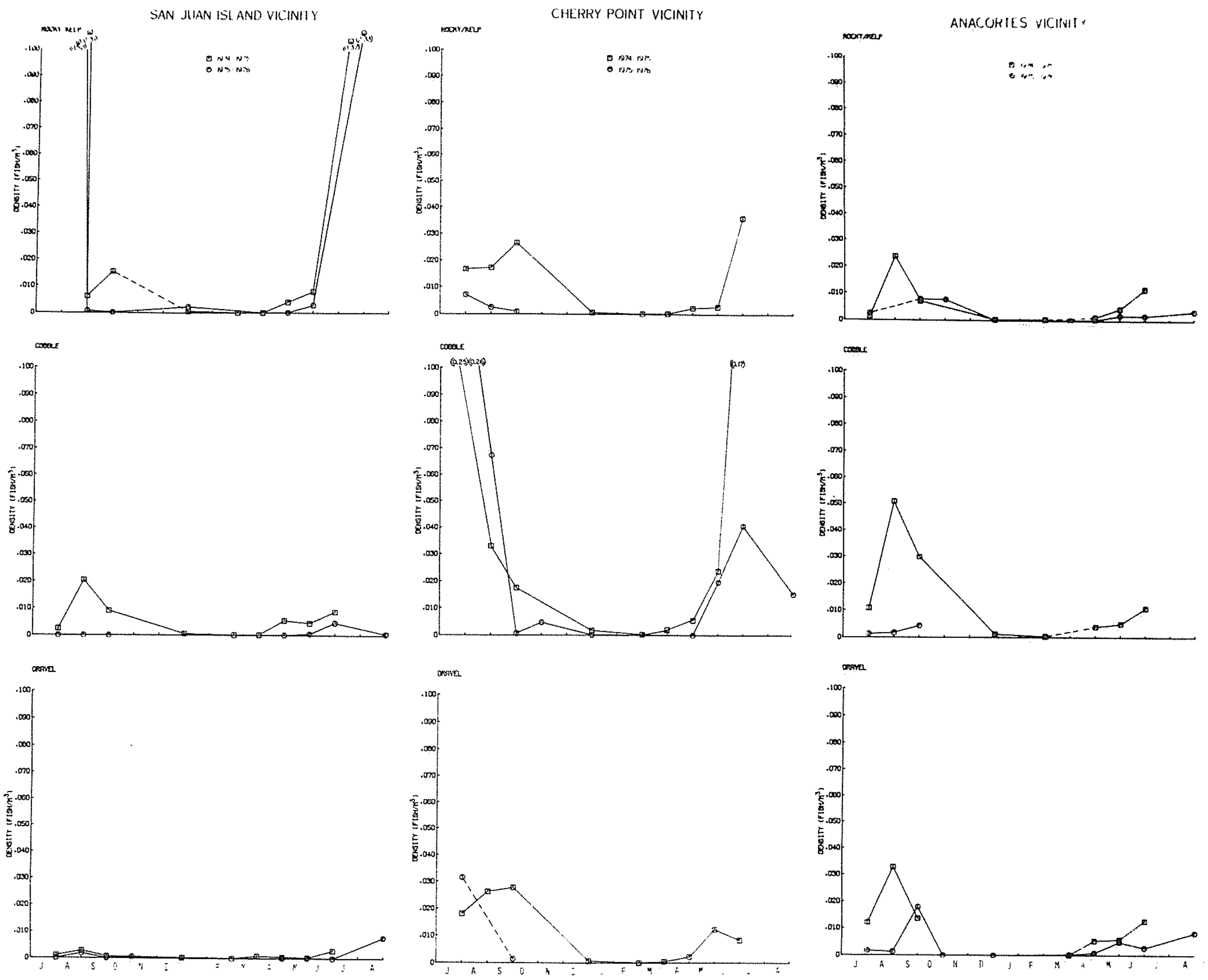

Fig. 16. Densities (fish/m^3) of neritic fishes in tow net collections for the two years of the Nearshore Fish Survey, 1974-1976.

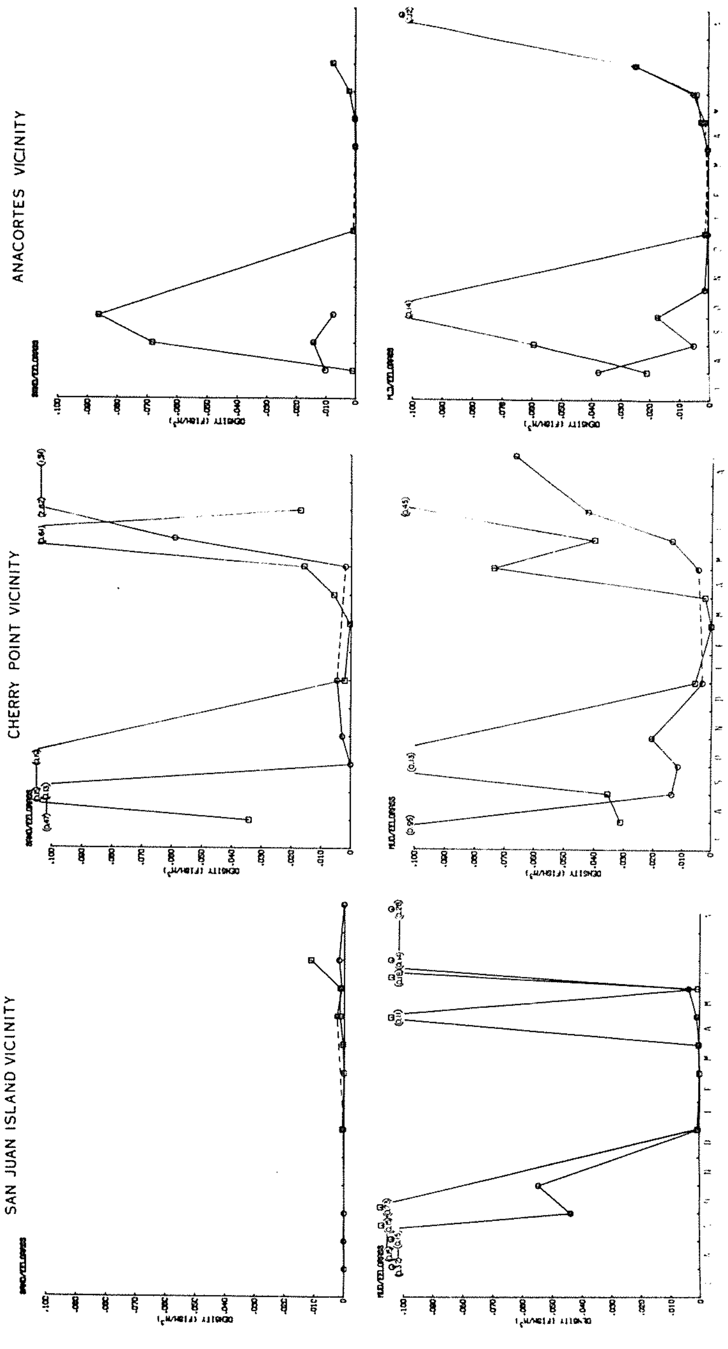
SAN JUAN ISLAND VICINITY
CHERRY POINT VICINITY
ANACORTES VICINITY
SAND/EELGRASS
MUD/EELGRASS
DENSITY (FISH/m²)
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
0

Fig. 16, cont'd

the Point George site but not at the other two sites of this habitat type. As a result, mean density at Point George was over 30 times greater than at either of the other two rocky/kelp bed sites (Table 7). Densities at the three cobble sites were similar to each other in the winter but differed substantially during spring through fall. At South Beach, consistently low densities were observed during spring through fall (values never exceeded 0.02 fish/m^3), while at Cherry Point much higher densities were observed during this period. Densities as high as 0.30 fish/m^3 at Cherry Point were due primarily to schooling Pacific herring. Shannon Point densities were intermediate between Cherry Point and South Beach densities. All sites of the sand/eelgrass habitat differed greatly in their respective densities. Eagle Cove had consistently low densities that never exceeded 0.01 fish/m^3 during the entire study period. Densities at Birch Bay were high, the average density (0.32 fish/m^3) being greater than at any of the other 14 sites. Pacific herring dominated these large catches at Birch Bay. Catches at the Guemes East site were intermediate between the other two sites, averaging 0.02 fish/m^3.

Seasonal trends were consistent from year to year, although the timing varied somewhat. There was also some annual variation in maximum densities.

Standing Crop

Catch biomass, converted to standing crop in g/m^3, was plotted against collection month (Fig. 17). The patterns of standing crop values were similar to density patterns, exhibiting spring increases to maximum values of standing crop in the summer. There was then a fall decrease to sparse levels in the winter. The most protected habitats had the highest mean standing crop values while the most exposed habitats had the lowest (Table 7).

Standing crop was greatly influenced by sporadic catches of a very few, large individuals, primarily spiny dogfish, Pacific staghorn sculpin, and starry flounder. Catches of these large species were more common at the Cherry Point area and Anacortes area habitats.

Seasonal trends in standing crop were consistent between the two years although, as with density, the timing varied. The greatest variations in magnitude between the two years were during the summer, with the least variation in the winter.

Diversity

Due to the low species richness and the high variability characterizing the neritic fish catch data (unlike the demersal fish data), it was felt that use of the Shannon-Weiner (H') diversity and biomass indices was neither appropriate nor useful.

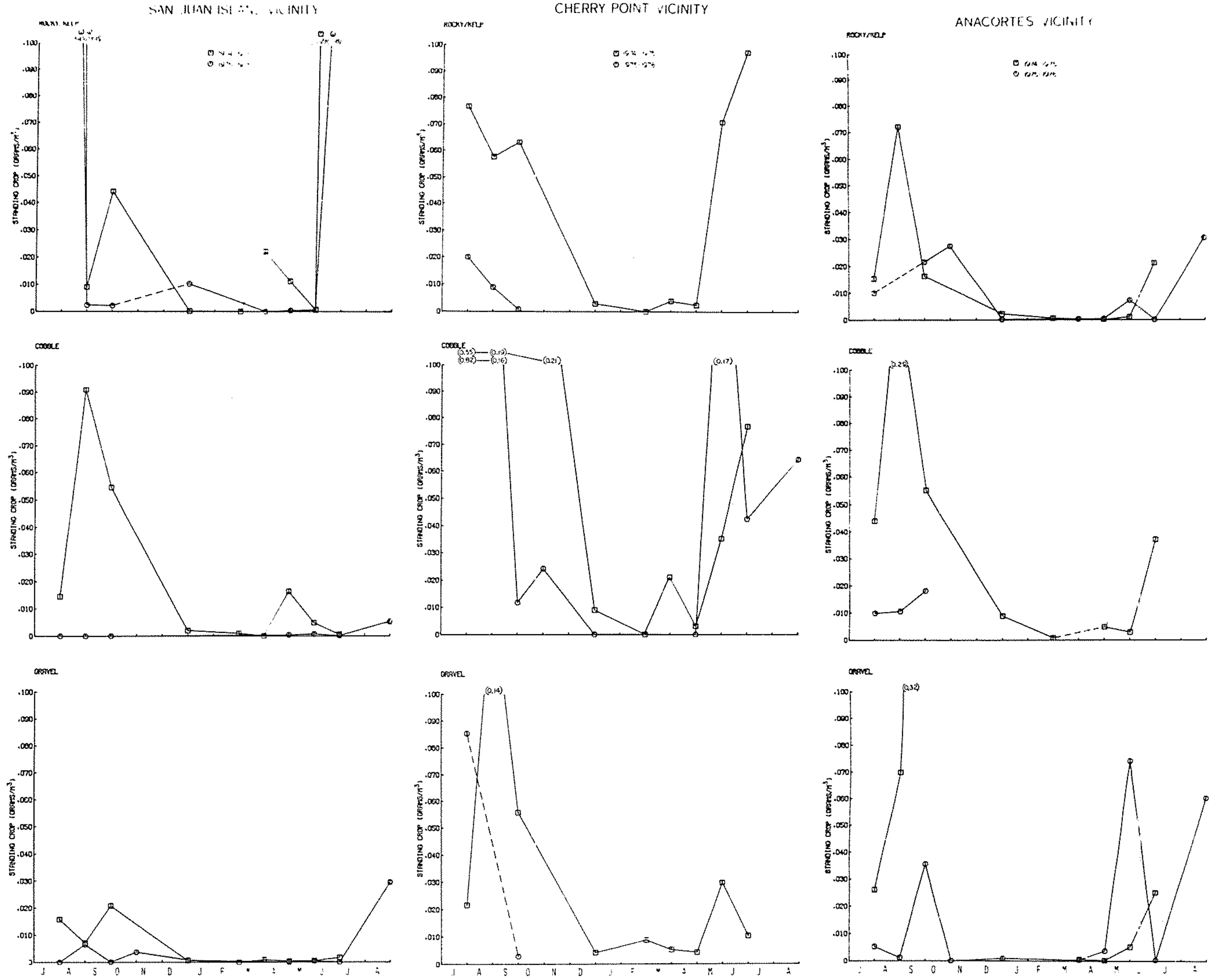

Fig. 17. Standing crop (grams/m^3) of neritic fishes in tow net collections for the two years of the Nearshore Fish Survey, 1974-1976.

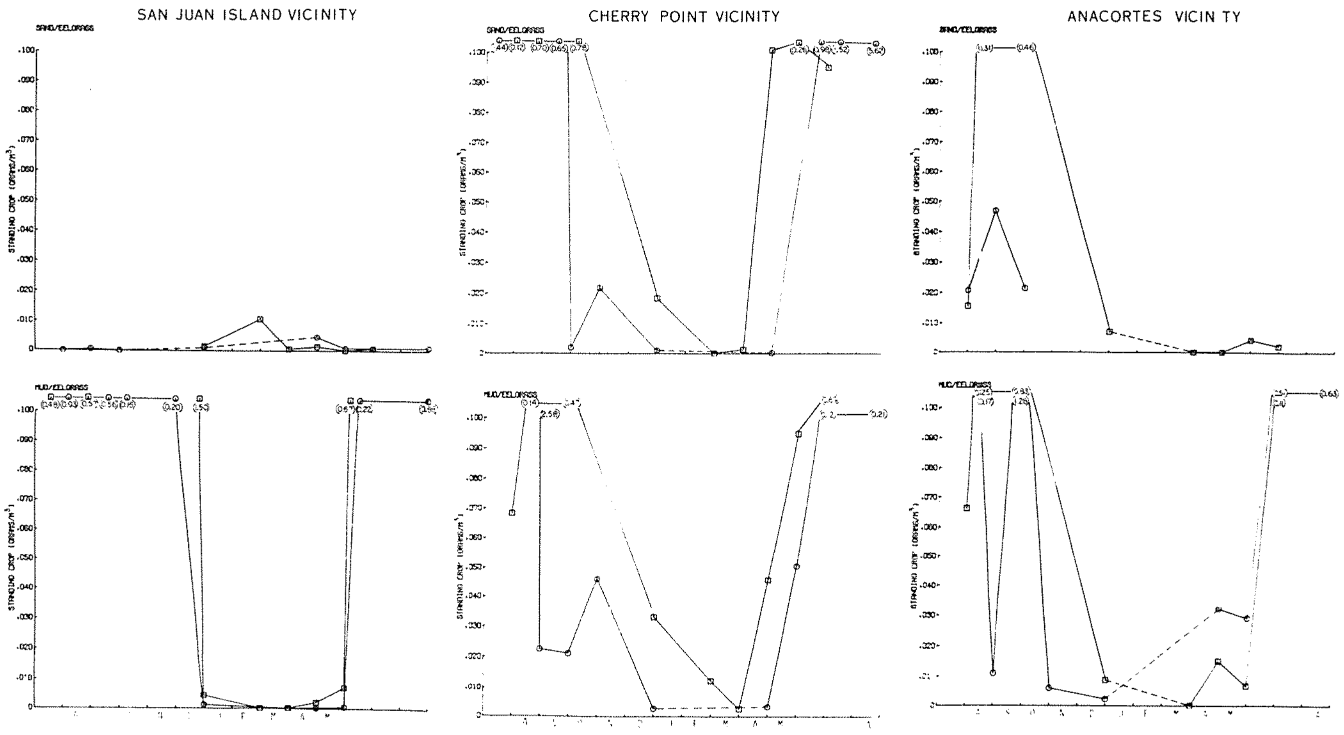
SAN JUAN ISLAND VICINITY
CHERRY POINT VICINITY
ANACORTES VICINITY
SAND/EELGRASS
MUD/EELGRASS
STANDING CROP (GRAMS/M³)
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
0

Fig. 17, cont'd

the fall, as the juveniles occupied the neritic waters. Longfin smelt, surf smelt, Pacific staghorn sculpin, and juvenile chinook salmon were other less common members of the neritic fish assemblage adjacent to this habitat. Other species, principally demersal, were infrequently captured, accounting for the high species richness values.

This habitat exhibited considerable regional variation, as did the rocky/kelp bed and sand/eelgrass habitats. The northeastern cobble sites were more species-rich than the San Juan Island site. Density and standing crop were also typically higher at the northeastern sites, with the Cherry Point site exhibiting greater densities and standing crop than the other two sites. The larger catches at Cherry Point were dominated by herring. The reduced exposure and closer proximity to known herring spawning grounds of Cherry Point might account for some of this between site variation.

As was observed at the other habitats, salmon catches were considerably lower at the San Juan Island site, possibly reflecting the closer proximity of eastside sites to spawning rivers. In addition, smelt catches and Pacific staghorn sculpin catches were higher at the northeastern sites than at the San Juan Island site.

Gravel

The gravel habitat possessed the least species-rich fauna and was also poorest in terms of density and standing crop, perhaps because of greater exposure and the stronger currents sweeping this habitat. Homogeneous substrate and lack of algal coverage may also help account for the lack of a rich neritic fish fauna.

Patterns in species richness, density, and standing crop at this habitat were most like those of the other more exposed habitats--rocky/kelp bed and cobble. Again, a spring increase in fish larvae was seen to succeed the sparse fauna present in the winter. Maximum species richness, density, and standing crop were then maintained from late spring through late summer. In late summer and early fall, there occurred a rapid decrease in the neritic fish density and biomass.

Juvenile Pacific herring and threespine stickleback were the most common members of this assemblage. Herring usually appeared first as larvae in early spring and were most abundant as juveniles in the summer, although their numbers were fewer here than at any other site. Threespine stickleback were first caught in the early spring as juveniles and then reached their maximum numbers as adults in the summer.

Other species, caught less frequently and in smaller numbers than the Pacific herring and threespine stickleback, included Pacific sand lance and surf smelt. Their larvae were present at this habitat in early spring. Small numbers of juveniles of these two species persisted throughout the summer until early fall. Juvenile chum salmon and coho salmon appeared during late spring and were found intermittently in our catches until early fall.

The San Juan Island gravel habitat at Deadman Bay typically possessed the least species-rich and least dense assemblage as compared to the eastside sites, possibly because of the greater exposure of the San Juan Island site, the more confined nature of this site, and the more turbid estuarine conditions (possibly decreasing net avoidance) present around the Anacortes and Cherry Point sites.

Sand/Eelgrass

A great amount of variation exists in the data from the three study sites for the sand/eelgrass habitat. It was therefore difficult to obtain a clear view of the characteristic neritic assemblage present adjacent to this habitat.

Trends observed at sites in this habitat appeared similar to those found in the mud/eelgrass habitat, although the late fall decrease of fish was not as prominent in this habitat as a whole. This decrease was, however, far more evident at Birch Bay than at the other two sites.

Juvenile Pacific herring, threespine stickleback, and Pacific sand lance were the most prominent species in this habitat. Other important members of the assemblage, especially from the northeastern sites, were juvenile chinook salmon, surf smelt, and longfin smelt. Some typical demersal species--snake prickleback, staghorn sculpin, and starry flounder--were also observed in the catches. Nocturnal migration might account for the presence of these demersal fishes.

Substantial geographical variations in catch existed within this habitat and may be the consequence of a number of factors. The two northeastern sites, Birch Bay and East Guemes Island, covered a far greater area than the confined San Juan Island site at Eagle Cove. Additionally, it was only possible to sample the waters just adjacent to Eagle Cove rather than within the embayment itself; whereas at the Birch Bay and East Guemes Island sites it was possible to sample in the bays, directly over the eelgrass. Eagle Cove was also far more exposed and subject to stronger currents than the other two sites.

Birch Bay, the Cherry Point area site, appeared to be a very important area in the nearshore environment in north Puget Sound. It seemed to be a particularly important area for larval and juvenile Pacific herring since more nonadult herring (an average of 3,555 per tow) were caught there than at any other site. This was also reflected by the fact that 95.5 percent of the total catch at Birch Bay was herring, more than at any other site. Many of these larvae and juveniles may originate from adjacent habitats and migrate into the embayment. It was difficult from our data to assess the importance of the bay to adults since none were captured by our gear. This was somewhat surprising since the sampling site is close to known spawning grounds (Millikan et al. 1974). However, the actual spawning activity covers a very short period and may have been missed within our sampling frequency.

Mud/Eelgrass

The mud/eelgrass habitat supported the richest, most abundant fish assemblages. While low levels of density and standing crop were similar to those observed in the other habitats, maximum levels attained during the summer and early fall were generally greater in the mud/eelgrass habitat. Observed increases and decreases in density were typically more marked in this habitat, indicating a more rapid immigration and emigration of fish.

The reasons for the high density and standing crop characteristic of this habitat cannot be determined precisely, although some explanations can be suggested. Temperature preferences of the pelagic fish or their food items might be important since the mud/eelgrass habitats were warmer than most other habitats. Also, eelgrass might afford more protection and food, hence a more favorable environment for spawning fish and fish larvae in the spring and for older fish in the summer and fall. The mud/eelgrass habitats may also be preferred because their protected nature makes them less physically stressful to fish than more exposed habitats.

The late fall decrease in density observed at mud/eelgrass sites (and at the Birch Bay sand/eelgrass site) may also be a function of exposure. As the more exposed habitats become more influenced by weather in the fall, fish may leave these exposed areas for the less exposed bays before eventually moving into deeper water for the winter. Temperature preferences may also be a factor since these sites were warmer longer in the fall than other sites.

Pacific herring, threespine stickleback, Pacific sand lance, and surf smelt were the dominant pelagic species caught adjacent to this habitat. Juvenile salmonids, longfin smelt, staghorn sculpin, shiner perch, spiny dogfish, tadpole sculpin and northern anchovy were other, less commonly encountered, species in this habitat. A number of other species of fish, mostly demersal, were captured infrequently during our collections, accounting for the richer fauna observed in the mud/eelgrass habitat when compared to the other habitats. As with all the habitats, sparse levels during the winter were followed by a spring influx (usually a month before the influx into more exposed habitats) of larval Pacific herring. Peak levels of juvenile Pacific herring and juvenile and adult stickleback were maintained throughout the summer and into the fall, before decreasing to the winter lows.

Although the San Juan Island site was the least species-rich, it maintained higher standing crop values than the two eastside habitats. This apparently greater standing crop of neritic fishes at Westcott Bay may be due to its being more enclosed and hence more protected as compared to the other two sites.

There were some interesting geographical variations in a number of the less dominant species observed in this habitat. Juvenile salmonid catches were consistently greater at the two eastside habitats than at the San Juan site. Catches at Padilla Bay and Lummi Bay included more large, typically demersal predators than catches at Westcott Bay. Since these predators were usually caught in tows made late at night, it is possible that these fish were undergoing a nocturnal, vertical migration into the surface waters where they were caught by our gear. It is also possible that these fish were caught when the townet was on or near the bottom during sampling.

Characteristic Neritic Fish Assemblages

While by no means conclusive, the data indicate that the neritic fish assemblage follows predictable seasonal trends in species composition, species richness, density, and standing crop in all five habitats.

In general, the nearshore pelagic fauna was sparse in the winter, the fish probably moving into deeper, offshore waters. In the early spring, the appearance of larval fish caused a rapid increase in species richness and abundances with maximum values attained during the summer when the density of juveniles was high. In the fall, the fish moved rapidly out of the immediate nearshore environment. There are indications that the appearance of larval forms in the spring in the more protected habitats was of greater magnitude than in the more exposed habitats. Also, while there is a decline of fish in the more exposed habitats during the early fall, there is evidence that fish do not leave the less exposed habitats until later in the fall.

Few neritic species were confined to a particular habitat. Larval and juvenile Pacific herring, juvenile and adult threespine stickleback, larval and juvenile Pacific sand lance, larval to adult longfin smelt, larval to adult surf smelt, and juvenile salmonids appeared at all habitats. These neritic species did, however, appear more concentrated in certain habitats and areas. The degree of exposure appears to be an important variable in determining characteristic fish assemblages, possibly even more important than the actual habitat characteristics.

While the great majority of fish caught were neritic species, a number of typically demersal species were captured infrequently, such as English sole, Pacific staghorn sculpin, starry flounder, and snake prickleback. Our townet data for these demersal species should not be used as an indication of their relative density and standing crop in the nearshore environment. Possibly these species were undergoing nocturnal migration into the surface waters that made them accessible to our gear, or our net was on or near the bottom where these species were then more catchable.

The northeastern habitats were typically more species-rich than the San Juan Island sites. Additionally, they appeared to possess a neritic fauna that had higher densities and standing crop than in the San Juan Island area. However, an obvious exception to this generalization was the low densities in the northeastern rocky/kelp bed habitat.

These differences could be attributed to one or more of the following: 1) the greater estuarine conditions present at the northeastern habitats (possibly decreasing net avoidance); 2) proximity of the northeastern sites to spawning grounds of neritic species; 3) overall greater exposure present at the San Juan Island sites; and 4) other physical differences in the habitats in the different areas (i.e., size of sites, sediment differences, etc).

Significant numbers of adult fish were notably lacking in our catches. Threespine stickleback and the smelt accounted for most of the adults captured. The lack of adult herring in the catches was surprising because spawning takes place near some of the sites (Millikan et al. 1974). Adult herring either avoided the net or were not present during the sampling periods.

The data indicated that the nearshore waters were of particular importance to larval and juvenile fish as nursery areas. Juveniles of all five species of Pacific salmon were found during the first year of their marine life throughout the study area, particularly at the northeastern sites. Sockeye salmon, however, were caught infrequently, perhaps they tend to move immediately into offshore or deep water after migrating downstream. Chum and pink salmon were the earliest-appearing salmon in their respective spawning years. They appeared in early spring and were present for a relatively short time, usually not later than July. Coho and chinook salmon were usually present from middle to late spring, through the summer, and into early fall. As the numbers of salmon caught per tow were very small, the significance of these juvenile salmonid catches is uncertain.

Larval and juvenile Pacific herring were the most abundant, most frequently occurring species in the catches. The species appears to utilize the nearshore environment extensively as larvae and juveniles, most probably for food and protection. Although they occurred at all habitats, they appeared most frequently in the shallow protected eelgrass embayments such as Birch Bay and Westcott Bay.

Townet Efficiency

Even though townetting has been used extensively to investigate the movement of juvenile salmonids that have just entered saltwater (Stober and Salo 1973; Sjolseth 1969; and Tyler 1964), the effectiveness of this gear is largely undocumented. Before discussing the predictability of the nearshore pelagic fish fauna, we will present the problems and biases associated with townetting and the sampling design.

From the data it is clear that comparatively few adult fish were caught by the townet. While it is possible that adult fish were more prevalent offshore and scarce throughout the (nearshore) neritic environment, it is also possible that they avoided the townet. As fish increase in size, their mobility and hence ability to avoid the net increase. As a result, it seems reasonable to suppose that above a certain size, highly mobile neritic species can avoid the net.

Larval fish catches should only be considered on a qualitative basis because the only portion of the net capable of catching fish smaller than 30 mm was the cod end which was fitted with a 1/4-inch mesh liner. Between-sample comparisons of this portion of the catch were acceptable because the bias (for a given length) was considered to be constant.

Net avoidance by both small and large fish was compounded by a number of different factors. Clear water, calm weather, large amounts of bioluminescence, and moonlight would tend to make the net more visible and probably increase avoidance. Dark nights, increased levels of turbidity (caused by plankton blooms, storms, freshwater runoff, etc.), rougher water, and little or no bioluminescence would tend to obscure the net and probably decrease avoidance.

Numerous other variables have unquantifiable effects on catches. For instance, although we sampled at night, we were seldom able to sample the same site at the same approximate time at night. Ideally, in order to minimize effects of vertical and horizontal nocturnal migrations, every site during every collection should have been sampled at the same time and tidal state, a practical impossibility. What effect the tidal height and currents had on our catches is also unknown. It seems reasonable to expect some species of neritic fish to move either vertically or horizontally according to the changing tides. We do not have enough data to clarify this assumption.

Another variable affecting our catches is the degree the net was spread during the tow, which directly influences the amount of water strained. This was a function of the amount of maneuvering the two boats had to do because of wind, currents, amount of floating debris in the water, and changing shoreline contours. Thus, the net was often not spread the same for any two tows. As a result, the volume of water strained was not exactly the same, although in our calculations we assumed it was.

The decision to standardize the sampling by engine speed and time rather than by boat speed and shoreline distance was made to fix the volume of water sampled, regardless of tide and currents, during each tow. Tide and currents often exerted a major influence on the sampling and therefore weakened the assumption of statistical replication.

Predictability of Fish Assemblages

The predictability of the characteristic neritic fish assemblages at habitats in northern Puget Sound can be considered, provided that the limitations and biases in the sampling design are understood. The reliability of prediction depends greatly on the variances associated with the sampling design and the biological variation of the fish populations under consideration. Since these variances are not well understood at this point, this aspect of the discussion will be largely qualitative and descriptive in nature.

The data indicate that similar trends of species occurrence, density, and standing crop occurred in all the exposed habitats while different trends were common to the protected habitats. It is reasonable to predict that minimum species richness, density, and standing crop will occur during the winter and the maximums will occur in the summer and early fall. Rapid increases brought on by the appearance of larvae occurred in the spring, with juveniles occurring in maximum numbers in the summer and early fall. An apparent offshore movement of fish during fall results in corresponding rapid decreases in species richness, density, and standing crop. Examination of the associated variances indicates that while these changes might not be observed in the nearshore environment at precisely the same time each year, they are probably consistent each year. However, the possibility of greater net avoidance with increasing fish size may account for some of the observed winter decrease of fish.

The principal neritic fish species in northern Puget Sound--Pacific herring, threespine stickleback, and Pacific sand lance, while apparently more numerous in certain habitats, were not confined to any single habitat or area. Surf smelt, longfin smelt, and juvenile salmonids, however, were in greater abundance in the habitats along northeastern Puget Sound. It is not possible to explain these apparent geographical differences in these species other than to suggest that because of migration routes, feeding and spawning preferences, and environmental preferences, these species were more numerous in these regions.

A more comprehensive understanding of some of the relationships between neritic species and the nearshore habitats would aid in prediction of fish assemblages characteristic to northern Puget Sound. That is, until we know how the physiochemical characteristics, food resources, predator populations, etc., of a particular habitat relate to the occurrence and abundance of a particular neritic species, we cannot make predictions about the role of that species in the nearshore environment.

The high variability observed in the townet data does not yield any seasonal trends nor generalizations concerning the annual coefficients of variation; accordingly, these have not been plotted for these data.

Summary

1. Neritic fishes were sampled by two-boat surface trawl (townet) over a 25-month period during 1974-76 at 15 sites, representing five nearshore habitats in three northern Puget Sound regions (San Juan Island, Cherry Point, and Anacortes vicinities).

2. Seventy species were collected overall, with juvenile Pacific herring dominating the catches, followed by threespine stickleback (not by biomass) and Pacific sand lance. Spiny dogfish and starry flounder ranked high in total biomass but relatively lower in occurrence and total abundance; juvenile salmonids (Salmonidae), smelt (Osmeridae), and several sculpins (Cottidae) also ranked high in the neritic assemblages.

3. Mean species richness was generally highest in the mud/eelgrass habitat ($\bar{x}$ = 8.1), followed by the cobble habitat ($\bar{x}$ = 7.3); mean fish density was usually highest in the sand/eelgrass habitats ($\bar{x}$ = 0.115 fish/m^3) and mean standing crop was highest in both the mud/eelgrass ($\bar{x}$ = 0.264 gr/m^3) and sand/eelgrass ($\bar{x}$ = 0.257 gr/m^3) habitats. The Cherry Point geographic region averaged highest in all three indices, with the San Juan Island vicinity ranking ahead of the Anacortes area in mean density and mean standing crop.

4. Seasonal trends in the occurrence and abundance of neritic fishes were evident. The fauna was sparse in the winter, presumably because the fish moved into deeper, offshore waters in the fall. In spring, the appearance of larvae caused rapid increases in species richness, density and standing crop. Maximum values in these parameters were obtained during the summer and early fall.

5. The dominant neritic species appeared to be present throughout the various nearshore habitats of northern Puget Sound with little evidence of distinct assemblages in different habitats. The estimated density and standing crop of the species composing the assemblage, however, were significantly higher in the protected, contained embayments, notably mud/eelgrass and sand/eelgrass habitats, and as such may constitute important nursery or feeding areas for these species.

6. Annual variability was considerably higher in the neritic fish assemblage than in the demersal fish assemblages.

7. While the townet is one of the few affective gears for capturing the large larvae and juveniles of fast-swimming, schooling neritic species, sampling biases due to weather conditions, tide and current speed and direction, water turbidity, amount of bioluminescence and moonlight, and floating debris affected replicability. The difficulty in accurately measuring the volume of water strained, severely limits the use of this data for quantifying fish densities; it should be considered more as an indication of relative abundance. Modifications to improve net efficiency and estimation of sampling volume would greatly increase the precision of townet data.

Rocky/Kelp Bed Fishes (SCUBA Transect Observations and Trammel Net): Results

Environmental Conditions

Subsurface measurements of temperature, salinity, and dissolved oxygen made in conjunction with SCUBA transect observations showed physiochemical characteristics similar to those in the surface waters with somewhat more variable salinity and dissolved oxygen values (Fig. 18). Temperature minima appeared in February, maxima in June through August. Salinity values remained relatively high throughout the year with evidence of lower salinity water only during the summer months. Dissolved oxygen values were considerably more variable among the three sampling areas and illustrated no uniform trends over the year. These data indicate that the water column in this habitat is well-mixed seasonally with relatively large fluctuations in salinity and dissolved oxygen.

Species Occurrence

Twenty-four species representing eight families were identified from the three main rocky/kelp bed habitat study areas (Table 8). Eight species were sculpins (family Cottidae) and six species were rockfish (family Scorpaenidae). An additional 13 species were identified during the study period from similar habitats in northern Puget Sound.

The predominant species in terms of frequency of sighting (percentage of dives in which the species was sighted) was the kelp greenling. This species was also the most abundant solitary species. The schooling yellowtail rockfish was the most abundant in total numbers. The black rockfish was second in total abundance, again owing to its presence in large schools. The longfin sculpin was fifth in abundance behind the kelp greenling and copper rockfish and third in frequency of occurrence, a surprising fact for a species which rarely exceeds 100 mm (4 inches). Other abundant solitary species were the quillback rockfish and lingcod.

Point George had more species than the other two sites; 22 species occurred at Point George, 15 at Allan Island, and 16 at Barnes Island (Table 9). The greater species richness at Point George could be due partly to the greater number of dives made at Point George. As indicated, 15 species were sighted at Allan Island and 16 at Barnes Island, although Allan Island was surveyed much more intensively (21 dives at Allan Island, eight dives at Barnes Island). The average number of species sighted per dive was highest at Point George (8.1), followed by Barnes Island (6.5), and Allan Island (5.8). While Barnes Island was characterized by an absence of schooling species, the quillback rockfish was much more abundant, comprising 25 percent of the fish sighted along that transect, compared to 8 percent and 9 percent of the solitary species at Point George and Allan Island, respectively. The percentage composition of the remaining four predominant species (copper rockfish, kelp greenling, lincod, and longfin sculpin) was higher at Point George. The

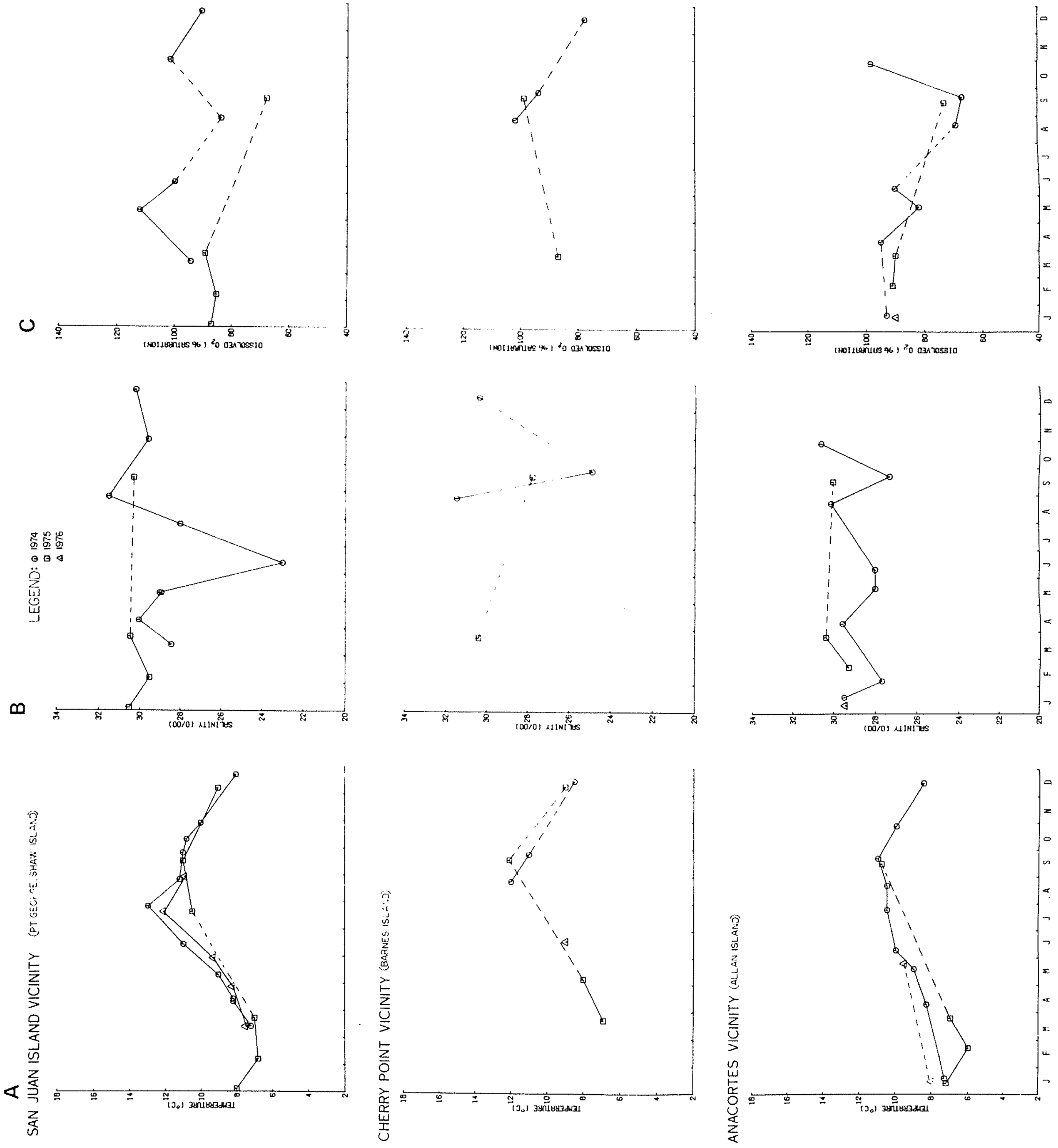

Fig. 18. (A) Temperature, °C; (B) salinity,°/₀₀; and (C) dissolved oxygen, % saturation, values coincident with SCUBA transect observations made at three rocky/kelp bed habitats during the Nearshore Fish Survey, 1974-1976.

Table 8. Fish species sighted during SCUBA transect observations in the rocky/kelp bed habitat during the two years of the nearshore fish survey, 1974-1976

Common name	Scientific name	Frequency of occurrence[1]	Percent of total no. observed	Percent of total no. (schoolers excluded)
Spiny dogfish	*Squalus acanthias*	2	0.04	0.09
Pacific herring[2]	*Clupea harengus*	12	--	--
Tubesnout	*Aulorhynchus flavidus*	+3	--	--
Threespine stickleback	*Gasterosteus aculeatus*	+	--	--
Striped seaperch[2]	*Embiotoca lateralis*	22	8.8	--
Pile perch	*Rhacochilus vacca*	2	0.04	0.09
Mosshead warbonnet	*Chirolophis nugator*	+	--	--
Decorated warbonnet	*C. polyactocephalus*	+	--	--
Penpoint gunnel	*Apodichthys flavidus*	+	--	--
Wolfeel	*Anarrhichthys ocellatus*	2	0.04	0.09
Blackeye goby	*Coryphoptorus nicholsi*	25	1.1	2.7
Silvergrey rockfish	*Sebastes brevispinus*	+	--	--
Copper rockfish	*S. caurinus*	87	9.0	21.6
Puget Sound rockfish[2]	*S. emphaeus*	18	2.9	--
Yellowtail rockfish[2]	*S. flavidus*	57	31.8	--
Quillback rockfish	*S. maliger*	67	4.9	11.8
Black rockfish[2]	*S. melanops*	57	15.4	--
China rockfish	*S. nebulosus*	+	--	--
Tiger rockfish	*S. nigrocinctus*	3	0.08	0.2
Kelp greenling	*Hexagrammos decagrammus*	97	11.9	28.7
Whitespotted greenling	*H. stelleri*	2	0.04	0.09
Lingcod	*Ophiodon elongatus*	57	2.5	6.0
Painted greenling	*Oxylebius pictus*	7	0.3	0.7
Scalyhead sculpin	*Artedius harringtoni*	40	1.5	3.4
Puget Sound sculpin	*A. meanyi*	+	--	--
Spinynose sculpin	*Asemichthys taylori*	+	--	--
Buffalo sculpin	*Enophrys bison*	10	0.3	0.7
Red Irish lord	*Hemilepidotus hemilepidotus*	10	0.3	0.7
Northern sculpin	*Icelinus borealis*	+	--	--
Longfin sculpin	*Jordania zonope*	85	8.1	19.6
Great sculpin	*Myoxocephalus polyacanthocephalus*	3	0.1	0.3
Sailfin sculpin	*Nautichthys oculofasciatus*	2	0.04	0.09
Grunt sculpin	*Rhamphocottus richardsoni*	2	0.04	0.09
Cabezon	*Scorpaenichthys marmoratus*	8	0.04	0.8

Table 8. Fish species sighted during SCUBA transect observations in the rocky/kelp bed habitat during the two years of the nearshore fish survey, 1974-1976 - Continued

Common name	Scientific name	Frequency of occurrence[1]	Percent of total no. observed	Percent of total no. (schoolers excluded)
Monacled sculpin	*Synchirus gilli*	+	--	--
Smooth alligatorfish	*Anoplagonus inermis*	+	--	--

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[1] Frequency of occurrence = (# dives in which species was sighted/total # of dives) x 100.

[2] Considered schooling species in this study.

[3] + = sighted on non-study dives in similar habitat.

Table 9. Fish species sighted at each of the three rocky/kelp bed habitat study sites

Species	Pt. George			Allan Is.			Barnes Is.	
	Frequency of occurrence	Percent of total no. observed	Percent of total no. (excluding schoolers)	Frequency of occurrence	Percent of total no. observed	Percent of total no. (excluding schoolers)	Frequency of occurrence	Percent of total no. observed
Spiny dogfish							12.5	0.4
Pacific herring	16.7	--	--	9.5	--	--		
Striped seaperch	40.0	13.3	--				12.5	2.6
Pile perch	3.3	0.06	0.1					
Wolfeel	3.3	0.06	0.1					
Blackeye goby	33.3	1.3	3.1	9.5	0.8	3.2	25.0	0.9
Copper rockfish	93.3	9.4	22.5	71.4	4.4	16.9	100.0	22.4
Puget Sound rockfish	33.3	4.7	--					
Yellowtail rockfish	63.3	28.2	--	66.7	47.5	--	12.5	0.9
Quillback rockfish	76.7	3.3	8.0	47.6	2.3	8.7	75.0	25.4
Black rockfish	66.7	11.5	--	61.9	26.3	--	12.5	0.4
Tiger rockfish	3.3	0.07	0.1				12.5	0.4
Kelp greenling	100.0	12.1	26.7	90.5	9.9	37.9	100.0	24.6
Whitespotted greenling	3.3	0.1	0.3					
Lingcod	66.7	3.0	7.3	38.1	1.2	4.6	62.5	3.4
Painted greenling	6.7	0.3	0.7				25.0	1.3
Scalyhead sculpin	43.3	1.4	3.3	38.1	1.3	5.0	37.5	1.7
Buffalo sculpin	16.7	0.5	1.2					
Red Irish lord	3.3	0.06	0.1	23.8	0.7	2.7		
Longfin sculpin	86.7	9.9	23.7	71.4	4.1	15.5	100.0	11.6
Great sculpin	10.0	0.2	0.4					
Sailfin sculpin							12.5	0.4
Grunt sculpin				4.8	0.1	0.5		
Cabezon				9.5	0.2	0.9	37.5	3.0
Rockfish juveniles	10.0	0.8	1.9	14.3	0.4	1.4		
Cottids	6.7	0.1	0.3	4.8	0.6	2.3	12.5	0.4
No. Species		22	15		15		16	
No. Fish		1,650	688		836		232	
No. Dives		31	31		21		8	

Puget Sound rockfish was quite common at Point George (5 percent of the total number of fish seen), but was not seen at the other two sites. Studies at other areas indicated the species is very common in the San Juan Islands region (Moulton 1975).

At all three study areas, the number of species (species richness) sighted per dive was generally greatest during the summer, declining in the fall and winter, and rising again in the spring (Fig. 19-A). However, this trend was only weakly evident at the Barnes Island site.

Not all species exhibited seasonality in their occurrence. The predominant solitary species, the kelp greenling, was distinctly nonseasonal in distribution (Fig. 20). The greenling was abundant in the study areas throughout the year. There was no distinct seasonal pattern of depth distribution in either main study site, although the 0- to 5-m interval was utilized most heavily from June-July to August-September at Point George and from April-May to August-September at Allan Island. There was a distinct depth segregation by sex which persisted throughout the year with males averaging 3 m deeper than females (Fig. 21).

The copper rockfish and longfin sculpin were extremely seasonal, being almost absent from the nearshore zone in the fall and winter (Figs. 22 and 23). Copper rockfish were not seen in the 0- to 5-m depth range from October-April. Longfin sculpin were not seen in the 0- to 5-m depth range from October-May at Point George and from August-March at Allan Island. Peak values for both species were recorded from June-September.

The two schooling rockfish species, the yellowtail rockfish and black rockfish, were also sighted more frequently in the summer (Figs. 24 and 25). Observations made in the fall and winter indicated that both species remained along the same section of shoreline at slightly greater depths than the 0- to 15-m depth range surveyed in this study. A school of Point George yellowtail rockfish which resided at depths of 12-13 m during the summer was seen at the same location in December and March at depths of 22-22 m. Similar observations were made on both black rockfish and yellowtail rockfish in other areas during the study period.

The sample sizes of quillback rockfish and lingcod were probably not large enough to distinguish definite seasonal patterns.

Density

An estimated 2,554 fish were sighted during the study. Of this total, 1,650 individuals were sighted at Point George (53.2 per dive), 863 individuals at Allan Island (39.7 per dive), and 232 individuals at Barnes Island (29.0 per dive). Point George averaged 415 fish/hectare*

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*Hectare = $10^4 m^2$.

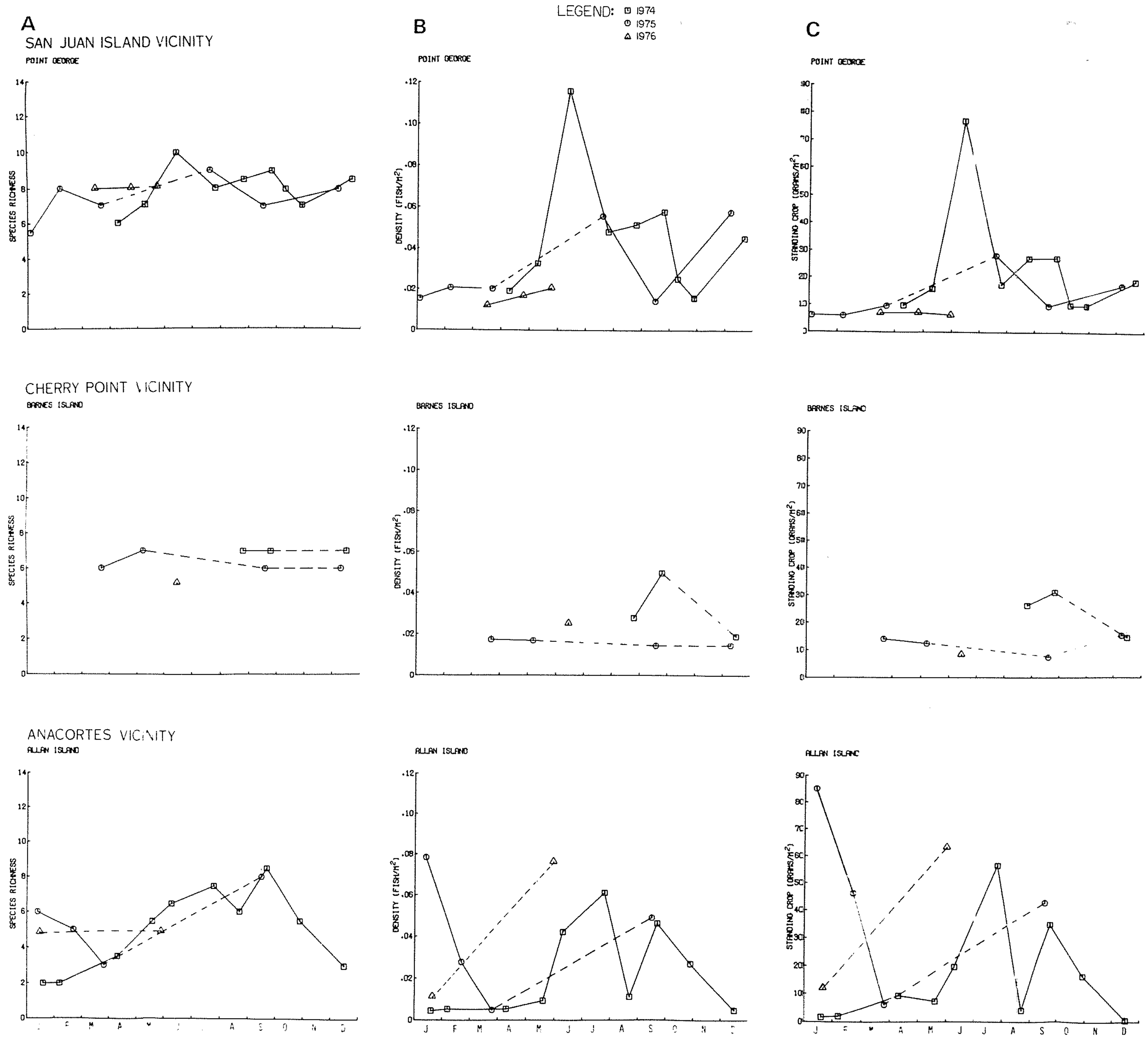


Fig. 19. (A) Species richness, number of species; (B) density, fish/m^2; and (C) standing crop, grams/m^2, at three rocky/kelp bed habitat study sites surveyed during the Nearshore Fish Survey, 1974-1976.

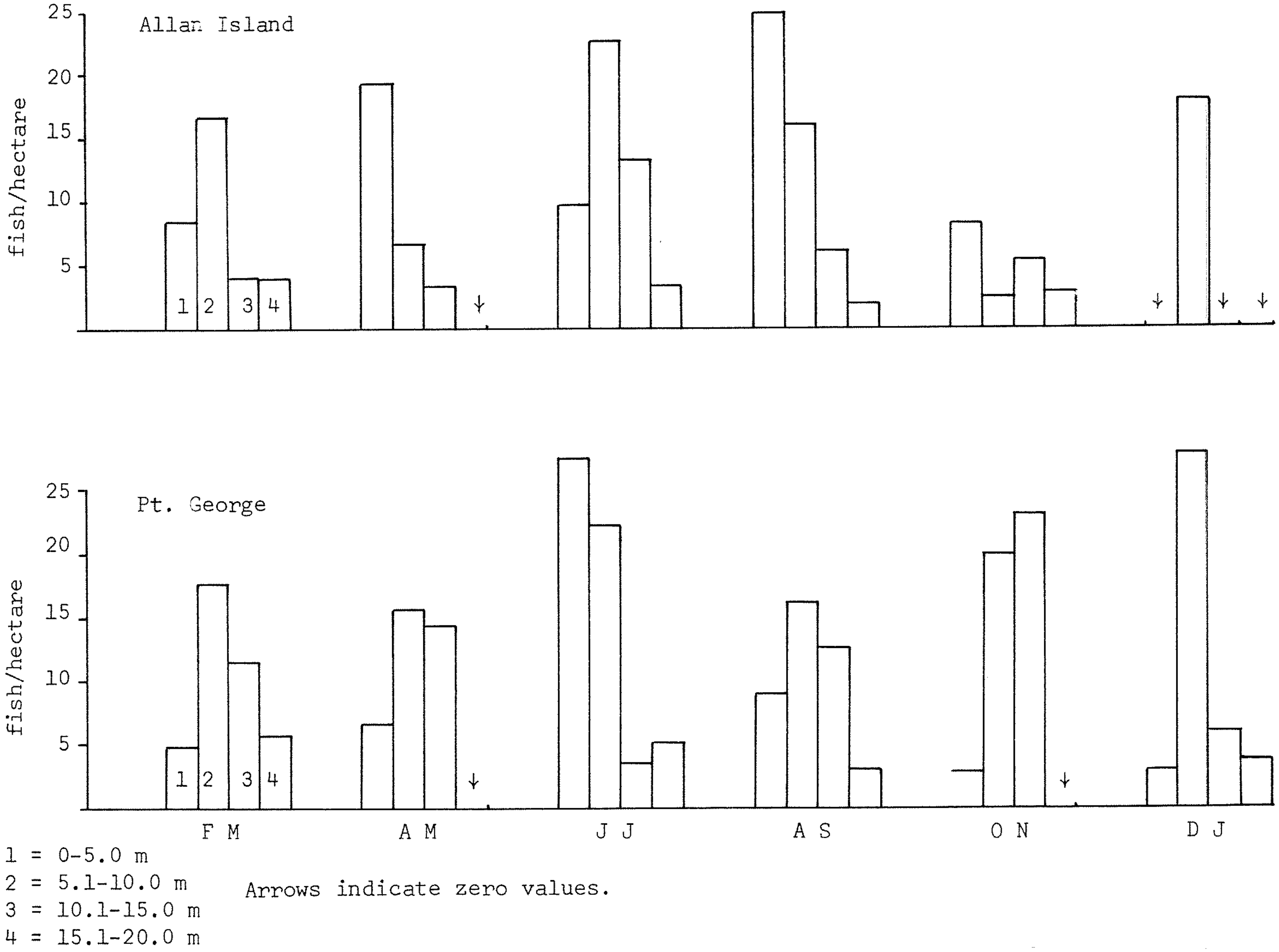


Fig. 20. Bimonthly depth distribution of kelp greenling.

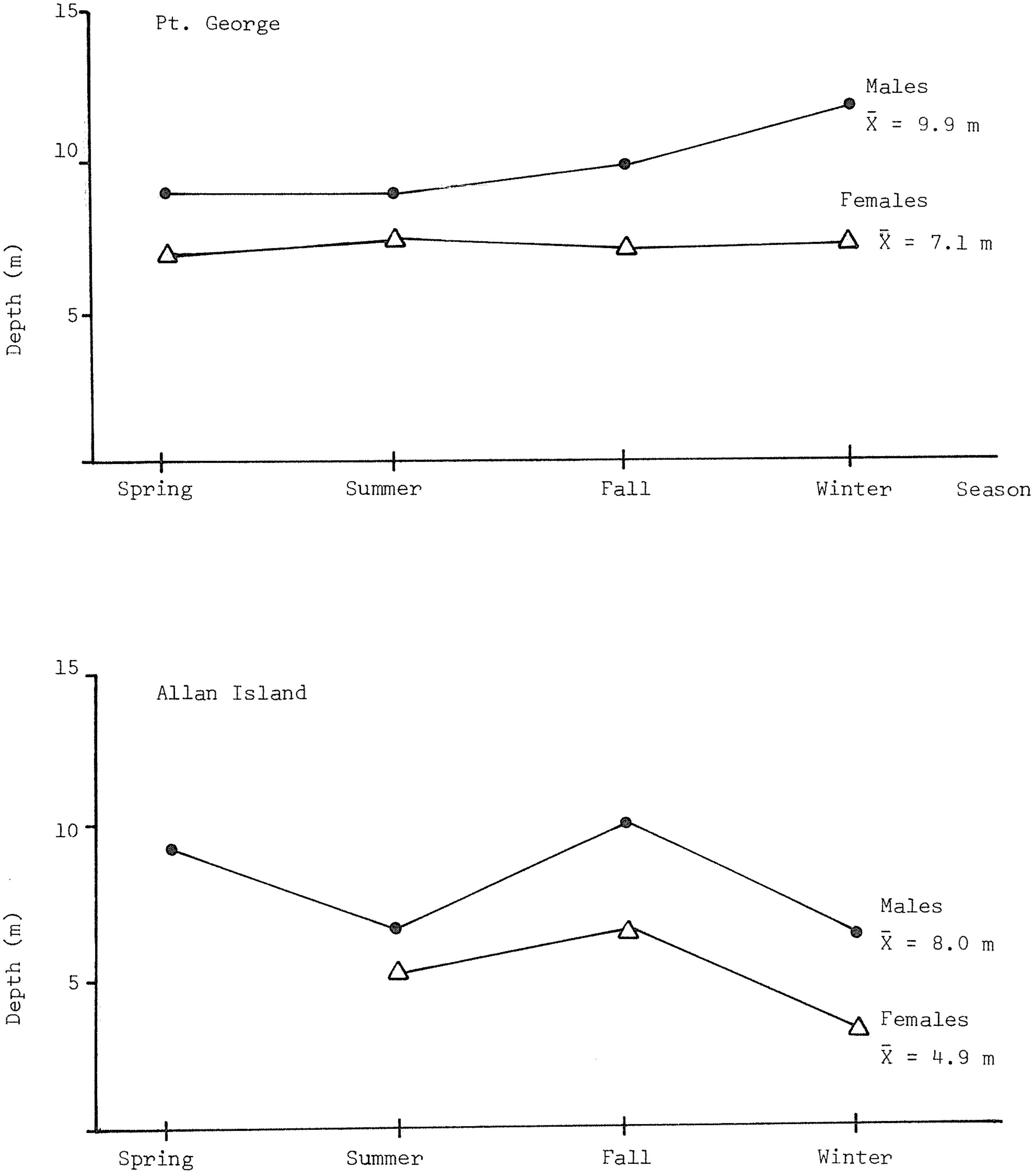


Fig. 21. Average seasonal depth of kelp greenling by sex.

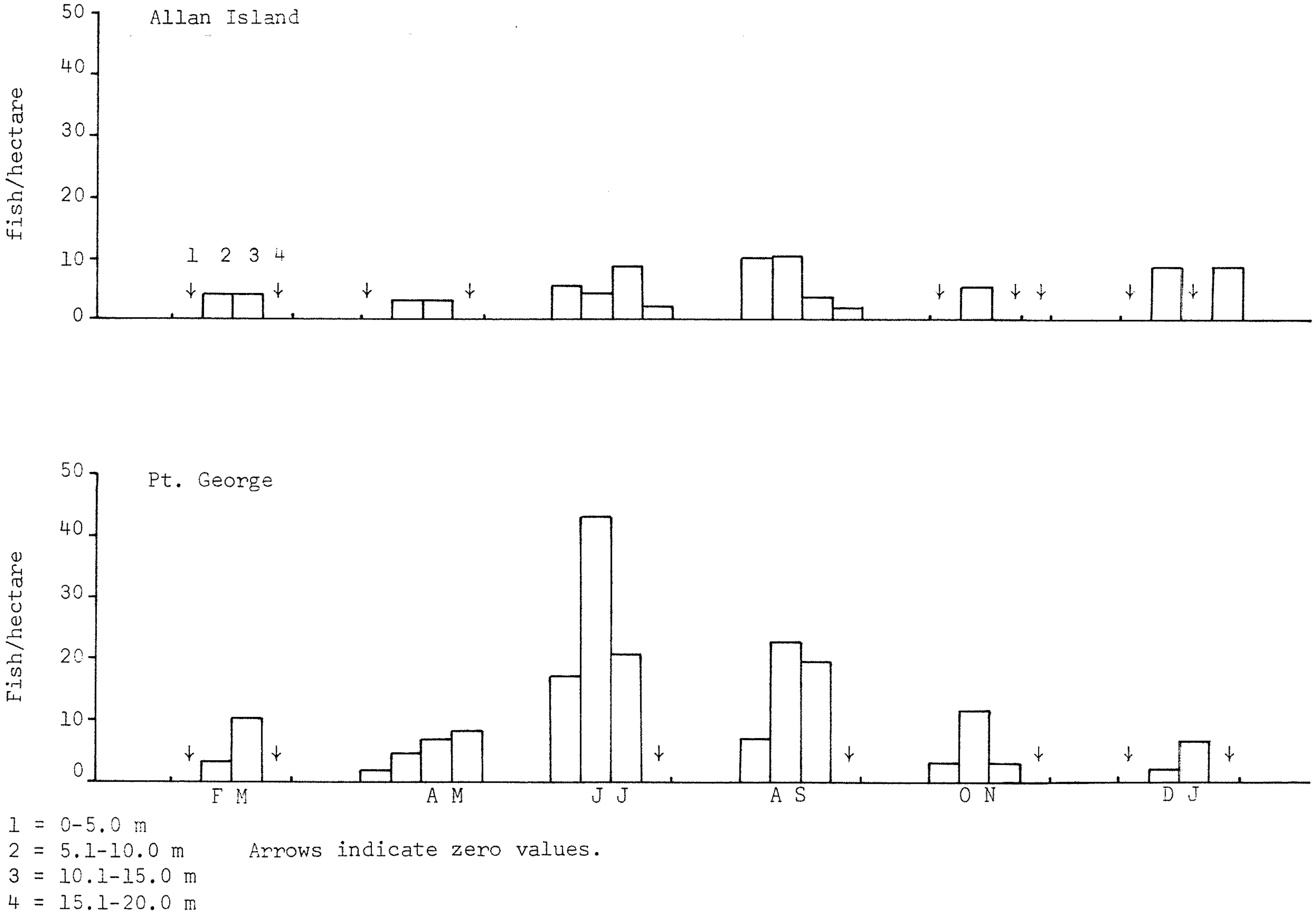
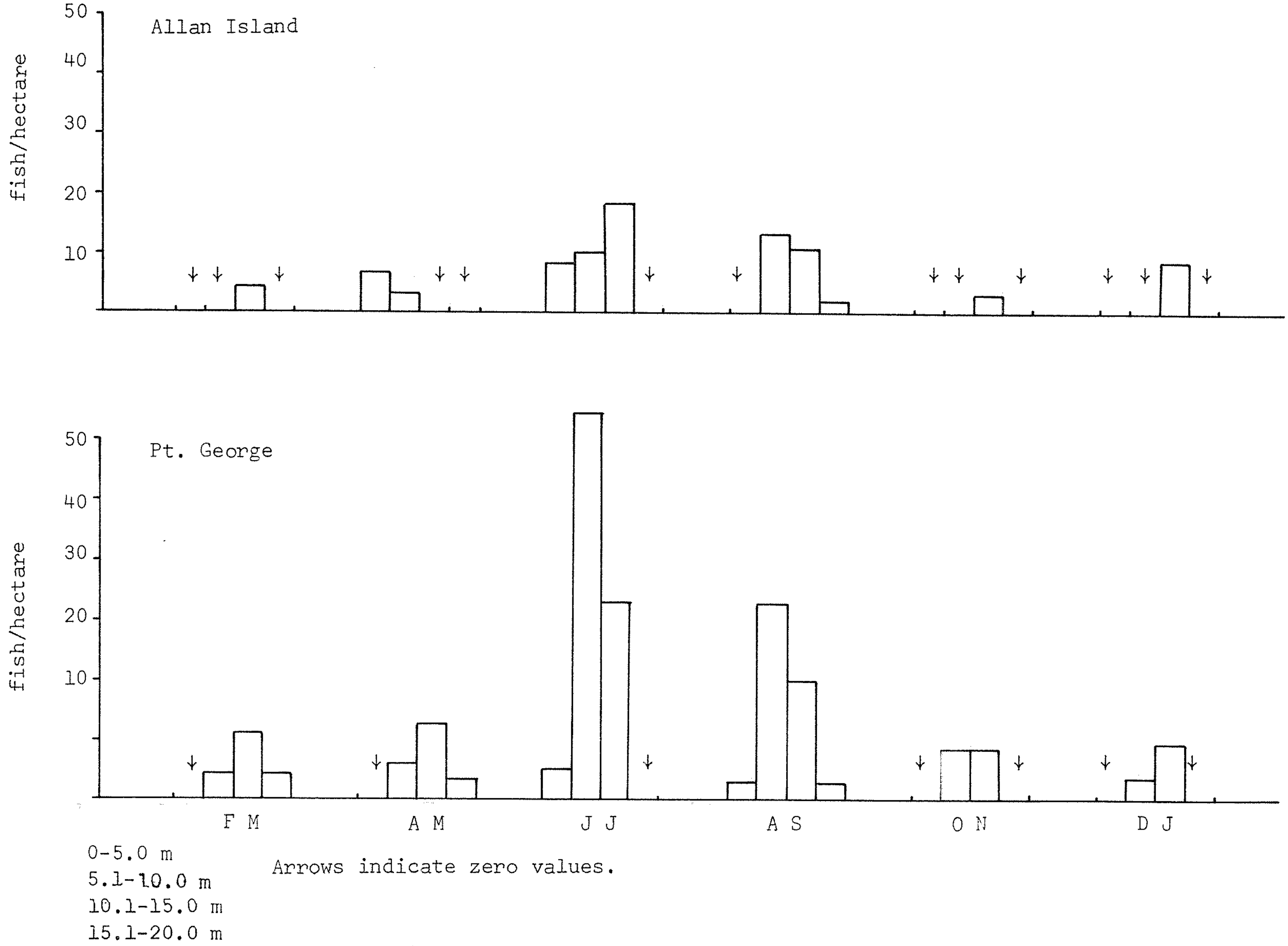


Fig. 22. Bimonthly depth distribution of copper rockfish.



Arrows indicate zero values.

Fig. 23. Bimonthly depth distribution of longfin sculpin.

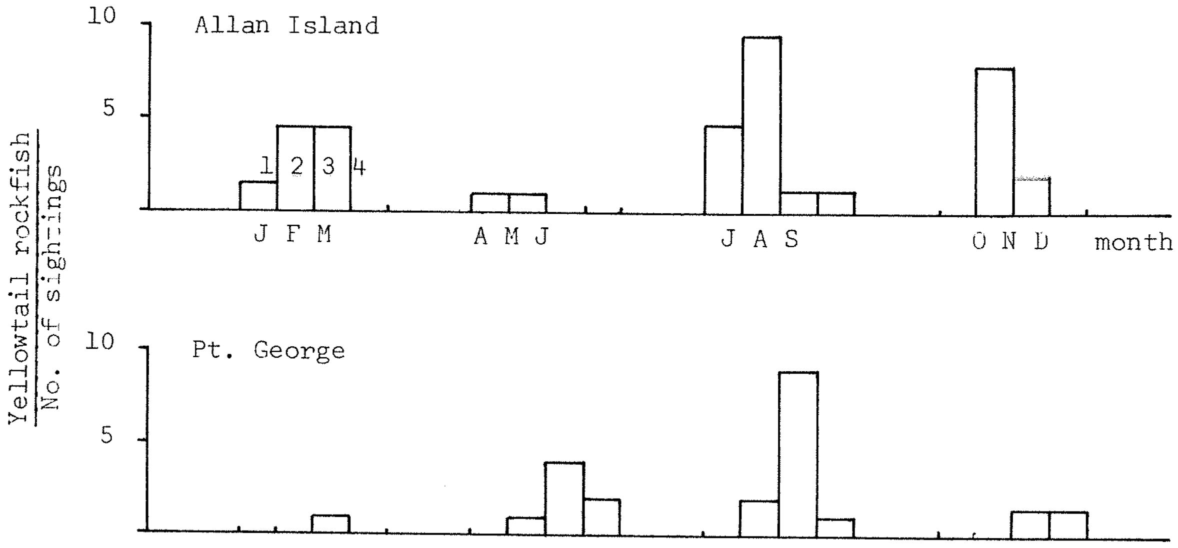
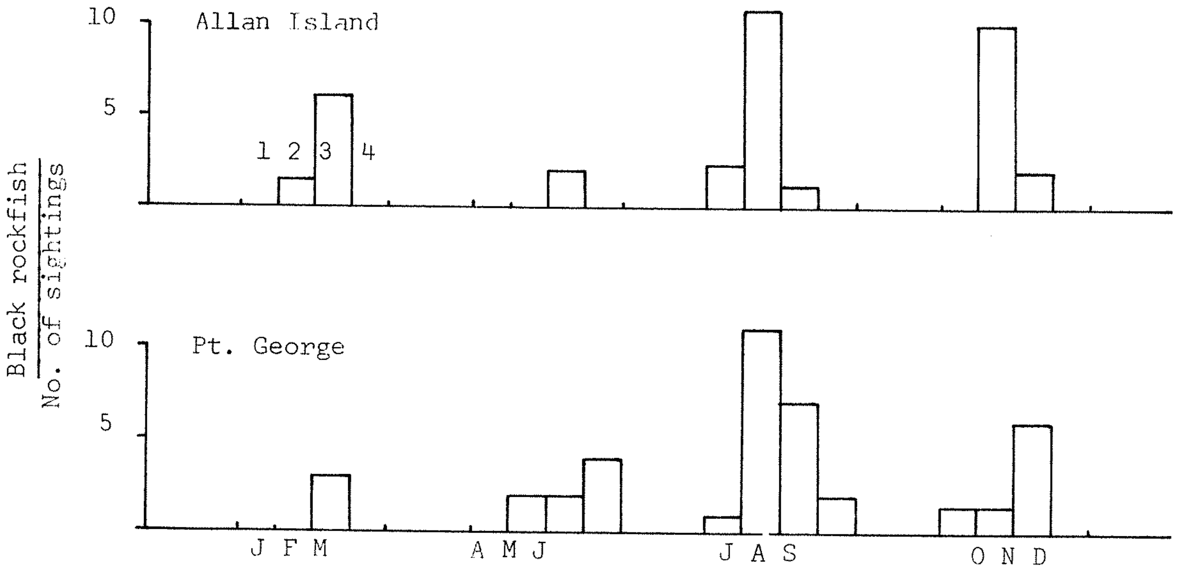


Fig. 24. Seasonal depth distribution of yellowtail rockfish.



1 = 0-5.0 m
2 = 5.1-10.0 m
3 = 10.1-15.0 m
4 = 15.1-20 m

Fig. 25. Seasonal depth distribution of black rockfish.

(168 fish/hectare excluding schoolers), Allan Island averaged 360 fish/hectare (95 fish/hectare excluding schoolers), and Barnes Island averaged 255 fish/hectare (schoolers not sighted). Over 70 percent of the density values were between 50 and 500 fish/hectare. When schooling species were excluded from the density values, 80 percent of the values fall between 50 and 250 fish/hectare.

The seasonal pattern in the number of species was also evident in the seasonal density estimates (Table 10). An examination of the monthly density estimates reveals a distinct pattern in the fluctuations (Fig. 19-B). This is especially evident when the schooling species are excluded from the calculations (Fig. 26-B), as the periodic sighting of schools masks the seasonality of the solitary species. The important trends were those that took place from April 1974 to March 1975 at Point George and Allan Island and from March to August 1976 for Point George. The density values for June-September were considerably higher than those for October-May. The increase in density was noticeable in May and was completed by June. Density values (Table 10) did not indicate great differences between years during the study period. Most of the density values for a particular season, especially for solitary species, did not vary greatly between years. The values for the summer period, for which three years of data are available, show little difference in mean density. The monthly density values for the three years of data at Point George (Fig. 19-B) show comparable peaks in the summer and lows in the winter. The monthly sampling during 1974 and 1976 gave a clearer indication of the seasonal fluctuation that the quarterly sampling of 1975. The densities in 1976 were slightly higher than comparable densities in 1974.

Standing Crop

The seasonality was not as evident in the standing crop estimates (Fig. 19-C) because two species which exhibited little seasonal variability, the lingcod and kelp greenling, dominated the standing crop estimates when schooling species were excluded (Fig. 26-C). The density values include many small species which did not greatly influence the total standing crop values.

The standing crop at Point George, and particularly at Allan Island, fluctuated greatly, influenced by the sighting of large schooling species (Fig. 19-C). Since schooling species were not sighted at Barnes Island, the fluctuations were considerably less. The overall averages were 201 kg/ha at Point George, 310 kg/ha at Allan Island, and 169 kg/ha at Barnes Island. Eighty percent of the standing crop estimates were between 50 and 400 kg/ha.

Diel Effects

All data presented heretofore are the result of daytime surveys. A limited number of nocturnal observations were made to determine if the

Table 10. Seasonal densities of fish in fish/hectare (1000 m^2). (Variance value is 1 standard deviation, values in parentheses are for solitary species)

	Spring	Summer	Fall	Winter
Pt. George				
1974	571 ± 602 (184 ± 137)	578 ± 301 (221 ± 82)	327 ± 281 (112 ± 32)	191 ± 103 (107 ± 33)
1975	--	374 ± 328 (214 ± 102)	577 (205)	106 (83)
1976	353 ± 311 (199 ± 88)	492 ± 311 (217 ± 62)		
Allan Is.				
1974	217 ± 288 (104 ± 49)	484 ± 512 (140 ± 50)	234 ± 332 (45 ± 13)	444 ± 582 (77 ± 30)
1975	--	492 (117)	--	112 (64)
1976	775 (75)			
Barnes Is.				
1974	--	455 ± 136 (455 ± 136)	230 (230)	209 (209)
1975	167 (167)	143 (143)	178 (178)	--
1976	223 (223)			

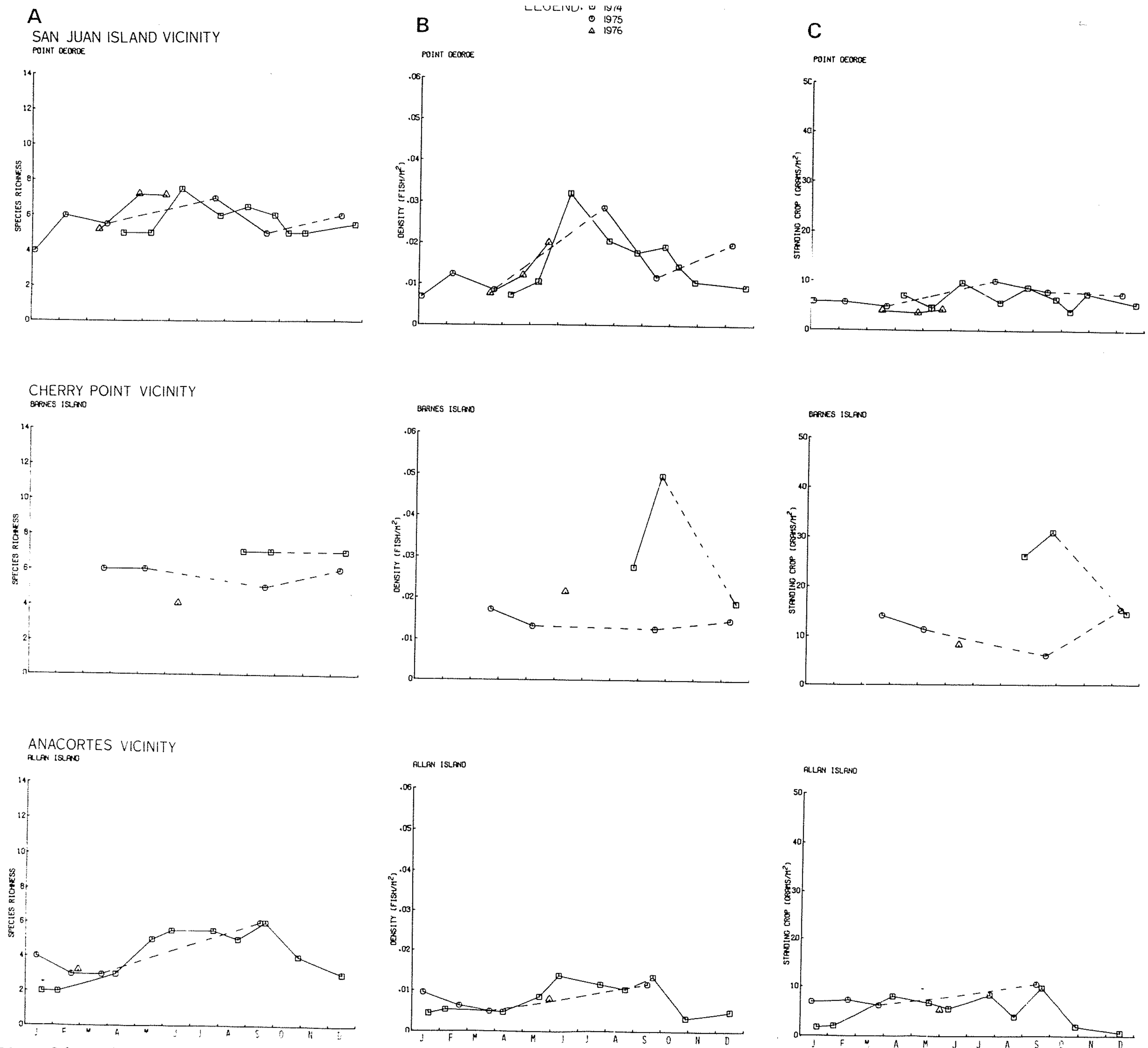


Fig. 26. (A) Species richness, number of species; (B) density, fish/m^2; and (C) standing crop, grams/m^2, for nonschooling species at three rocky/kelp bed habitats surveyed during the Nearshore Fish Survey, 1974-1976.

species altered their behavioral patterns or if the species composition changed noticeably during the night. These observations were supplemented by overnight trammel net catches.

The night dives indicated that most species became inactive during darkness. The kelp greenling was the first species to reduce activity with approaching darkness. Slightly later, the black rockfish and yellowtail rockfish moved from open water into crevices or pockets between the rocks. The copper rockfish and quillback rockfish reduced their activity at approximately the same time as the two pelagic species. Juvenile rockfish and small species, such as Puget Sound rockfish, increased their activity in the evening but became less active within two hours after darkness. Ratfish observed at midnight were swimming actively.

The predominant species in the trammel net catches were primarily the species seen during daylight SCUBA transect observations, with the exception of sailfin sculpin, dogfish, and ratfish (Table 11). The nets were set before darkness and retrieved after dawn. Since direct observation at night indicated the majority of species reduced their activity at night, the majority of the catches were probably made in the dim light of dusk or dawn immediately before the species became inactive or after they resumed activity. Sailfin sculpin, dogfish, and ratfish were the only species which could be considered nocturnal and these three species comprised almost 40 percent of the total catch. All species caught in the trammel nets, except for shiner seaperch, redstripe rockfish, and northern spearnose poacher, were observed during daytime dives in the rocky/kelp bed habitats.

Spawning and Nursery Areas

The time of spawning for the major species inhabiting the rocky/kelp bed habitat observed during this study and inferred from the literature, is illustrated in Fig. 27. For the rockfish species, the period refers to the release of the young. Ripe copper rockfish, quillback rockfish, and Puget Sound rockfish were observed at the study sites. Male lingcod were also observed guarding egg masses at all three sites.

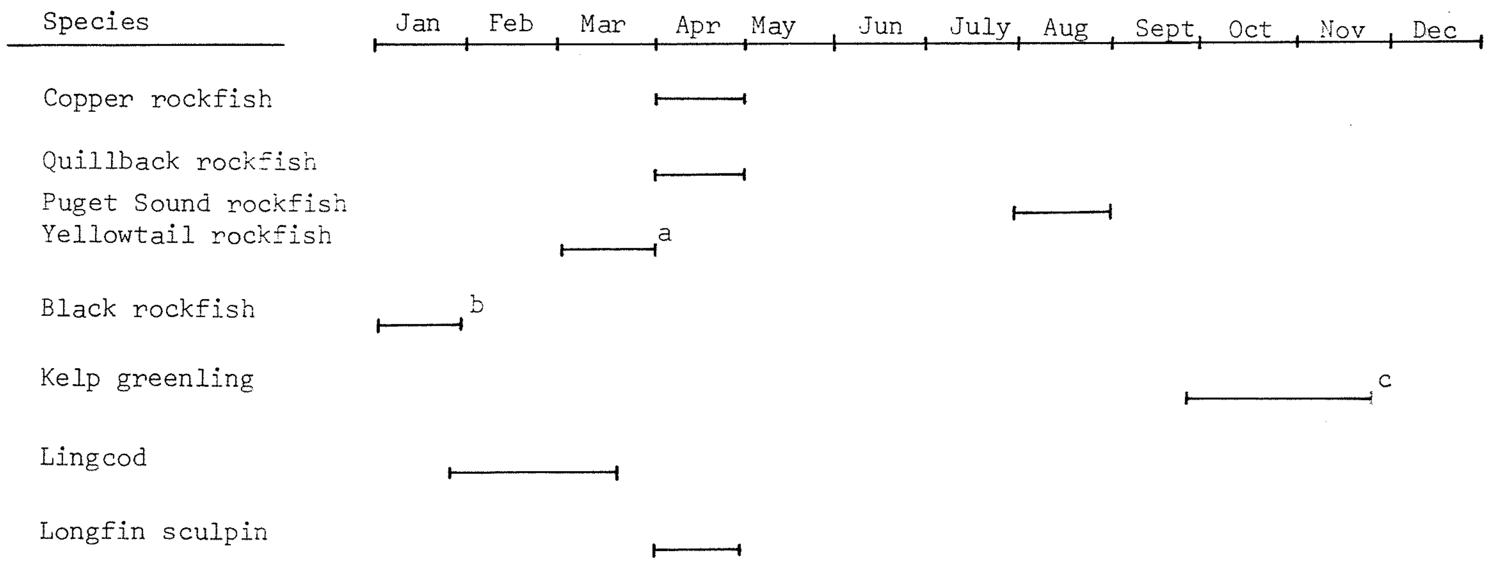
Egg masses of the longfin sculpin were not found, but spent females and ripe males were collected in late April. Fish egg masses were found on occasion but were not identifiable.

Juveniles of all the major species and many of the minor species were frequently observed in the study sites. Large numbers of juvenile yellowtail rockfish and lingcod became evident in the late summer of 1975 and the spring of 1976, respectively, indicating strong year classes. A large influx of as yet unidentified juvenile rockfish occurred at Point George in the late spring of 1976.

Table 11. Catches from trammel nets set in rocky/kelp bed habitats during two years of the Nearshore Fish Survey, 1974-75

Species	Collins Cove, SJI			Pt. Lummi	Migley Is.	Cantilever FHL, SJI	Pt. George Shaw Is.				
	30 Oct 74	30 Mar 75	4-12[1] July 75	5 Dec 74	11 Mar 75	23 Jun 75	4-12[1] July 75	Total	%	Rank	Diving transect
Dogfish	1	1	5	15	1		22	45	18.9	1	
Ratfish	2		12	5	1	2	2	24	10.1	3	-
Shiner seaperch				2				2	0.8	15	-
Striped seaperch	2	2						4	1.7	11	5
Copper rockfish			9			11	3	23	9.7	5	4
Puget Sound rockfish							10	10	4.2	8	7
Yellowtail rockfish		1				1	3	5	2.1	10	1
Quillback rockfish			6			2	11	19	8.0	6	6
Black rockfish	2	1				6	9	18	7.6	7	2
Redstripe rockfish			1					1	0.4	18	-
Kelp greenling	12	6	11	4	4	1	2	40	16.8	2	3
Whitespotted greenling		1						1	0.4	18	12
Lingcod			1				2	3	1.3	13	8
Buffalo sculpin				1	1			2	0.4	15	9
Red Irish lord			4					4	1.7	11	9
Great sculpin		2						2	0.4	15	11
Sailfin sculpin		1	21			2		24	10.1	3	12
Grunt sculpin			1					1	0.4	18	12
Cabezon					2	1		3	1.3	13	12
Northern spearnose poacher							7	7	2.9	9	-
Number of fish	19	15	71	27	9	26	71	238			
Number of species	5	8	10	5	5	8	10	20			
			(4 sets)				(4 sets)				

[1] Data from Barker (1975).



a. Westrheim (1975).
b. Dunn & Hitz (1969).
c. Hart (1973).

Fig. 27. Spawning periods of dominant species inhabiting rocky/kelp bed habitat in northern Puget Sound.

Effectiveness of Diving Transects

To test the effectiveness of the visibility correction, the visibility was plotted against the number of fish spotted on a dive before standardizing for visibility (Fig. 28-A), and the number of fish per hectare after standarizing for visibility (Fig. 28-B). Before standardizing for visibility, there was an obvious trend of increasing numbers of fish with increasing visibility. The fitted regression line had a correlation coefficient of $r = 0.57$. After standardizing, the correlation coefficient reduced to $r = 0.30$, hence the density values were not greatly influenced by visibility.

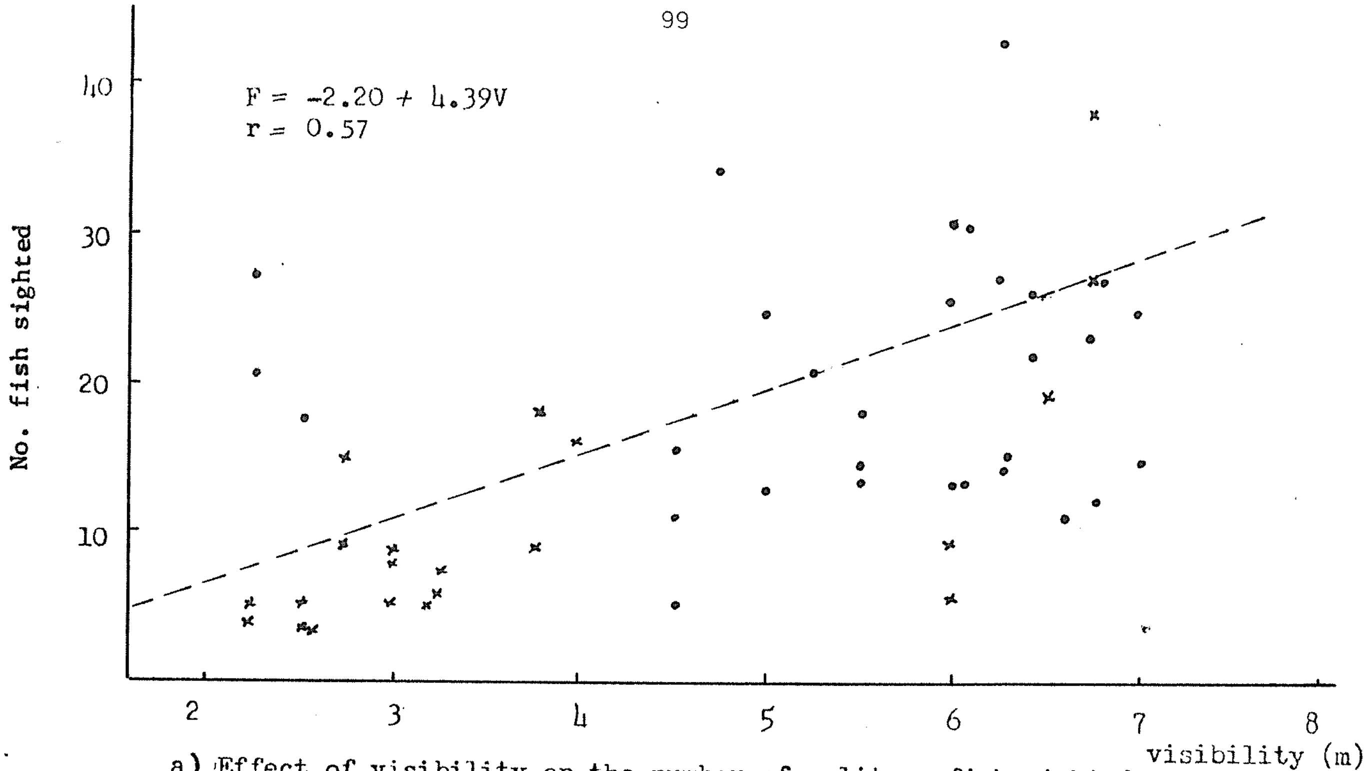
The 18 sets of replicates (seven at Allan Island, 11 at Point George) indicated relatively good agreement within a pair of replicate samples (Table 12). The average coefficient of variation was 28.1 (S.D. = 15.9). The coefficients of variation for the two areas were quite similar, with averages of 26.9 for Point George and 28.7 for Allan Island. These values compare favorably with replicate beach seine samples, which averaged 21.6 (S.D. = 31.6) for 56 samples, and were considerably less than the highly variable townet samples (Miller et al. 1976).

Rocky/Kelp Bed Fishes: Discussion

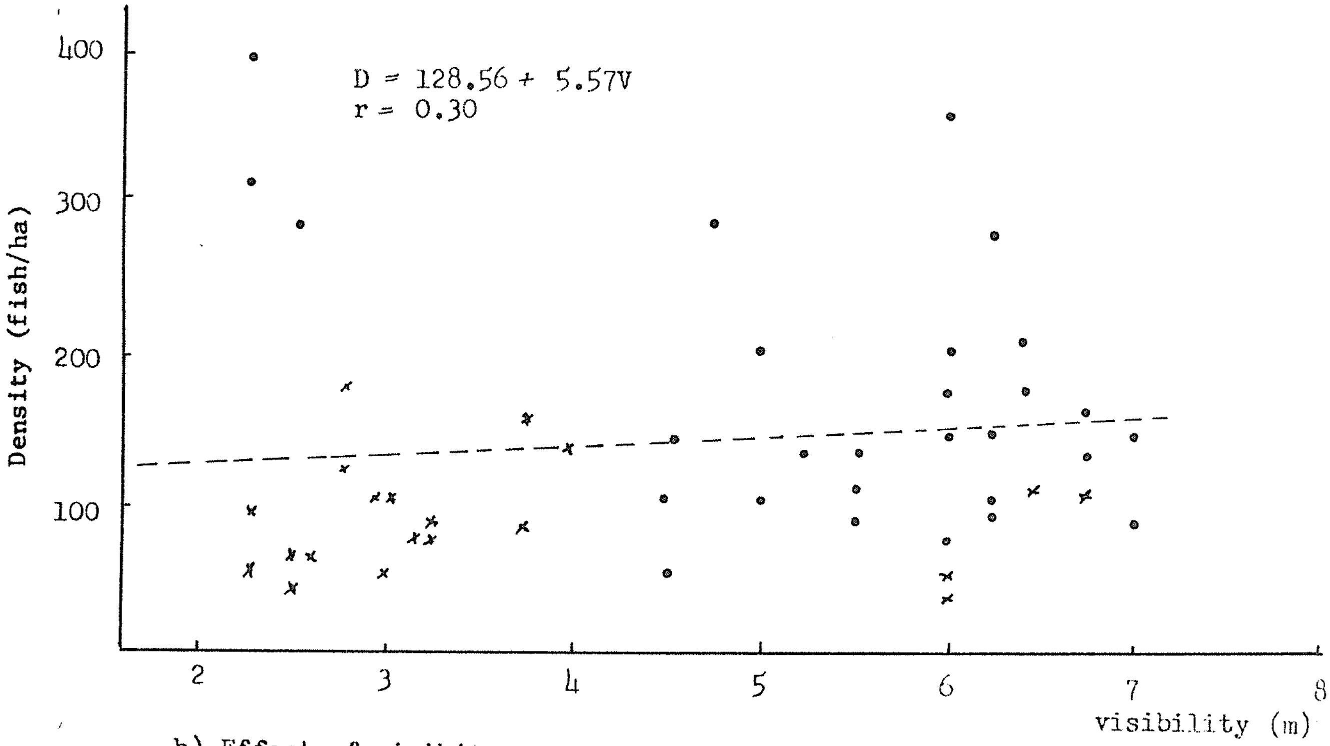
Seven of the 36 species seen during the rocky/kelp bed studies could be considered dominants by their occurrence in over 50 percent of the surveys. As mentioned before, the survey technique was better suited to detecting large species; therefore, small species may be under-represented or missed altogether (e.g., gunnels, pricklebacks, small sculpins).

The kelp greenling was the most frequently encountered fish (97 percent of the dives), and was third in total abundance, behind two schooling rockfish species--black rockfish and yellowtail rockfish. The kelp greenling was the only fish which showed relatively constant abundance in the study areas throughout all seasons and years.

Four rockfish species--copper, quillback, black, and yellowtail--were found consistently in the Point George and Allan Island study areas. Copper rockfish and quillback rockfish are solitary bottom-dwellers; black rockfish and yellowtail rockfish are schooling pelagic species. Because of the schooling behavior of the latter two species, they were the dominant species in terms of number of fish and standing crop. Both species occurred seasonally, being absent from the areas in winter and spring and consistently present during the summer and fall. The two species apparently moved to deeper water during the winter. Only solitary individuals of the schooling species were seen at Barnes Island. Of the two bottom-dwelling species, the copper rockfish was the more abundant. These species also exhibited strong seasonality, being



a) Effect of visibility on the number of solitary fish sighted.



b) Effect of visibility on the estimated density of solitary fish.

Fig. 28. Relationship between visibility and (a) number of fish sighted per dive and (b) density. (F = No. of fish, D = density, V = visibility, x = Allan Island, • = Point George.)

Table 12. Variability between diving transect replicate samples (density values in fish/hectare for non-schooling species)

	Allan Island			Pt. George		
	Replicate 1	Replicate 2	Coefficient of variation	Replicate 1	Replicate 2	Coefficient of variation
April	40	67	35.7	104	75	22.9
May	107	107	0	133	91	26.5
June	122	182	27.9	311	400	17.7
July	80	160	47.1	361	172	50.1
August	-	-		275	150	41.6
September	111	212	44.2	207	160	18.1
October	30	50	35.4	86	143	35.2
November	-	-		-	-	-
December	-	-		136	83	34.2
January	-	-		53	107	47.7
February	74	86	10.6	131	142	5.7
March	-	-		102	96	4.3

present in greatest numbers during the summer and fall. An additional four species of this genus were sighted during the study period, but only the schooling Puget Sound rockfish occurred in significant numbers.

The longfin sculpin (third in frequency of occurrence and fifth in overall abundance) rarely exceeded 100 mm TL and may be much more common that the data indicate.

The total number and densities of lingcod were not high, which is not surprising since top predators such as this species are typically territorial and require larger foraging areas than species at lower trophic levels.

Dogfish and ratfish are two species which did not appear during the daylight surveys but which apparently made nocturnal migrations into the habitat, as indicated by night dives and trammel net catches. The other predominant species in the trammel net catches were probably captured at dusk or dawn before or after their nocturnal period of inactivity.

The densities of fish in the rocky region varied with the season, being highest in the summer, dropping in the fall and winter, and rising again in the spring. These seasonal fluctuations, however, were not as severe as observed in the shallower fish assemblages sampled by beach seine and townet. The deeper waters sampled by diving transect (0-15 m) may be less environmentally influenced in the winter than the shallower beach habitats. The control area, Point George, indicated higher densities than the main study area, Allan Island. Barnes Island, surveyed by one dive quarterly, showed the highest densities of solitary species.

The standing crop estimates were similar for all three areas, with most values falling between 50 and 400 kg/ha and peak estimates in the 720-1330 kg/ha range. Standing crop estimates made in California kelp beds ranged from 330-375 kg/ha in three areas near La Jolla (Quast 1968*b*) to 705 kg/ha and 1,120 kg/ha, for 1969 and 1970, respectively, off Hopkins Marine Station (Miller and Geibel 1973).

An interesting aspect of the data is that only one fish, female kelp greenling, appeared to be associated with the kelp zone. The remaining species were seen in apparently equal densities in areas with and without kelp beds. The shallow depth range of the kelp in the northern Puget Sound region may account for the lack of fish in kelp beds. Water depth, or other physical factors, may be a more important criterion than kelp cover in determining fish distribution.

Spawning occurred throughout the year in the study areas with the various species being separated in their principal time of spawning. This separation of spawning times may be a mechanism to reduce competition between the pelagic larvae. Separate spawning times mean that pelagic larvae are present throughout the year and perturbations at any period of the year can be expected to affect the recruitment of several species. The unexpectedly large year classes of lingcod and yellowtail rockfish in 1975 indicate the unpredictability of recruitment.

The results of the diving transects indicate that the method is valuable in assessing fish populations where other methods are unsatisfactory. The sample variability was similar to that shown in beach seine samples. As with any sampling method, the technique has weaknesses which must be recognized. The method is biased toward larger fish as they are more easily observed. The young stages and small species are undersampled. Beach seining shows the opposite selectivity, catching primarily small species which larger individuals have a greater probability of escaping.

The trammel net will catch most of the species present in the rocky subtidal. The catches are small, however, and there are many problems in handling and maintaining the nets. Swift tidal currents adversely affect the efficiency of the nets. The areas in which the nets are set must be surveyed by diving to ensure that the subtidal region represents the desired habitat. The time of capture is not accurately known, reducing the amount of obtainable data (e.g., the specimens are useless for food analysis). Specimens in the net are often attacked by scavengers and may attract dogfish and ratfish.

The diving transect technique requires a greater degree of expertise than the other methods as the fish must be detected and identified underwater. The diver must be at ease in the aquatic environment and must know all the encountered species on sight. A knowledge of the behavior of each species aids in detection.

The permanent transects are superior to the temporary transects as time is not lost trying to maintain a compass heading. The temporary transects are quite satisfactory, however, and are valuable for short-term studies or for situations where there is insufficient time to install permanent transects. A suitable material for permanent transects has not been discovered. The buoyancy of the polypropylene line caused it to bow upwards allowing the currents to fray the line at the pitons. The lines lasted approximately one year. The stainless steel cable became brittle after one to two months in saltwater and broke in sections. The cable remained in place on the bottom, however, and could still be followed.

Problems inherent in the assessment of fish populations through the use of divers are discussed in Quast (1968*b*). Some of these problems are the behavior of a fish as influenced by divers (attraction or repulsion), amount of predation by large animals (e.g., seals), the influence of sport fish and spear fishing on behavior, and the variability of behavior induced by natural conditions such as current, temperature, turbidity, illumination, and spawning condition. In an associated study, the fish in an area with heavy predation by seals were noted to be wary of divers at first but later became more accustomed to divers. A long-term study in such an area would yield low estimates until the fish were able to distinguish between divers and seals. An additional factor to consider in northern diving studies is the effect of cold water on diver performance. Diving in cold water (8.3°C with 5-mm wet suit) causes motor loss, distraction and disruption in mental tasks, and lowered memory capability (Adolfson and Berghage 1974). They also report that divers can acclimate to cold water and show better performance with increased diving activity. The effects of cold water on diver performance indicate the need for adequate preplanning and support facilities so that the divers can concentrate on data gathering with as few distractions as possible.

Summary

1. Three areas were surveyed by diving transects--Allan Island and Barnes Island on high-risk areas and one control area, Point George on Shaw Island. Point George showed the highest diversity and density of fish, Allan Island showed the lowest diversity, and Barnes Island had the greatest density of solitary species.

2. Seven species dominated the fish fauna by being present in over 50 percent of the samples and making up 84 percent of all fish sighted--copper rockfish, quillback rockfish, yellowtail rockfish, black rockfish, kelp greenling, lingcod, and longfin sculpin.

3. The fish species, except for kelp greenling, showed marked seasonality in abundance with populations being greatest during the summer and lowest during the winter. The average density and biomass estimates of all three study areas were in the same general range with 70 percent of the density values between 50 and 500 fish/ha and 80 percent of the biomass values between 50 and 400 kg/ha.

4. The three study sites were utilized as spawning and nursery areas by the dominant species. The spawning times of the various species are staggered, with the result that spawning occurs year-round.

5. The diving transect method proved to be a reliable method for obtaining quantitative data in the rocky subtidal habitat.

Nearshore Ichthyoplankton: Results

Species Occurrence

Ichthyoplankton collections were made during six months (February-August 1976) at 10 of the northern Puget Sound sites sampled for nearshore fishes (Table 13). Environmental conditions associated with these samples correspond with those from the townet collections (Figs. 10A to 10C). A total of 200 bongo net samples were obtained, 107 with the 333μ mesh and 93 with the 505μ mesh nets.

Seventy-two of the 200 ichthyoplankton samples collected during the six-month study period were analyzed in detail. These consisted of 55 surface samples and 17 oblique samples. Only a small number of oblique

Table 13. Nearshore ichthyoplankton sampling sites, dates, number and type of sample (S = surface, O = oblique)

Date	Location	Sample type	Samples	
			333μ	505μ
16 February 1976	Padilla Bay	S	2	2
20 February 1976	Birch Bay	S	2	2
"	Cherry Pt.	S	2	2
"	Lummi Bay	S	2	2
"	Burrows Island	S	2	2
"	Guemes Island S.	S	2	2
24 February 1976	Pt. George	S	2	2
"	Eagle Cove	S	2	2
"	Deadman Bay	S	2	2
"	Westcott Bay	S	2	2
19 March 1976	Birch Bay	S	2	2
20 March 1976	Burrows Island	S	2	2
"	Guemes Island S.	S	2	2
"	Padilla Bay	S	2	2
"	Lummi Bay	S	2	2
21 March 1976	Pt. George	S	2	2
"	Westcott Bay	S	2	2
"	Deadman Bay	S	2	2
"	Eagle Cove	S	2	2
"	South Beach	S	2	2
7 April 1976	Birch Bay	S	2	2
"	Cherry Pt.	S	2	2
8 April 1976	Lummi Bay	S	2	–
"	Padilla Bay	S	4	–
"	Guemes Island S.	S	4	–
9 April 1976	South Beach	S	2	2
"	Eagle Cove	S	2	2
10 April 1976	Deadman Bay	S	2	2
"	Westcott Bay	S	2	2
"	Pt. George	S	2	2
		O	2	2
11 April 1976	Birch Bay	O	1	1
"	Cherry Pt.	O	1	1
12 April 1976	Padilla Bay	O	1	1
7 May 1976	Burrows Island	S	2	–
"	Guemes Island S.	S	2	–
"	"	O	2	–
8 May 1976	Birch Bay	S	1	1
9 May 1976	"	S	–	2
"	Cherry Pt.	S	2	2
"	"	O	1	1
"	Westcott Bay	S	1	1
10 May 1976	Eagle Cove	S	1	1
"	"	O	1	1

Table 13. Nearshore ichthyoplankton sampling sites, dates, number and type of sample (S = surface, 0 = oblique). Continued

			Samples	
Date	Location	Sample type	333μ	505μ
10 May 1976	Pt. George	S	1	1
"	"	0	1	1
14 June 1976	Burrows Island	S	1	1
15 June 1976	Lummi Bay	0	1	1
"	Birch Bay	S	1	1
16 June 1976	Cherry Pt.	S	1	1
"	"	0	1	1
"	Lummi Bay	S	1	1
"	"	0	1	1
"	Westcott Bay	S	1	1
17 June 1976	Eagle Cove	S	1	1
18 June 1976	"	0	1	1
"	Pt. George	S	1	1
"	"	0	1	1
9 August 1976	Birch Bay	S	1	1
10 August 1976	Cherry Pt.	S	1	1
"	"	0	1	1
"	Lummi Bay	S	1	1
"	"	0	1	1
11 August 1976	Guemes Island S.	S	1	1
"	"	0	1	1
"	Burrows Island	S	1	1
"	Westcott Bay	S	1	1
12 August 1976	Eagle Cove	S	1	1
"	"	0	1	1
			107	93

tow samples was analyzed, therefore only surface tows were considered in the analysis. Data from oblique tows are, however, presented in Appendix 3. Raw abundance data for each tow were converted to numbers/100 m^3.

Eggs of at least nine species and larvae of at least 34 species were present in these samples, although some could be identified only to family or genus (Table 14).

The five most common taxonomic groups in surface tows in terms of eggs and the 10 most common in terms of larvae were ranked by frequency of total occurrence and density (Table 15). The overwhelmingly dominant egg type was identified as either sand sole or butter sole, occurring in 80 percent of the surface tows and representing 89.3 percent of the eggs caught. The second most abundant egg type, but ranking only fourth in frequency of occurrence, was Pacific sanddab or speckled sanddab, occurring in 13 percent of the samples and comprising only 5.0 percent of the egg catch. All eggs caught and positively identified were either pleuronectids or northern anchovy.

In contrast, flatfish did not dominate the species of larvae caught. Pacific herring were the dominant larval group, comprising 76.1 percent of the total catch and occurring in 58 percent of the samples. Other species groups such as Pacific sand lance, Pacific cod or walleye pollock, rockfish, and Osmeridae were frequently caught but were low in abundance compared with Pacific herring.

Species Richness

The species richness* for eggs and larvae was plotted against collection month (Figs. 29 and 30) and summarized by site, habitat, and geographical area (Tables 16 and 17). It should be noted that the unidentified group was counted as a separate species. The mean species richness for eggs was generally low and did not vary greatly between months. Mean species richness was highest during April and lowest during February at most sites (Fig. 29) and did not vary greatly between sites except for Westcott Bay, where observed species richness was generally low.

Egg species richness was generally high at Deadman Bay and Lummi Bay. There was little variation in mean species richness between habitats and between geographic areas (Table 16).

Species richness for larvae was highest for all sites during March or April and lowest in August (Fig. 30). Deadman Bay yielded the highest

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*"Species richness" for the ichthyoplankton data should be considered as a <u>minimum</u> species richness because species categories (i.e., Osmeridae) and the unidentified category were included in the calculations.

Table 14. Ichthyoplankton collected from surface tows during 1976

Species or family	Common name	Percent Freq. of occurrence (surface tows)	Mean density (numbers/ 100 m^3)
Eggs			
Engraulis mordax	northern anchovy	40	0.19
Citharichthys sp.	Pacific sanddab or speckled sanddab	13	15.70
Eopsetta jordani	petrale sole	7	0.48
Glyptocephalus zachirus	rex sole	10	0.11
G. zachirus or *Lyopsetta exilis*	rex sole or slender sole	4	0.11
G. zachirus or *Microstomus pacificus*	rex sole or Dover sole	4	0.11
Hippoglossoides elassodon	flathead sole	16	0.62
Microstomus pacificus	Dover sole	3	0.02
*Pleuronichthys coenosus**	C-O sole	35	9.81
Psettichthys melanostictus or *Isopsetta isolepis*	sand sole or butter sole	80	278.93
Unidentified		44	6.30
9 spp. identified			312.36
Larvae			
Clupea harengus pallasi	Pacific herring	58	162.59
Engraulis mordax	northern anchovy	3	0.03
Clupea harengus pallasi or *Engraulis mordax*	Pacific herring or northern anchovy	1	0.02
Hypomesus pretiosus	surf smelt	1	0.11
Spirinchus thaleichthys	longfin smelt	9	0.44
Osmeridae	smelts	27	2.77
Stenobrachius leucopsarus	northern lampfish	1	0.01
Gadus macrocephalus or *Theragra chalcogramma*	Pacific cod or walleye pollock	47	1.36
Brosmophycis marginata	red brotula	1	0.02
Gasterosteus aculeatus	threespine stickleback	4	0.08
Anoplarchus sp.	cockscomb	33	5.81
Chirolophis sp.	warbonnet	18	0.55
Lumpenus sagitta	snake prickleback	20	0.26
Xiphister atropurpureus	black prickleback	20	1.07
Pholis sp.	gunnel	40	0.15
Gobiidae	gobies	15	0.42
Ammodytes hexapterus	Pacific sand lance	60	12.01
Sebastes sp.	rockfish	44	2.26
Hexagrammos sp.	greenling	1	0.01

Table 14 cont'd

Species or family	Common name	Percent freq. of occurrence (surface tows)	Mean density (numbers/ 100 m^3)
Larvae cont'd			
Ophiodon elongatus	lingcod	29	1.24
Zaniolepis latipinnis	longspine combfish	1	0.01
Enophrys bison	buffalo sculpin	1	0.01
Gilbertidia sigalutes	soft sculpin	4	0.04
Leptocottus armatus	Pacific staghorn sculpin	29	3.31
Myoxocephalus polyacanthocephalus	great sculpin	7	0.06
Psychrolutes paradoxus	tadpole sculpin	4	0.01
Scorpaenichthys marmoratus	cabezon	11	0.36
Cottidae	sculpins	51	1.44
Agonus acipenserinus	sturgeon poacher	4	0.10
Agonidae	poachers	7	0.09
Cyclopteridae	snailfishes	3	0.05
Isopsetta isolepis	butter sole	5	0.07
Parophrys vetulus	English sole	13	2.26
Platichthys stellatus	starry flounder	18	6.71
Psettichthys melanostictus	sand sole	11	4.98
Pleuronectidae	righteye flounder	18	0.30
Unidentified		29	0.85

34 spp. positively identified

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*We were unable to positively identify that the C-O sole eggs were not curlfin sole (*Pleuronichthys decurrens*) eggs, but as the latter species is extremely rare in the study area, we assumed the eggs caught were C-O sole eggs.

Table 15. The most common taxonomic groups collected by bongo net surface tows, ranked according to frequency of occurrence and density.

	Occurrence		Mean density (number/100 m^3)		
Taxonomic group	Rank	Percent frequency	Rank	Density	% Total
<u>Eggs</u>					
Psettichthys melanostictus or *Isopsetta isolepis*	1	80	1	278.93	89.3
Pleuronichthys sp.	2	35	3	9.81	3.1
Hippoglossoides elassodon	3	16	4	0.62	0.2
Citharichthys sp.	4	10	2	15.70	5.0
Glyptocephalus zachirus	5	10	7	0.11	0.0
Eopsetta jordani	6	7	5	0.48	0.2
G. zachirus or *Microstomus pacificus*			6	0.11	0.0
Total				305.63	97.8
<u>Larvae</u>					
Ammodytes hexapterus	1	60	2	12.01	5.8
Clupea harengus pallasi	2	58	1	162.59	76.1
Cottidae	3	51	10	1.44	0.7
Gadus macrocephalus or *Theragra chalcogramma*	4	47	11	1.36	0.7
Sebastes sp.	5	44	9	2.26	1.1
Anoplarchus sp.	6	33	4	5.81	2.8
Leptocottus armatus	7	29	6	3.31	1.6
Ophiodon elongatus	8	29	12	1.24	0.6
Osmeridae	9	27	7	2.77	1.3
Lumpenus sagitta	10	20	20	0.26	0.1
Xiphister atropurpureus	11	20	13	1.07	0.5
Chirolophis sp.	12	18	15	0.55	0.3
Platichthys stellatus	13	18	3	6.71	3.2
Parophrys vetulus	14	13	8	2.26	1.1
Psettichthys melanostictus	15	11	5	4.98	2.4

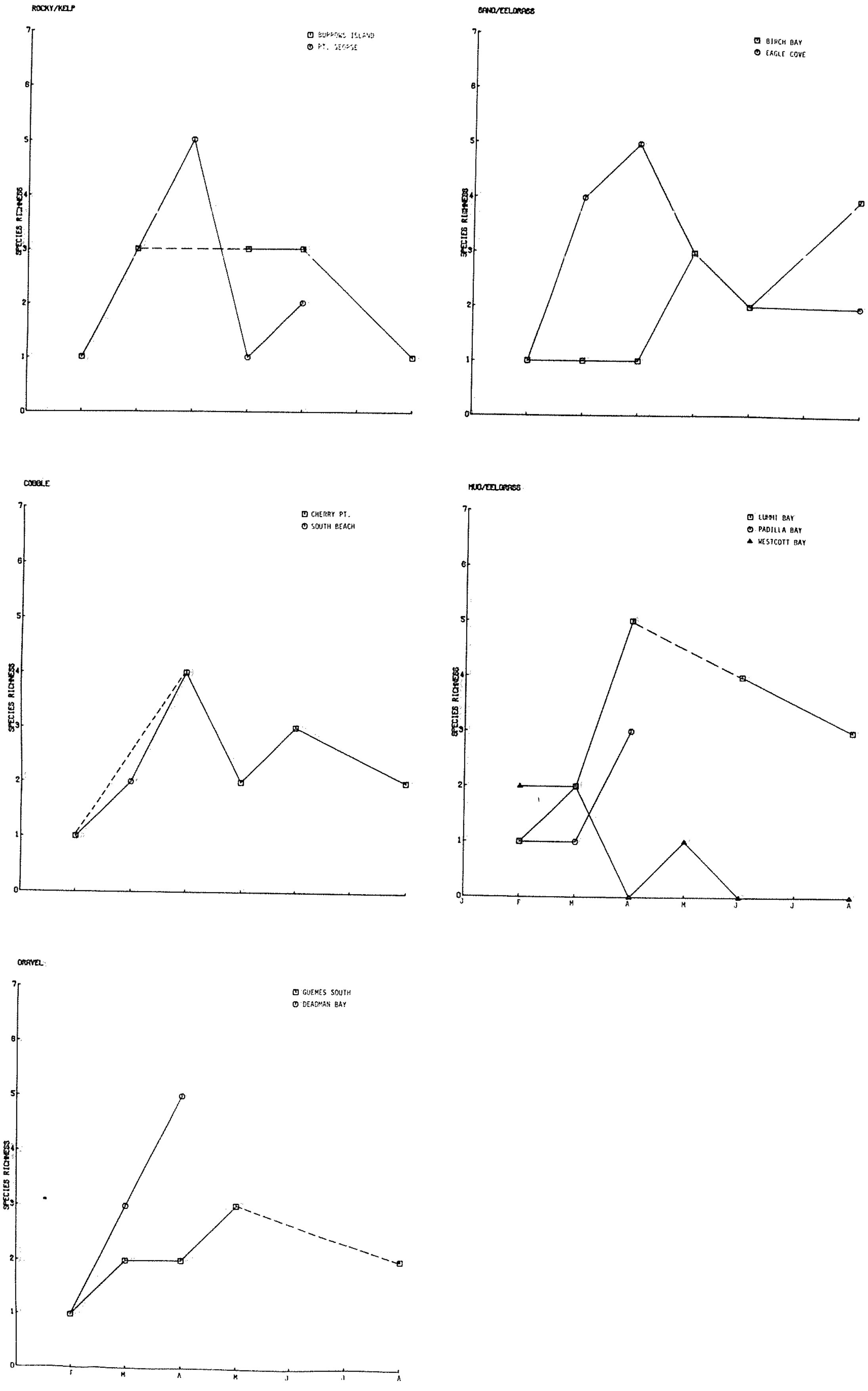

Fig. 29. Species richness of eggs in bongo net surface collections during 1976.

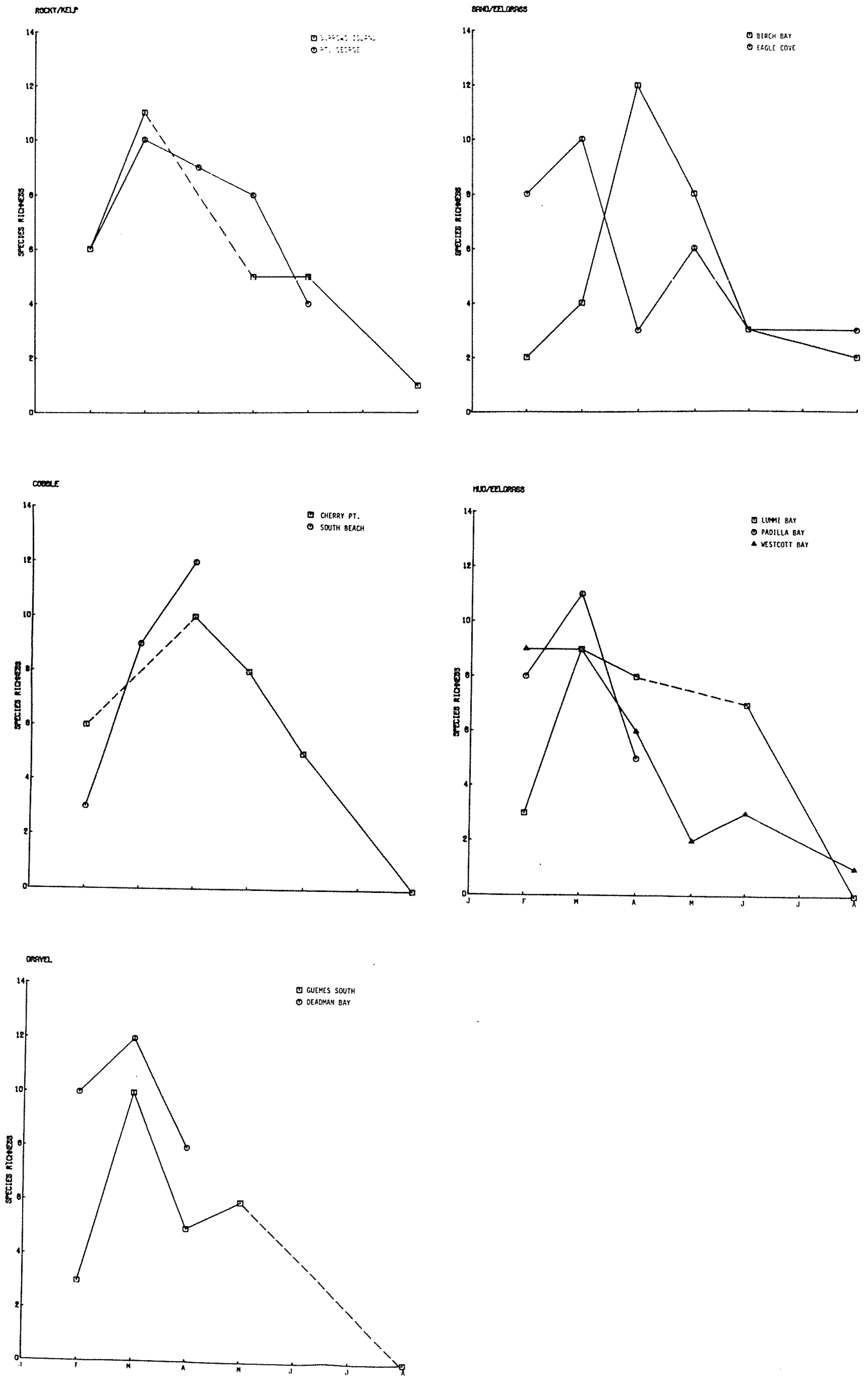

Fig. 30. Species richness of larvae in bongo net surface collections during 1976.

Table 16. Mean catch data for eggs from bongo net surface collections during 1976, summarized by (a) site, (b) habitat, and (c) geographical area

		Sample size n	Mean species richness	Mean density (number/100m^3)
Habitat	Site			
Cobble	Cherry Point	5	2.4	475.8
	South Beach	3	2.3	14.5
Gravel	Guemes South	5	2.0	57.6
	Deadman Bay	3	3.0	6.0
Sand/eelgrass	Birch Bay	6	2.0	1,542.8
	Eagle Cove	6	2.8	19.0
Mud/eelgrass	Lummi Bay	5	3.0	785.0
	Padilla Bay	3	1.7	201.3
	Westcott Bay	6	0.8	13.6
Rocky/kelp bed	Burrows Island	5	2.2	10.4
	Point George	5	2.4	15.6
Habitat				
Cobble		8	2.4	302.9
Gravel		8	2.4	38.3
Sand/eelgrass		12	2.4	780.9
Mud/eelgrass		14	1.8	329.4
Rocky/kelp bed		10	2.3	13.0
Geographic area				
San Juan Island		23	2.2	14.6
Cherry Point		16	2.4	972.6
Anacortes		13	2.0	74.6

Table 17. Mean catch data for larvae from bongo net surface collections during 1976 summarized by (a) site, (b) habitat, and (c) geographic area

		Sample size n	Mean species richness	Mean density (number/100m^3)
Habitat	Site			
Cobble	Cherry Point	5	5.8	87.6
	South Beach	3	8.0	25.4
Gravel	Guemes South	5	4.8	13.8
	Deadman Bay	3	10.0	56.7
Sand/eelgrass	Birch Bay	6	5.2	806.5
	Eagle Cove	6	5.5	98.2
Mud/eelgrass	Lummi Bay	5	5.4	22.6
	Padilla Bay	3	8.0	21.6
	Westcott Bay	6	5.0	55.7
Rocky/kelp bed	Burrows Island	5	5.6	9.0
	Point George	5	7.4	26.4
Habitat				
Cobble		8	6.7	64.3
Gravel		8	6.8	29.9
Sand/eelgrass		12	5.3	452.3
Mud/eelgrass		14	5.8	36.6
Rocky/kelp bed		10	6.5	17.7
Geographic area				
San Juan Island		23	6.7	56.6
Cherry Point		16	5.4	336.9
Anacortes		13	5.8	13.8

mean species richness, whereas the lowest value was from another gravel site, Guemes South (Table 17). Mean species richness varied more between sites within habitat type than between habitats or geographic areas.

Density

The relative densities (number/100 m^3) of eggs and larvae were plotted against collection month (Figs. 31 and 32) and summarized by site, habitat, and geographic area (Tables 16 and 17).

Egg densities were highest in late winter and early spring because of the large influx of sand sole or butter sole eggs. This influx was most evident at Birch Bay, Lummi Bay, and Cherry Point and accounted for the disparity of mean density values between the Cherry Point area and the other two geographic areas (Table 16). San Juan Island sites lacked this influx and thus had lower mean density values. Egg densities were lowest during the period from June to August with some sites (notably the sand/eelgrass sites) showing an increase in August due to an influx of sanddab eggs. Mean density values varied greatly between sites within habitat types. Sites of the rocky/kelp bed habitat demonstrated greater consistency of mean density than did other sites within habitat types. The greatest variations in mean densities occurred in sites of the mud/eelgrass habitat.

Densities of larvae were greatest in late winter and spring and generally lowest in August (Fig. 32). There was great variation in mean density between sites, habitats, and geographic areas (Table 17). There was little correlation between sites within the same habitat type in terms of mean density. Sites which had the highest density values in early spring were largely from the San Juan Island area and were dominated by larvae of Pacific sand lance and a cockscomb species. High spring densities were principally at Birch Bay and Cherry Point and were heavily dominated by Pacific herring larvae. Increased densities in June at Eagle Cove and Westcott Bay were also due to Pacific herring and smelt, respectively. The sand/eelgrass habitat had the greatest overall mean density but this was due primarily to large concentrations of Pacific herring larvae at Birch Bay in May. In terms of geographic areas, the San Juan Island and Anacortes areas had relatively low total mean density values.

Nearshore Ichthyoplankton: Discussion

Rocky/Kelp Bed Habitat

Mean egg densities were low but quite similar for the two rocky/kelp bed sites. Both Burrows Island and Point George egg catches were dominated by sand sole or butter sole eggs.

Point George had higher mean densities of larvae than Burrows Island. Point George had a peak in larval density in May and was dominated by a rockfish, Pacific cod or walleye pollock, a sculpin, and Pacific

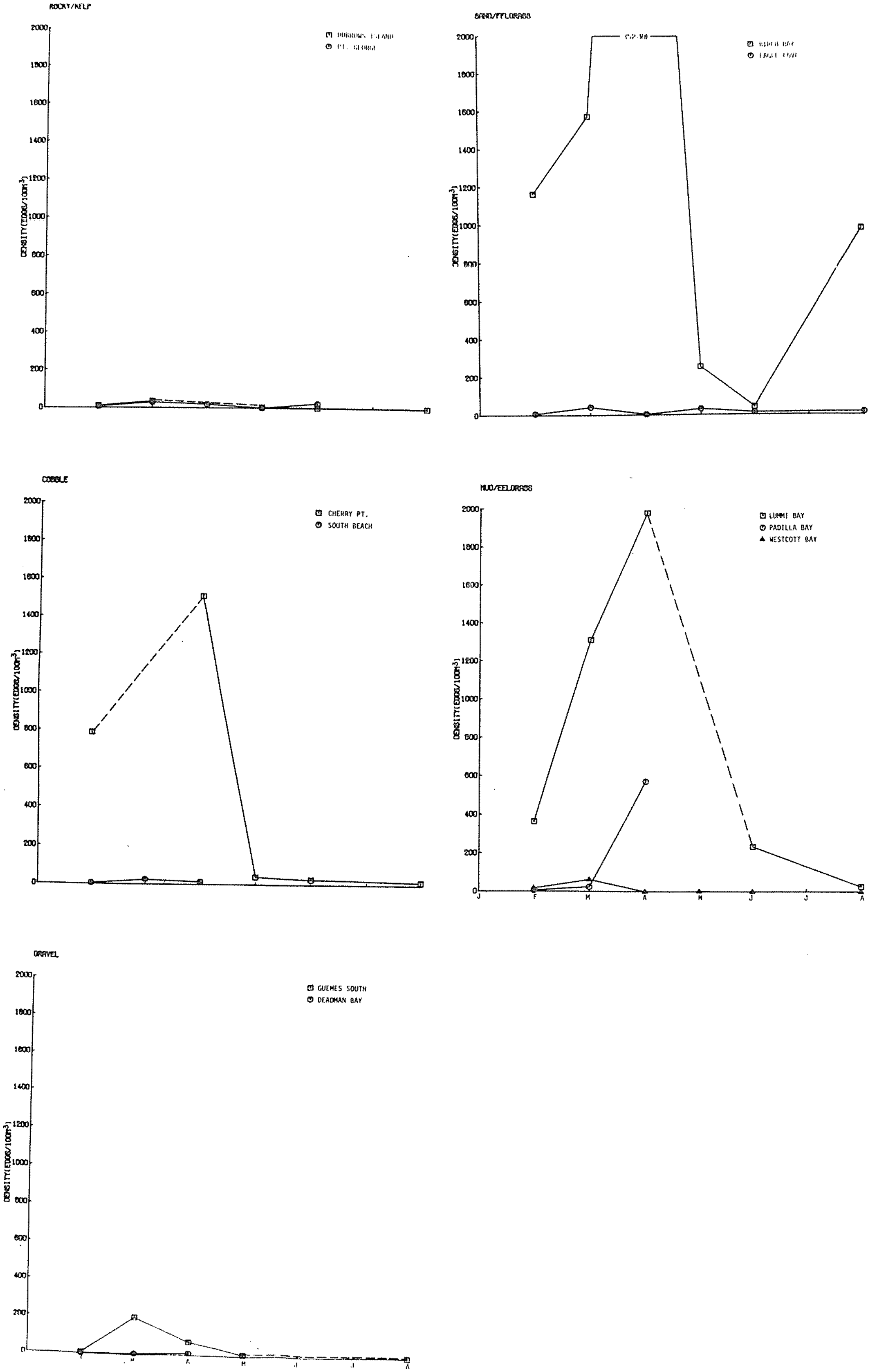

Fig. 31. Monthly density of eggs in bongo net surface collections during 1976.

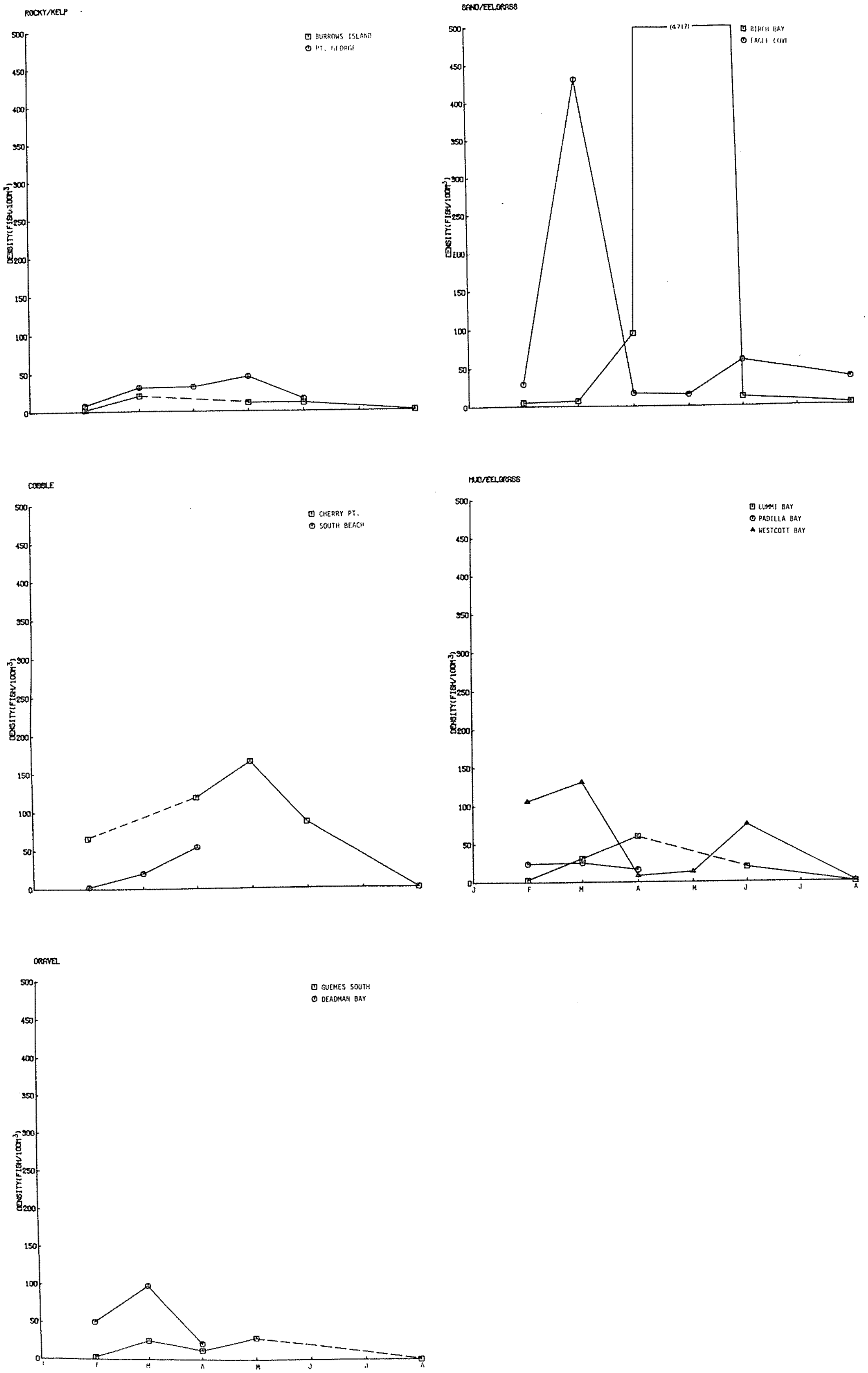

Fig. 32. Monthly density of larvae in bongo net surface collections during 1976.

herring. Burrows Island differed considerably with the peak density occurring in March and with Pacific herring and a cockscomb species the dominant taxa. Again, differences here are apparently related to geographic location of the sites.

Cobble Habitat

Observed egg densities at the two cobble sites varied substantially. Mean density of eggs at Cherry Point was greater than that at South Beach by more than an order of magnitude; both of these sites, however, were dominated by sand sole or butter sole eggs.

Catches of larvae at Cherry Point were also an order of magnitude greater than those at South Beach. This was due to large catches of Pacific herring larvae at Cherry Point. Pacific sand lance larvae dominated the catches at South Beach.

The differences in catches between cobble habitat sites may be due to a number of factors. Cherry Point is less exposed than South Beach, consequently it may provide a less stressed and more preferred environment for the eggs and larvae. Current patterns may effectively flush South Beach but not Cherry Point. Closer proximity of Cherry Point to spawning grounds may also account for some of the catch differences. This is especially likely with herring larvae and sand or butter sole eggs, which were abundant at all of the Cherry Point area sites and not the San Juan Island area sites.

Gravel Habitat

Although egg densities were not high at either gravel site, Guemes Island had a mean density ten times that of Deadman Bay. Deadman Bay had the lowest mean egg density found in the study. Both sites were dominated by sand sole or butter sole eggs, but Guemes Island had considerable numbers of C-O sole eggs.

Both sites also had relatively low densities of larvae, but the density of larvae at Deadman Bay was higher than at Guemes Island, both in mean species richness (highest of all the sites) and mean density. Catches at Guemes Island were highest in May and were dominated by Pacific herring and Pacific cod or walleye pollock. Catches at Deadman Bay were highest in March (also quite high in February) and dominated by Pacific sand lance and a cockscomb species. The high egg and larval species richness that characterized Deadman Bay may be due to its greater subtidal habitat complexity compared with Guemes Island. Differences in egg density were a function of the sand sole or butter sole eggs.

Sand/Eelgrass Habitat

Egg densities were extremely high (higher than at any other site) at Birch Bay and quite low at Eagle Cove. This was due almost entirely to the large catches of a single egg type (sand sole or butter sole) in Birch Bay during late winter and early spring. High densities of a sanddab egg were found in Birch Bay in August. The Eagle Cove catches were dominated by C-O sole eggs and small numbers of sand sole or butter sole eggs. Differences in egg densities between the two sand/eelgrass sites were primarily a function of the higher densities of sand sole or butter sole eggs at the northeastern site.

Densities of larvae were also much higher at Birch Bay than at Eagle Cove. However, the presence of large numbers of Pacific herring larvae during a single month (May) at Birch Bay were responsible for this. There were marked differences in dominant species. Birch Bay catches were highest in May and were dominated by Pacific herring. Eagle Cove catches were highest in March and were dominated by Pacific sand lance and a cockscomb species. Large catches of Pacific herring larvae at Birch Bay may be expected because of its proximity to Pacific herring spawning grounds. The presence of large numbers of cockscomb larvae at Eagle Cove is probably not related to its sand/eelgrass habitat type, but is more likely a function of its proximity to large populations of adult cockscomb in the adjacent rocky intertidal habitat prevalent in the San Juan Islands.

Mud/Eelgrass Habitat

Egg catches at all three mud/eelgrass sites were dominated by sand sole or butter sole eggs. Lummi Bay, like other Cherry Point area sites, had high egg densities, primarily sand sole or butter sole. Padilla Bay had a moderately high mean density of eggs due to a large catch of sand sole or butter sole eggs during one month (April). Westcott Bay had very low egg densities. This again reflected the consistently low egg densities that appeared characteristic for the San Juan Island sites. Low egg densities at the San Juan Island sites may be correlated with the relative scarcity of sandy beaches for flatfish larvae to settle on or the lack of suitable offshore habitat for spawning adults.

Mean densities of larvae were relatively similar at the three mud/eelgrass sites. In contrast to egg densities, the highest densities of larvae were found at Westcott Bay. Pacific herring, smelt, and Pacific sand lance were the predominant species in the Westcott Bay catches. Westcott Bay had a higher density of larvae in February than any of the other sites, and was the only site where Pacific herring were caught in February. These early high densities may be due to the shallow and enclosed nature of Westcott Bay, making it more favorable to early spawners. Lummi Bay and Padilla Bay had similar mean densities but differed in species dominance. Catches of larvae at Lummi Bay were dominanted by Pacific herring and Pacific cod or walleye pollock; whereas those at Padilla Bay were dominated by Pacific sand lance and a rockfish species.

Summary

1. Catches of eggs were totally dominated by flatfish, with one type (sand sole or butter sole) comprising 89.3 percent of the total egg catch.

2. Egg catches differed strikingly between sites and within habitats. Geographic areas were more closely related than sites of similar habitat. Large catches of sand sole or butter sole eggs at the Cherry Point area sites were the main feature distinguishing geographic areas.

3. Catches of fish larvae were dominated by Pacific herring (70.1 percent of the catch). Other species commonly occurring were Pacific sand lance, Pacific cod or walleye pollock, a rockfish, and longfin smelt or surf smelt.

4. Larval catches differed greatly between sites and within habitats both in terms of species present and density. As with eggs, geographic areas were more closely related than sites of similar habitat. The Cherry Point area sites were characterized by having the highest Pacific herring densities, reaching highest levels in May (except for Lummi Bay where no data were collected in May). San Juan Island area sites had highest densities in March and April (most sites in March) largely dominated by Pacific sand lance and cockscomb larvae. Anacortes area sites had different catches of larvae probably due to extreme habitat differences between sites.

Food Organisms of Nearshore Fishes: Results and Discussion

Contents of 1,305 stomachs extracted from 57 species of marine fish were analyzed over the 2-year duration of the Nearshore Fish Survey (Table 18); time and funds were depleted before a remaining 500-800 stomachs could also be analyzed. The stomach samples from WWSC collections included 611 stomachs from 42 species (Table 19).

Overall diet compositions, including Index of Relative Importance (IRI) diagrams for sample sizes $\geq$ 25, are described in the following section for each species individually. Where sample sizes were sufficient for further analysis comparisons of prey composition, abundance, and biomass were made between diets of fish from different habitats, seasons, years, and life history stages.

Appendix 4 is an even more general summarization of the data which is based on the percentage of total IRI (*see* page 1) for each fish

Table 18. Nearshore fish species utilized for stomach analysis, 1974-76

Species	Sample size n	% empty	Condition factor $\bar{x}$±S.D.	Digestion factor $\bar{x}$±S.D.	Total contents wt. $\bar{x}$±S.D. (gr)	Shannon-Wiener Diversity Indices H'	
						Abundance	Biomass
Squalus acanthias, spiny dogfish (immature adult)	8	0	4.5 ± 1.2	2.5 ± 1.3	13.4 ± 12.7	2.22	0.31
Hydrolagus colliei, ratfish (adult)	8	0	4.1 ± 1.0	2.5 ± 0.5	17.1 ± 10.0	3.25	2.87
Clupea harengus pallasi, Pacific herring (juveniles)	163	29	2.6 ± 1.5	2.4 ± 1.4	0.08 ± 0.19	2.62	3.07
Engraulis mordax, northern anchovy (inc. 2 juveniles)	32	3	3.0 ± 1.1	2.4 ± 1.4	0.09 ± 0.07	3.21	3.02
Oncorhynchus gorbuscha, pink salmon (juveniles)	44	13	3.3 ± 1.3	3.4 ± 1.2	0.10 ± 0.11	3.10	3.25
O. keta, chum salmon (juveniles)	37	8	3.4 ± 1.1	3.5 ± 1.2	0.17 ± 0.20	2.55	3.00
O. kisutch, coho salmon (juveniles + 1 adult)	154	3	4.1 ± 1.5	3.4 ± 1.0	0.76 ± 0.78	3.86	3.85
O. nerka, sockeye salmon (juvenile)	45	13	3.6 ± 1.5	3.4 ± 1.5	0.24 ± 0.33	2.00	2.86
O. tshawytscha, chinook salmon (juveniles + 1 adult)	143	8	3.9 ± 1.3	3.8 ± 1.2	0.44 ± 0.57	3.56	3.20
Salmo gairdneri, steelhead trout (adult)	1	0	2.0	4.0	0.06	0.92	0.92
Salvelinus malma, Dolly Varden (juveniles)	1	0	5.0	5.0	0.49	1.21	0.61
Hypomesus pretiosus, surf smelt (61 juveniles, 32 adults)	93	39	2.7 ± 1.7	2.1 ± 1.3	0.11 ± 0.29	2.92	2.29

Table 18. Nearshore fish species utilized for stomach analysis, 1974-76 - Continued

Species	Sample size n	% empty	Condition factor $\overline{x}$±S.D	Digestion factor $\overline{x}$±S.D.	Total contents wt. $\overline{x}$±S.D. (gr)	Shannon-Wiener Diversity Indices H'	
						Abundance	Biomass
Spirinchus thaleichthys, longfin smelt (adult)	3	0	4.0 ± 1.0	4.3 ± 0.6	0.16 ± 0.14	0.88	1.15
Gadus macrocephalus, Pacific cod (juvenile)	1	0	6.0	4.0	0.14	0.0	0.0
Microgadus proximus, Pacific tomcod (adult)	3	0	4.7 ± 1.2	5.0 ± 0.0	1.25 ± 1.58	1.52	0.96
Theragra chalcogramma, walleye pollock (juvenile)	1	0	5.0	4.0	1.90	0.81	0.47
Lycodes palearis, wattled eelpout (adult)	1	0	5.0	3.0	0.17	1.48	2.13
Aulorhynchus flavidus, tubesnout (adult)	11	27	2.9 ± 1.6	3.2 ± 1.4	0.04 ± 0.07	1.39	1.32
Gasterosteus aculeatus, threespine stickleback (adult)	15	6	3.7 ± 1.6	2.9 ± 1.0	0.05 ± 0.09	1.59	1.21
Cymatogaster aggregata, shiner perch (11 juveniles, 30 adults)	41	24	3.3 ± 1.8	2.3 ± 1.3	0.36 ± 0.46	2.61	2.60
Embiotoca lateralis, striped seaperch (adult)	3	67	1.7 ± 1.2	1.7 ± 1.2	0.41 ± 0.72	0.0	0.0
Trichodon trichodon, Pacific sandfish (7 juveniles, 2 adults)	9	11	3.8 ± 1.9	3.4 ± 1.5	0.60 ± 0.82	2.14	1.53
Lumpenus sagitta, snake prickleback (adult)	15	20	3.6 ± 1.6	3.4 ± 1.2	0.06 ± 0.06	2.73	2.39

Table 18. Nearshore fish species utilized for stomach analysis, 1974-76 - Continued

Species	Sample size n	% empty	Condition factor $\overline{x}\pm$ S.D.	Digestion factor $\overline{x}\pm$S.D.	Total contents wt. $\overline{x}\pm$S.D. (g)	Shannon-Wiener Diversity Indices H' Abundance	Shannon-Wiener Diversity Indices H' Biomass
Apodichthys flavidus, penpoint gunnel (3 juveniles, 13 adults)	16	6	4.1 ± 1.5	4.2 ± 1.2	0.51 ± 0.88	1.34	2.13
Pholis laeta, crescent gunnel (5 juveniles, 8 adults)	13	7	3.6 ± 1.3	4.0 ± 1.2	0.10 ± 0.11	2.48	2.25
P. ornata, saddleback gunnel (adult)	4	0	4.8 ± 1.3	3.8 ± 0.5	0.20 ± 0.22	2.32	1.91
Ammodytes hexapterus, Pacific sand lance (4 juveniles, 27 adults)	31	64	2.0 ± 1.6	1.8 ± 1.3	0.01 ± 0.03	1.62	1.48
Sebastes brevispinus, silvergrey rockfish (juveniles)	1	0	5.0	4.0	0.10	1.44	1.62
S. caurinus, copper rockfish (30 juveniles, 41 adults)	71	26	3.7 ± 2.0	3.2 ± 1.5	2.13 ± 5.28	3.75	3.86
S. emphaeus, Puget Sound rockfish (adult)	14	21	4.6 ± 2.1	3.6 ± 1.5	0.44 ± 0.44	1.99	2.75
S. flavidus, yellowtail rockfish (13 juveniles, 6 adults)	19	21	3.9 ± 1.9	3.2 ± 1.4	1.94 ± 3.84	2.98	2.85
S. melanops, black rockfish (8 juveniles, 18 adults)	26	26	3.5 ± 1.9	3.2 ± 1.5	3.18 ± 5.45	1.94	3.21
S. nigrocinctus, tiger rockfish (adult)	1	0	6.0	5.0	4.52	2.16	2.09
S. ruberrimus, yelloweye rockfish (adult)	1	0	6.0	5.0	5.36	1.00	0.07
Anoplopoma fimbria, sablefish (adult)	1	0	5.0	3.0	20.0	1.61	1.54

Table 18. Nearshore fish species utilized for stomach analysis, 1974-76 - Continued

Species	Sample size n	% empty	Condition factor $\overline{x}\pm$S.D.	Digestion factor $\overline{x}=$S.D.	Total contents wt. $\overline{x}\pm$S.D. (gr)	Shannon-Wiener Diversity Indices H' Abundance	Shannon-Wiener Diversity Indices H' Biomass
Hexagrammos decagrammus, kelp greenling (4 juveniles, 27 adults)	31	0	5.5 ± 0.8	3.6 ± 0.6	13.07 ± 17.66	3.42	4.57
H. stelleri, whitespotted greenling (2 juveniles, 11 adults)	13	0	5.6 ± 0.8	3.8 ± 0.7	3.15 ± 3.44	3.12	3.31
Ophiodon elongatus, lingcod (6 juveniles, 8 adults)	14	14	4.2 ± 2.1	3.9 ± 1.4	16.14 ± 31.43	2.00	0.83
Artedius fenestralis, padded sculpin (1 juvenile, 5 adults)	6	0	5.0 ± 0.6	3.8 ± 0.8	0.20 ± 0.33	0.99	1.34
A. harringtoni, scalyhead sculpin (3 juveniles, 4 adults)	7	0	6.0 ± 0.0	4.1 ± 1.1	0.18 ± 0.28	2.59	3.43
A. lateralis, smoothhead sculpin (adult)	1	0	4.0	4.0	0.06	1.58	1.32
Blepsias cirrhosus, silverspotted sculpin (5 juveniles, 15 adults)	20	0	4.8 ± 1.4	3.6 ± 1.0	0.18 ± 0.40	1.96	1.91
Dasycottus setiger, spinyhead sculpin (adult)	1	0	5.0	3.0	29.3	1.51	2.14
Enophrys bison, buffalo sculpin (ad.)	4	0	5.8 ± 0.5	4.3 ± 1.0	27.36 ± 42.8	1.50	0.12
Hemilepidotus hemilepidotus, red Irish lord (adult)	8	0	5.0 ± 0.9	4.0 ± 0.8	12.44 ± 14.01	1.81	3.09
Icelinus borealis, northern sculpin (1 juvenile, 1 adult)	2	50	3.5 ± 3.5	1.5 ± 0.7	0.02 ± 0.03	1.58	0.0
I. tenuis, spotfin sculpin (adults)	11	0	5.7 ± 0.6	4.0 ± 0.0	1.25 ± 1.22	2.38	2.86
Jordania zonope, longfin sculpin (2 juveniles, 20 adults)	22	0	5.7 ± 0.7	3.5 ± 0.7	0.09 ± 0.09	2.16	3.07

Table 18. Nearshore fish species utilized for stomach analysis, 1974-76 - Continued

Species	Sample size n	% empty	Condition factor x±S.D.	Digestion factor x±S.D.	Total contents wt. x±S.D. (gr)	Shannon-Wiener Diversity Indices H' Abundance	Biomass
Leptocottus armatus, staghorn sculpin (22 juveniles, 31 adults)	53	3	4.2 ± 1.6	3.7 ± 1.1	1.71 ± 4.55	2.99	3.42
Myoxocephalus polyacanthocephalus, great sculpin (juveniles)	1	0	3.0	3.0	1.24	0.0	0.0
Rhamphocottus richardsoni, grunt sculpin (juvenile)	1	0	6.0	4.0	0.01	0.56	1.84
Scorpaenichthys marmoratus, cabezon (juvenile)	2	0	5.5 ± 0.7	4.0 ± 0.0	0.53 ± 0.23	0.72	1.23
Eopsetta jordani, petrale sole (adult)	1	0	3.0	3.0	1.88	0.0	0.0
Lepidopsetta bilineata, rock sole (adult)	6	0	5.0 ± 1.4	4.0 ± 0.0	3.86 ± 4.72	2.38	2.41
Parophrys vetulus, English sole (juvenile)	47	2	5.1 ± 1.3	3.7 ± 0.7	0.39 ± 1.71	2.36	2.49
Platichthys stellatus, starry flounder (3 juveniles, 17 adults)	20	15	2.6 ± 2.1	2.4 ± 1.6	2.28 ± 3.05	2.06	2.85
Pleuronichthys coenosus, C-O sole (1 juvenile, 2 adults)	3	0	4.7 ± 0.6	4.0 ± 0	1.40 ± 0.33		
Psettichthys melanostictus, sand sole (juvenile)	1	0	6.0	4.0	0.05	1.74	1.30
	1,305						

Table 19. Nearshore fish species from WWSC collections utilized for stomach analysis, 1974-76

Species	Sample Size n	% Empty	Condition Factor $\bar{x}$±S.D.	Digestion Factor $\bar{x}$±S.D.	Number of prey organisms $\bar{x}$±S.D.	Total contents weight $\bar{x}$±S.D. (gr.)	Shannon-Wiener Diversity Indices, H' Abundance	Shannon-Wiener Diversity Indices, H' Biomass
Squalus acanthias, spiny dogfish (immature adult)	1	0	2.0	2.0	7.0	8.0	1.33	0.40
Clupea harengus pallasi, Pacific herring (juvenile)	87	6	2.7±0.9	2.7±1.0	48.9±48.7	0.02±0.04	1.97	1.46
Oncorhynchus keta, chum salmon (juvenile)	2	0	3.0±0.0	3.0±0.0	11.0±4.2	0.06±0.01	1.49	0.00
O. kisutch, coho salmon (juvenile)	1	0	2.0	1.0	0.0	0.03±0.00	0.00	0.00
O. nerka, sockeye salmon (juvenile)	6	0	3.5±0.8	3.7±0.5	118.8±78.2	0.39±0.36	1.50	1.39
O. tshawytscha, chinook salmon (juveniles + 1 adult)	14	7	3.1±1.1	3.3±1.1	15.6±17.1	0.18±0.19	1.40	1.25
Hypomesus pretiosus, surf smelt (adults + 1 juvenile)	47	10	2.5±1.1	3.1±1.4	45.6±55.7	0.07±0.09	3.24	2.71
Spirinchus thaleichthys, longfin smelt (juvenile)	1	0	4.0	4.0	17.0	0.11	0.32	0.00
Microgadus proximus, Pacific tomcod (41 juveniles, 5 adults)	46	0	3.6±1.0	3.5±0.7	9.3±9.8	0.30±0.64	2.89	2.17
Theragra chalcogramma, walleye pollock (13 juveniles, 8 adults)	21	4	3.2±1.5	2.7±1.1	6.0±7.5	0.08±0.07	2.36	2.43
Aulorhynchus falvidus, tubesnout (adult)	8	25	3.0±1.3	2.5±1.1	17.0±16.4	0.01±0.01	1.71	1.99
Gasterosteus aculeatus, threespine stickleback (12 adults, 4 juveniles)	16	6	3.4±1.3	2.9±1.4	51.3±64.6	0.07±0.07	2.39	1.79
Syngnathus griseolineatus, bay pipefish (adult)	2	0	3.5±0.7	2.5±0.7	7.5±0.7	0.06±0.02	0.57	0.92

Table 19. Nearshore fish species from WWSC collections utilized for stomach analysis - Continued

Species	Sample Size n	% Empty	Condition Factor $\bar{X}\pm$S.D.	Digestion Factor $\bar{X}\pm$S.D.	Number of prey organisms $\bar{X}\pm$S.D.	Total contents weight $\bar{X}\pm$S.D. (gr.)	Shannon-Wiener Diversity Indices, H' Abundance	Shannon-Wiener Diversity Indices, H' Biomass
Cymatogaster aggregata, shiner perch (adult)	66	22	2.6±1.2	2.4±1.2	34.7±59.3	0.06±0.09	1.53	1.26
Embiotoca lateralis, striped seaperch (6 adults, 2 juveniles)	8	25	3.5±1.9	2.3±1.2	51.5±71.1	1.22±1.52	0.66	2.18
Rhacochilus vacca, pile perch (adult + 2 juveniles)	13	38	3.3±2.2	2.4±1.3	11.7±27.9	3.11±5.04	1.68	0.43
Lumpenus sagitta, snake prickleback (adult)	3	0	4.7±0.6	3.0±1.0	7.3±8.5	0.34±0.40	0.88	0.61
Phytichthys chirus, ribbon prickleback (adult)	1	0	3.0	4.0	14.0	0.17	0.00	0.00
Apodichthys flavidus, penpoint gunnel (adult)	3	0	4.3±1.2	3.3±1.2	53.0±73.8	0.46±0.39	0.30	1.16
Pholis laeta, crescent gunnel (adult + 2 juveniles)	15	26	2.7±1.4	2.9±1.4	18.2±38.8	0.06±0.09	1.66	1.67
P. ornata, saddleback gunnel (adult)	1	0	4.0	4.0	5.0	0.07	0.72	0.47
Ammodytes hexapterus, Pacific sand lance (adult + 1 juvenile)	11	27	2.2±0.9	1.9±0.7	24.2±22.9	0.01±0.01	1.04	1.00
Sebastes caurinus, copper rockfish (3 adults, 3 juveniles)	6	33	2.8±1.7	3.0±1.7	3.0±3.7	1.05±1.65	2.28	1.83
S. melanops, black rockfish (juvenile)	3	0	2.0±0.0	3.0±0.0	4.7±6.4	0.01±0.01	0.95	0.00
Hexagrammos decagrammus, kelp greenling (adult)	2	0	6.0±0.0	4.0±0.0	124.0±175.4	14.0±0.0	0.74	1.49
H. stelleri, whitespotted greenling (10 adults, 3 juveniles)	13	0	4.4±0.7	3.3±0.6	13.6±28.9	3.26±6.35	1.72	3.15

Table 19. Nearshore fish species from WWSC collections utilized for stomach analysis - Continued

Species	Sample Size n	% Empty	Condition Factor $\overline{X}$±S.D.	Digestion Factor $\overline{X}$±S.D.	Number of prey organisms $\overline{X}$±S.D.	Total contents weight $\overline{X}$±S.D. (gr.)	Shannon-Wiener Diversity Indices, H'	
							Abundance	Biomass
Artedius fenestralis, padded sculpin (10 adults, 5 juveniles)	15	0	3.7±1.3	3.7±1.2	16.1±20.3	22.76±87.76	2.32	1.73
A. meanyi, Puget Sound sculpin (adult)	2	0	3.5±0.7	4.0±0.0	25.0±11.3	0.44±0.70	1.95	2.07
Blepsias cirrhosus, silverspotted sculpin (adult)	10	0	4.8±0.8	3.7±1.4	43.1±37.7	0.52±0.78	0.58	1.36
Clinocottus embryum, calico sculpin (adult)	2	0	3.5±0.7	4.0±0.0	16.0±7.1	0.05±0.04	0.86	0.30
Enophrys bison, buffalo sculpin (6 juveniles, 2 adults)	8	25	3.8±2.1	3.5±1.6	2.3±2.1	0.57±0.95	3.04	1.72
Leptocottus armatus, staghorn sculpin (73 adults, 20 juveniles)	93	2	4.0±1.3	3.3±0.9	8.1±14.0	2.21±4.18	3.28	4.06
Myoxocephalus polyacanthocephalus, great sculpin (3 adults, 1 juvenile)	4	50	2.5±1.9	2.5±1.7	0.8±1.0	1.19±1.59	1.58	0.96
Agonus acipenserinus, sturgeon poacher (adult)	4	0	4.5±1.0	3.8±0.5	77.5±60.1	0.23±0.36	2.05	1.36
Eumicrotremus orbis, Pacific spiny lumpsucker (adult)	3	0	6.0±1.0	4.0±0.0	33.3±42.3	0.24± 0.13	1.24	1.71
Liparis florae, tidepool snailfish (adult)	4	0	4.5±0.6	3.3±0.5	6.0±4.2	0.19±0.05	1.83	1.63
Hippoglossoides elassodon, flathead sole (juvenile)	1	0	4.0	4.0	59.0	0.15	2.40	0.82
Lepidopsetta bilineata, rock sole (8 juveniles, 3 adults)	11	9	3.6±1.4	3.5±1.0	14.9±15.0	0.35±0.47	1.32	2.49
Parophrys vetulus, English sole (10 juveniles, 2 adults)	12	0	4.0±1.0	2.8±1.3	21.4±22.6	0.13±0.19	1.34	2.02

Table 19. Nearshore fish species from WWSC collections utilized for stomach analysis - Continued

Species	Sample Size n	% Empty	Condition Factor $\bar{x}$±S.D.	Digestion Factor $\bar{x}$±S.D.	Number of prey organisms $\bar{x}$±S.D.	Total contents weight $\bar{x}$±S.D.(gr.)	Shannon-Wiener Diversity Indices, H' Abundance	Shannon-Wiener Diversity Indices, H' Biomass
Platichthys stellatus, starry flounder (23 juveniles, 3 adults)	26	15	3.0±1.5	3.0±1.4	12.0±11.4	0.66±2.10	2.84	1.39
Pleuronichthys coenosus, C-O sole (juvenile)	1	0	3.0	4.0	22.0	2.32	0.99	0.14
Psettichthys melanostictus, sand sole (juvenile)	18	11	3.5±1.8	3.4±1.0	19.2±27.4	0.04±0.03	1.71	1.98
TOTAL	611							

species; samples from FRI and WWSC collections have been separated in order to illustrate food habit differences between species in the western versus eastern regions of northern Puget Sound.

Squalus acanthias, Spiny Dogfish

Eight spiny dogfish were captured at the San Juan Island cobble habitat site (South Beach) during a September nighttime collection.

A high percentage (71 percent) of the stomach contents were highly digested and unidentifiable. Epibenthic gammarid amphipods and shrimp and benthic gastropods dominated the diet numerically, while Pacific sand lance contributed 95 percent of the total consumed (identifiable) biomass. The one spiny dogfish supplied by WWSC contained four gammarid amphipods, one polychaete annelid and one turbellarian.

Hydrolagus colliei, Ratfish

A nocturnal predator in the nearshore demersal fish assemblage at South Beach was the ratfish. Characterized by one of the most diverse diets examined, eight ratfish fed on an array of brachyuran crabs (*Cancer magister, C. oregonensis, Pugettia gracilis*, and *Telmessus chiragonus*), valviferan (*Synidotea* sp.) and flabelliferan isopods, gammarid amphipods (*Paraphoxus spinosa*, *Esiroides* sp., *Pontogeneia* sp., *Photis californica, Photis* sp., Lyssiansid sp., *Aorides* sp.), gastropods, other diverse peracaridan crustaceans (*Hippolyte clarki, Heptacarpus stimpsoni*, Parapaguridae, and *Paguristes* sp.), hyperiid amphipods, oniscoidean isopods, polychaetes, bivalves, fish, tanaidaceans, and amphineurans. The turbellaria found in the stomachs may have been parasitic, as were the *Gyrocotyle urna* (cestode) which was not included as a prey item.

Composition of the prey by weight was dominated by unidentifiable fishes (54 percent) and brachyuran crabs (13 percent).

Clupea harengus pallasi, Pacific Herring

Juvenile Pacific herring constituted the predominant species in north Puget Sound's neritic fish assemblage and, as such, represented the largest stomach analysis sample (163). The specimens examined indicated a low mean fullness factor, high stages of digestion, and the fifth highest percentage of empty stomachs; this was probably because of high digestive and gastric evacuation rates and because these typically diurnally feeding fish were collected at night.

These juvenile herring were planktivorus, preying upon planktonic or epibenthic crustaceans and their larvae (Fig. 33). Calanoid copepods dominated the overall diet composition by frequency of occurrence, percentage abundance, and percentage biomass. Harpacticoid and cyclopoid copepods, hyperiid amphipods, barnacle nauplius and cypris stages, and

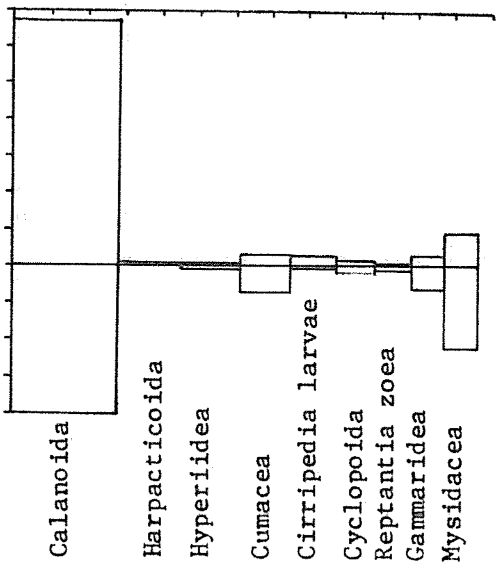

Fig. 33. Pacific herring juveniles, I.R.I. Prey Spectrum (n=115).

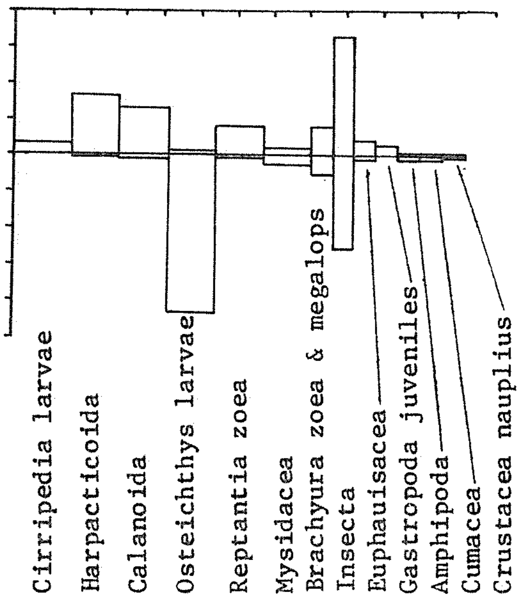

Fig. 34. Northern anchovy, I.R.I. Prey Spectrum (n=31).

crab zoea were less important while cumaceans, gammarid amphipods, and mysids contributed significant percentages of the total biomass of prey organisms. In addition to the prey indicated in Fig. 33, crab megalops, euphausiids, crustacean eggs, fish larvae, and diverse crustacean larvae contributed to the total diet.

Juvenile Pacific herring were also captured during WWSC beach seine collections, primarily along the northeast and south sides of Guemes Island, and at the Cherry Point and Birch Bay sites. These fish fed principally on shallow sublittoral epibenthic organisms such as harpacticoid copepods which comprised 81.7 percent of the total IRI; shrimp larvae and other pelagic organisms, accounted for only 13.5 percent. Other epibenthic organisms--gammarid amphipods, oniscoidean and valviferan isopods, shrimp and bivalves--made only incidental contributions to the total IRI.

The diet composition from several sites and sampling periods indicated major differences in food habits between habitats and seasons. A series of samples obtained from three of the northeastern Puget Sound sites--Birch Bay, Cherry Point, and Padilla Bay--indicated that different planktonic organisms were the principal dietary components at the different sites; calanoid copepods in Padilla Bay, mysids in Birch Bay, and barnacle (cypris) nauplii at Cherry Point (Table 20).

Herring caught in Westcott Bay in June and August 1976 indicated only slight temporal variability (Table 21). In June, harpacticoid copepods were preyed upon by the highest percentage of herring but calanoid copepods dominated total IRI composition. Crabs and crab zoea, mysids, ostracods, and larva of Pacific herring and Pacific sand lance composed the remaining prey. The diet composition from the August collections was less diverse but still indicated calanoids to be the predominant herring prey organism with a relatively slight contribution by hyperiid amphipods.

Engraulis mordax, Northern Anchovy

Northern anchovies were captured only in spring and early summer in the northeastern study areas, namely, the Padilla Bay, Birch Bay, and Cherry Point sites. As with herring, the anchovy samples indicated a high rate of digestion with a significant proportion of unidentifiable material in the total stomach contents sample (65.4 percent).

The identifiable organisms (Fig. 34) indicated rather unselective planktonic food habits. Fish (juvenile rockfish) and fish larvae (clupeidae), harpacticoid and calanoid copepods, crab and barnacle larvae, and insects, in descending order, comprised the prey organisms with the highest IRI values.

Table 20. Percent of total I.R.I. contributed by dominant prey taxa of juvenile Pacific herring from Birch Bay, Cherry Point, and Padilla Bay in May 1976

	n	Mysids	Cumaceans	Calanoid copepods	Gammarid amphipods	Barnacle nauplii	Fish	Harpacticoid copepods
Birch Bay	10	72.3	12.3	9.0	3.7	0.1	0.0	< 0.1
Cherry Point	12	0.0	0.0	6.2	0.3	86.8	2.0	0.1
Padilla Bay	9	0.2	0.0	91.7	0.2	0.9	0.0	2.0

Table 21. Percent of total I.R.I. contributed by dominant prey taxa of juvenile Pacific herring from Westcott Bay in June and August, 1976

	n	Calanoid copepods	Harpacticoid copepods	Crab larvae	Fish larvae	Ostra-cods	Crabs	Hyperiid amphipods	Mysids
June 1976	8	83.4	5.9	5.3	1.4	1.2	1.2	0.0	0.9
August 1976	10	95.4	< 0.1	0.2	0.0	0.0	0.0	4.3	0.0

Table 22. Percent of total I.R.I. contributed by dominant prey taxa of juvenile chum salmon captured by beach seine versus townet in northern Puget Sound, 1974-76

	Sample size n	Harpac-ticoid copepods	Gammarid amphipods	Onis-coidean isopods	Fish	Eupha siids	Cumaceans	Calanoid copepods	Hyperiid Amphi-pods
Beach Seine	35	70.9	11.6	10.6	2.7	2.0	1.1	0.0	0.0
Townet	32	3.6	1.1	0.0	0.2	< 0.1	0.6	80.0	12.3

Oncorhynchus gorbuscha, Pink Salmon (Juveniles)

Juvenile pink salmon were present in the largest numbers in the neritic waters of northern Puget Sound from June-August. Their presence was most evident in the sand/eelgrass and mud/eelgrass habitats, with the largest samples from Lummi Bay in mid-June.

Thirteen percent of the pink salmon had empty stomachs and 40.1 percent of the total stomach contents were unidentifiable. The stomach contents were, on the average, half full and the contents half digested.

Juvenile pinks preyed on a diverse assortment of epibenthic and neritic plankton, with calanoid copepods providing the highest percentage of the total IRI, and harpacticoid copepods, gammarid amphipods, barnacle larvae, and cumaceans contributing lower, but fairly equal proportions (Fig. 35).

Oncorhynchus keta, Chum Salmon (Juveniles)

Juvenile chum salmon occurred throughout the north Puget Sound study area from May-August, principally in the neritic fish assemblages. Lummi Bay, Burrows Island, and South Beach contributed the larger samples of this species. Two specimens examined from WWSC collections originated from a July 1974 beach seine collection at southern Guemes Island.

Similar to the juvenile pink salmon occurring at the same time, juvenile chum stomachs were typically half full (8 percent empty) and the contents half digested (51.2 percent unidentifiable organisms). Unlike the pink juveniles, however, chum juveniles had a less diverse prey spectrum (Fig. 36). Calanoid copepods completely dominated the total IRI (79.5 percent), with hyperiid amphipods being second in importance (12.3 percent). Harpacticoid copepods, gammarid amphipods, cumaceans, and eupausiids were other less important prey items.

The two juvenile chums from WWSC had consumed principally gammarid amphipods; cumaceans and harpacticoid copepods constituted the other prey organisms.

This prey spectrum indicates that juvenile chums had a more pelagic feeding behavior than juvenile pinks, although epibenthic organisms also were important prey organisms in the chum diet, especially when they frequented shallow sublittoral habitats (this is generally when the juveniles are $\leq$ 60 mm in length). When the combined prey compositions of juvenile chum salmon caught in beach seine collections were compared with those collected by townet (Table 22), it is apparent that the (earlier, smaller) chums frequenting the shallow sublittoral environment were feeding predominantly upon epibenthic organisms--harpacticoid copepods, gammarid amphipods, and oniscoidean isopods--while neritic (later, larger) chums utilized pelagic organisms--calanoid copepods and hyperiid amphipods.

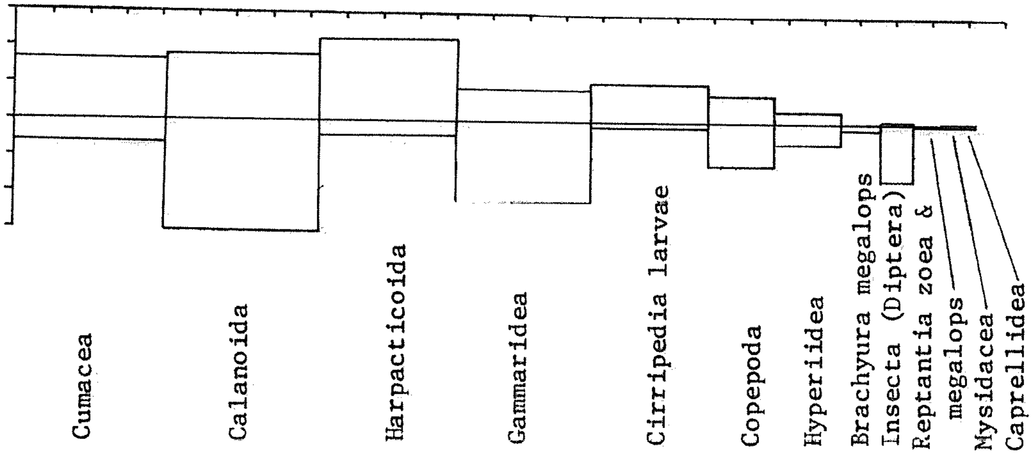

Fig. 35. Pink salmon juveniles, I.R.I. Prey Spectrum (n=38).

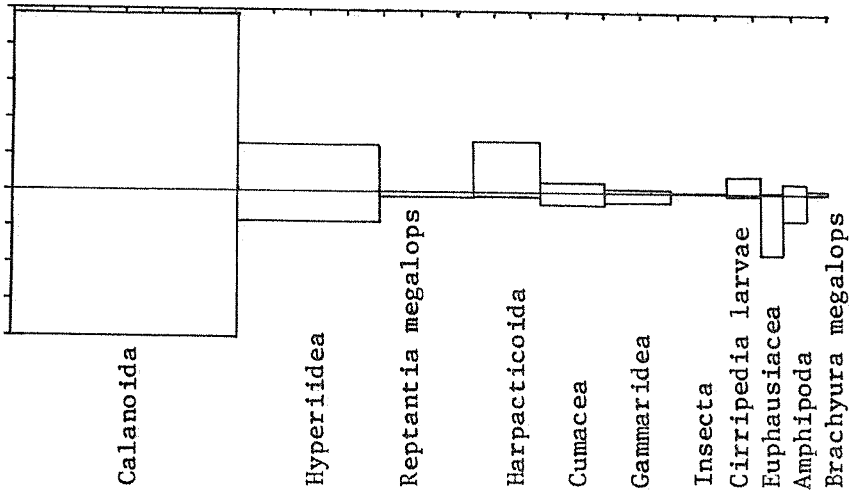

Fig. 36. Chum salmon juveniles, I.R.I. Prey Spectrum (n=34).

Oncorhynchus kisutch, Coho Salmon (Juveniles)

Juvenile coho salmon were present throughout the neritic waters of north Puget Sound from April-October. Townet collections at Birch Bay, Eagle Cove, Shannon Point, Cherry Point, and Padilla Bay produced the most fish for stomach samples. Of the stomach samples examined, only 3 percent were empty and the remaining 149 averaged over half full and the contents were only partially digested (26.7 percent unidentifiable).

The overall prey IRI spectrum (Fig. 37) shows that juvenile coho fed upon both epibenthic and pelagic organisms, but apparently equally so on those which were available within a certain size range. The pelagic organisms included drift insects (the most commonly taken item), crab zoea and megalops, hyperiid amphipods, and fish. Epibenthic prey included only crustaceans--gammarid amphipods, shrimp (Crangonidae), oniscoidean isopods, and ostracods.

In terms of the total IRI, the highest contributors were fish (23.1 percent), insects (21.7 percent), peracaridian crustaceans (15.2 (15.2 percent), oniscoidean isopods (14.2 percent), gammarid amphipods (8.9 percent), and crab larvae (6.7 percent). Identifiable amphipods included *Eusiroides* sp. (the most common), *Atylus* sp., *Allorchestes* sp., *Eohaustorius* sp., *Calliopius laeviusculus*, Talitroidea sp., *Paraphoxus (Trichophoxus)* spp., *Pontogeneia* spp., and unidentified Hyperiidae species. The mysid was *Holmsiella anomala*, the isopods were predominantly *Gnorimosphaeroma oregonense*, and the calanoid copepod was *Epilabidocera amphitrites*. The identifiable fish were all larval or juvenile herring.

Apparent habitat and temporal variations were evident when comparing the diet composition of juvenile coho caught in Padilla Bay (mud/eelgrass), Shannon Point (cobble), Birch Bay (mud/eelgrass), and Cherry Point (cobble) from June through August 1976 (Table 23). In June, crab larvae and euphausiids were the principal components of the total IRI at Padilla Bay, while euphausiids, fish and hyperiid amphipods dominated at Shannon Point. Juvenile coho occurring in the July collections further north at Birch Bay and Cherry Point showed little differences, however; insects and herring constituted the majority of the total IRI. In August, crab larvae were again important in the diet of coho appearing in the Padilla Bay and Shannon Point collections. Gammarid amphipods provided the highest percentage of the IRI from Birch Bay while insects were secondary in importance at Shannon Point.

Oncorhynchus nerka, Sockeye Salmon (Juveniles)

Except for a sizable catch at Birch Bay in May 1976, juvenile sockeye were infrequently encountered in the neritic waters of north Puget Sound, usually only in the northeastern study sites during May through September.

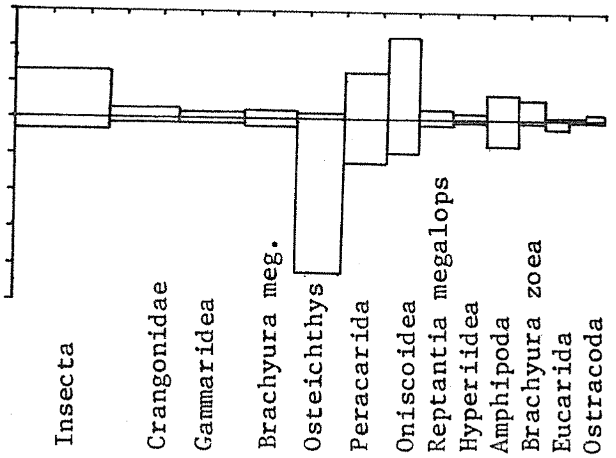

Fig. 37. Coho salmon juveniles, I.R.I. Prey Spectrum (n=149).

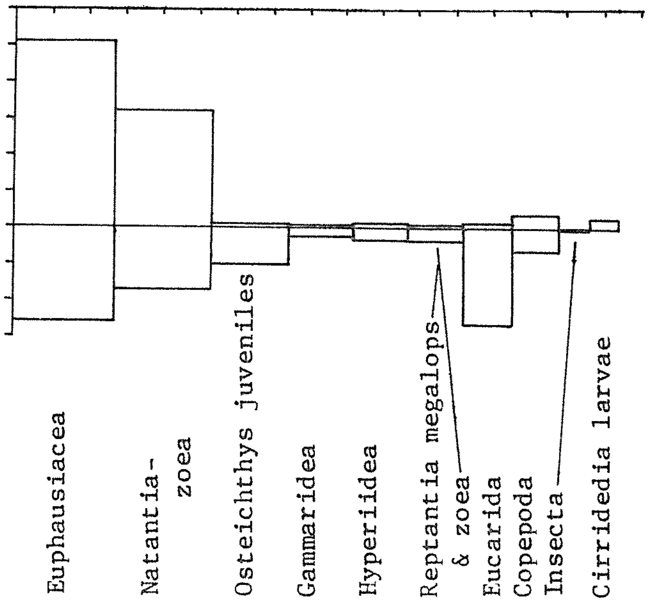

Fig. 38. Sockeye salmon juveniles, I.R.I. Prey Spectrum (n=39).

Table 23. Percent of total I.R.I. contributed by dominant prey taxa of juvenile coho salmon at Padilla Bay, Shannon Pt., Birch Bay and Cherry Point in summer, 1975

	Sample size n	Crab larvae	Euphausiids	Fish	Hyperiid amphipods	Gammarid amphipods	Poly-chaetes	Insect
June 1975								
Padilla Bay	10	70.6	20.2	6.7	0.3	0.8	0.0	0.0
Shannon Point	8	7.2	50.5	11.9	15.2	6.8	1.5	0.0
July 1975								
Birch Bay	8	0.4	0.0	36.7	0.0	0.7	0.0	61.9
Cherry Point	8	4.7	0.0	20.4	2.5	0.0	0.3	71.9
August 1975								
Birch Bay	20	35.1	0.0	50.9	< 0.1	0.2	0.0	13.5
Shannon Point	9	53.2	0.0	0.0	0.0	8.8	0.0	38.0

Table 24. Percent of total I.R.I. contributed by dominant prey taxa of juvenile chinook salmon at Padilla Bay and Burrows Island in July 1975

	Sample Size n	Polychaetes	Crabs	Insects	Gammarid amphipods	Calanoid copepods
Padilla Bay	8	69.	25.4	4.5	0.5	0.0
Burrows Island	8	0.2	72.5	9.5	16.8	0.7

Thirteen percent of the stomach samples were empty and, as in the other juvenile salmonids, the stomachs were on the average half full and the contents less than half digested.

Unlike other salmonids, sockeye juveniles were dependent upon euphausiids, shrimp and fish larvae, and general (unidentifiable) eucaridan crustaceans (typically epibenthic organisms), and to a lesser degree upon pelagic and surface prey items such as copepods, barnacle nauplii, and hyperiid amphipods (Fig. 38).

Six juvenile sockeye salmon included in the WWSC collections of July 1974 at Shannon Point and northeast Guemes Island had fed predominantly upon gammarid amphipods (68.8 percent of total IRI), larvaceans (18.5 percent of total IRI), and calanoid copepods (8.9 percent of total IRI).

Oncorhynchus tshawytscha, Chinook Salmon (Juveniles)

Juvenile chinook salmon were ranked among the 10 most common neritic fishes in north Puget Sound. All the stomach samples originated from the two eastern study sites from May through September with the largest samples from Padilla Bay, Birch Bay, and Burrows Island in July and August. Fitting the general pattern for juvenile salmonids, the chinook salmon samples indicated a low percentage of empty stomachs and mid-fullness and mid-digestion indices. Of all the juvenile salmonids, chinook salmon had the lowest percentage of unidentifiable material in the stomach samples (20.1 percent).

The generalized prey spectrum indicated both epibenthic and pelagic feeding behavior with an emphasis on the latter (Fig. 39). Overall, the most important prey taxa were crab megalops, insects, juvenile and larval fish (Pacific herring and surf smelt) and gammarid amphipods. Diogenetic trematodes found loose in the stomachs were probably parasitic forms.

Juvenile chinooks from July 1975 collections in Padilla Bay and Burrows Island (Table 24) were similar in prey composition, but polychaete annelids were more important in the diet of fish from Padilla Bay while brachyuran crabs dominated the total IRI values for the Burrows Island composition with gammarid amphipods (fourth at Padilla Bay) ranking second.

August 1976 prey spectra from Birch Bay, Cherry Point, Lummi Bay, Padilla Bay, and Burrows Island (Table 25) also indicated distinct between-habitat differences in juvenile chinook salmon prey composition during one month. Juvenile fish were the dominant food organism at Birch Bay (diogenetic trematodes were considered parasitic). Larvae, ostracods, and gammarid amphipods were the most important prey at Cherry Point. Fish from the mud/eelgrass site just south of Cherry Point, Lummi Bay, had a diet dominated by gammarid amphipods and crab larvae. The IRI composition of Padilla Bay (mud/eelgrass) chinooks was somewhat

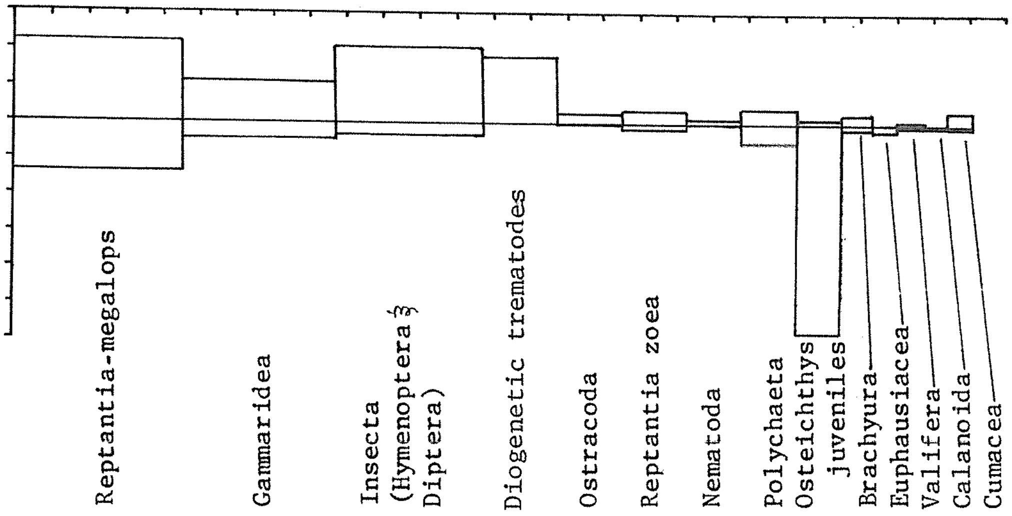

Fig. 39. Chinook salmon juveniles, I.R.I. Prey Spectrum (n=131).

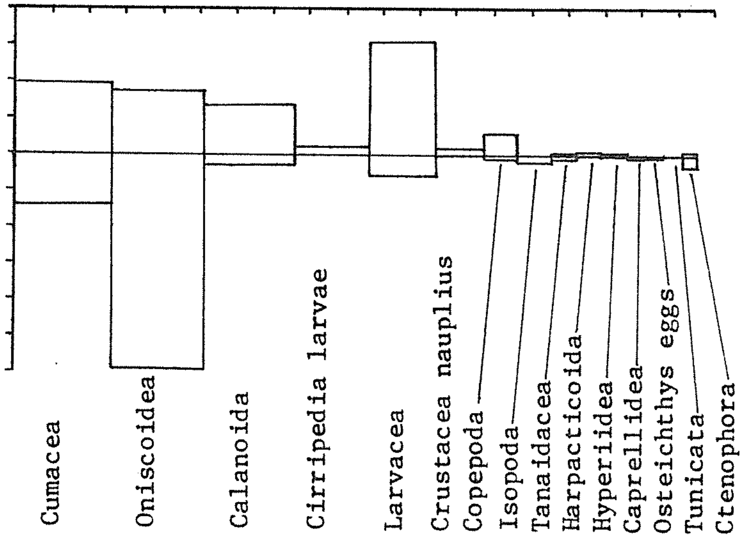

Fig. 40. Surf smelt I.R.I. Prey Spectrum (n=56).

Table 25. Percent of total I.R.I. contributed by dominant prey taxa of juvenile chinook salmon at Birch Bay, Cherry Point, Lummi Bay, Padilla Bay, and Burrows Island in August 1976

	Sample size n	Diogenetic trematodes	Fish	Poly- chaetes	Crab larvae	Ostra- cods	Gammarid amphipods	Insects	Cuma- ceans	Euphau- siids
Birch Bay	11	51.5	47.8	0.1	0.2	0.0	< 0.1	0.2	0.0	0.0
Cherry Point	11	0.5	1.4	0.3	35.2	31.5	26.3	3.5	< 0.1	< 0.1
Lummi Bay	11	0.6	1.0	0.0	38.2	1.7	48.9	3.8	1.3	0.0
Padilla Bay	31	0.2	0.2	2.9	70.8	0.6	6.1	15.6	< 0.1	0.9
Burrows Island	16	0.0	13.6	0.0	54.3	0.0	4.7	26.7	0.0	0.2

Table 26. Percent of total I.R.I. contributed by dominant prey taxa of copper rockfish at Deadman Bay, San Juan Island in July 1974, July 1975, and August 1974

	Sample size n	Oniscoi- dean isopods	Fish	Poly- chaetes	Crabs	Gammarid amphipods	Shrimp	Mysids	Rocks	Anthuridean isopods
July 1974	12	41.9	29.1	13.1	6.3	2.3	0.2	0.0	0.1	0.0
August 1974	10	0.0	4.8	0.1	3.1	73.3	8.8	3.7	2.9	1.8
July 1975	9	0.1	0.0	0.0	0.0	95.8	1.2	2.3	0.0	0.0

Table 27. Percent of total I.R.I. contributed by dominant prey taxa of staghorn sculpin captured by townet at Birch Bay and Cherry Point in August 1976

	Sample size n	Poly- chaetes	Crabs	Fish	Diogeneid trematodes	Shrimp	Crab larvae	Gammarid amphipods
Birch Bay	6	37.1	27.1	20.0	4.8	4.3	0.0	1.4
Cherry Point	14	38.2	3.0	0.0	4.3	0.0	40.5	11.8

comparable to Lummi Bay fish (with a contribution by crab larvae) but was supported by only insects. At the only rocky/kelp bed habitat site, Burrows Island, chinooks fed principally upon crab larvae, with insects and juvenile fish being somewhat less important.

Juvenile chinook salmon were caught in WWSC beach seine collections in southern North Sound (Guemes Island sites, Padilla and Fidalgo bays) during July and August. Their diet was almost entirely taken up by crab larvae (megalops) which constituted 89.3 percent of the total IRI for that species. Insects, gammarid amphipods, and polychaetes formed the majority of the remaining incidental prey organisms.

Salmo gairdneri, Steelhead (Rainbow Trout)

The one adult steelhead caught in a townet at Point Migley (rocky/kelp bed) in September 1975 had consumed two mysids and a brachyuran crab megalops.

Salvelinus malma, Dolly Varden

One Dolly Varden trout, captured by townet in August 1976 at Padilla Bay, had consumed 61 crab megalops (73.5 percent of total abundance, 90 percent of total biomass), 12 insects (14.5 percent of total abundance and 5.5 percent of total biomass), six gammarid amphipods, and four ostracods.

Hypomesus pretiosus, Surf Smelt

Surf smelt were similar to Pacific herring in their distribution; the eastern sites, Birch Bay and Padilla Bay, produced especially large stomach samples. Also like the herring, the overall surf smelt sample had a high rate of empty stomachs (39 percent) and the remaining specimens averaged just less than 25 percent full with the contents seldom identifiable (numerically, 70 percent unidentifiable material). The total sample was approximately two-thirds juveniles and one-third adults.

The overall prey spectrum (Fig. 40) include both pelagic and epibenthic organisms as important prey. According to the total IRI, epibenthic oniscoidean isopods were the most important prey organisms followed by cumaceans, larvaceans, and calanoid copepods. One specimen of *Lophopanopeus bellus* was also found in a stomach (but was not included in the IRI graph).

Hypomesus pretiosus were caught all along the eastern shoreline of northern Puget Sound during WWSC beach seine collections; the highest catches obtained for stomach samples were from Cherry Point in December 1975. Of the diverse array of prey organisms consumed, 31.8 percent of the total IRI were larvaceans; 28.3 percent, caprellids; 8.8 percent, gammarid amphipods; 8.6 percent netatodes; 8.1 percent, calanoid copepods; 8.0 percent, shrimp; and 5.5 percent, harpacticoid copepods. Thus, close to 60 percent of the prey were epibenthic organisms.

Spirichus thaleichthys, Longfin Smelt

Three adult longfin smelt caught during the September 1975 townet collection at Cherry Point had consumed principally crab larvae, calanoid copepods, and mysids, with supplemental contributions by hyperiid and gammarid amphipods. This prey spectra suggested a basically pelagic feeding behavior.

The single longfin smelt collected by WWSC for stomach analysis originated from a July 1974 northeastern Guemes Island collection; its stomach contained 16 insects and one gammarid amphipod.

Gadus macrocephalus, Pacific Cod

The stomach of one juvenile Pacific cod captured in a July 1974 beach seine haul at False Bay, San Juan Island (sand/eelgrass habitat), was full of gammarid amphipods only, with no digestion evident.

Microgadus proximus, Pacific Tomcod

Three adult Pacific tomcod captured during a Birch Bay townet collection in June 1976 had fed mostly upon gammarid amphipods (mean of 14.3/stomach; 60.4 percent of total IRI), but Pacific herring were the highest contribution to the total consumed biomass (mean of 2.7/stomach; 25.3 percent of total IRI). There were incidental contributions by other (unidentifiable) fish (9.1 percent of total IRI), shrimp, crab, cumaceans, tanaids, and mysid larvae. Except for the fish, these prey are principally epipelagic and benthic organisms. The stomachs were quite full and showed little digestion of the prey.

Juvenile Pacific tomcod were also often caught in large numbers during the WWSC beach seine collections, with large samples originating from Shannon Point in July 1974 and Birch Bay in December 1975. Shrimp (38.9 percent of total IRI), gammarid amphipods (38.0 percent of total IRI) and calanoid copepods (19.6 percent of total IRI) comprised the majority of the prey organisms from these samples.

Theragra chalcogramma, Walleye Pollock

The stomach of a single juvenile pollock caught by beach seine at South Beach in October 1974 was three-quarters full of six shrimp (*Heptacarpus tridens* and Crangon sp.; 89.9 percent of total biomass) and two oniscoidean isopods.

December 1975 beach seine collections made by WWSC at Birch Bay and Cherry Point produced a large number of juvenile walleye pollock. Epibenthic or benthic organisms were the principal prey organisms; gammarid amphipods constituted 71.2 percent of the total IRI, valviferan isopods contributed 16.8 percent, while hyperiid amphipods, shrimp, and calanoid copepods made up lower contributions.

Lycodes palearis, Wattled Eelpout

A stomach from this relatively rare eelpout, captured in a Westcott Bay beach seine sample in February 1976, was 75 percent full with less than 50 percent of the prey organisms identifiable. Of these, tanaids predominated, followed by gammarid amphipods, polychaetes, oligochaetes, and a clam siphon.

Aulorhynchus flavidus, Tube-snout

Tube-snouts were frequently captured in the mud/eelgrass and sand/eelgrass habitats and pocket gravel beaches in northern Puget Sound. Although the stomach sample size was small, the data on the empty stomach and digestion factor indicated a high rate of digestion (Table 18). Identifiable organisms which were the most important components of the diet were gammarid amphipods (90.0 percent of total IRI), with lower contributions by polychaete annelids (6.3 percent), and crab larvae (1.9 percent).

Eight tube-snouts included in the WWSC samples from Cherry Point, Birch Bay and northeast Guemes Island also indicated a high degree of digestion, with two of these stomachs being empty. Compared to the San Juan Island samples, the eastern shore fish tended to have more pelagic organisms in their diet. Pelagic calanoid copepods comprised 73.5 percent of the total IRI, while harpacticoid copepods (32.1 percent), gammarid amphipods (23.9 percent), and mysids (7.6 percent) made up the principal epibenthic prey composition.

Gasterosteus aculeatus, Threespine Stickleback

Although the stickleback was the second most frequently encountered neritic species, the lack of adults resulted in a small sample of stomachs. Only 6 percent of these were empty and few stomachs held much more than 50 percent identifiable organisms (64.9 percent unidentifiable). The more important organisms were both epibenthic--harpacticoid copepods (66.5 percent of the total IRI), and polychaetes (3.6 percent)--or pelagic--calanoid (14.2 percent), and euphausiids (13.1 percent).

Threespine sticklebacks were most common in WWSC collections in the southern North Sound sites at Guemes Island and Padilla Bay. 70.2 percent of the total IRI was gammarid amphipods, 13.6 percent harpacticoid copepods, 7.9 percent to diogenetic trematodes (probably parasitic), 4.2 percent crab larvae and 1.2 percent cumaceans; all but the crab larvae were epibenthic organisms.

Syngnathus griseolineatus, Bay Pipefish

Two adult bay pipefish captured during WWSC beach seining at Birch Bay were large enough to permit analysis of their stomach contents; 86.8 percent of the total IRI were isopods, the remainder, gammarid amphipods.

Cymatogaster aggregata, Shiner Perch

Shiner perch were relatively common in the nearshore beach seine catches (third and eighth in occurrence in 1974-75 and 1975-76, respectively), especially at Deadman and Westcott bays during summer; they were also caught in the townet at Birch Bay, Cherry Point, and Burrows Island. Their stomachs were seldom over 50 percent full and the contents were usually highly digested.

Prey composition was relatively equally divided between a number of epibenthic organisms (Fig. 41), gammarid amphipods (38.6 percent of total IRI), cumaceans (29.2 percent), and polychaetes (22.2 percent) with caprellid amphipods making a lesser contribution (8.0 percent).

Shiner perch ranked among the five most abundant species in the WWSC collections, being especially common in July through September at the Cherry Point (cobble habitat), Padilla Bay (mud/eelgrass), and Legoe Bay (gravel) sites. Despite a larger sample size than in the San Juan Island collections, the prey composition from the pooled WWSC collections was considerably less diverse ($H' = 2.61$ for abundance = 2.60 for biomass (FRI) versus $H' = 1.53$ for abundance = 1.26 for biomass (WWSC), and was dominated by gammarid amphipods (95.6 percent of total IRI) with only minor contributions by calanoid copepods and isopods.

Embiotoca lateralis, Striped Seaperch

Two of the three striped seaperch stomachs were empty. The remaining sample, from a December 1974 Deadman Bay beach seine, contained only 25 oniscoidean isopods and a large amount of unidentifiable material (83.9 percent).

Six striped seaperch from WWSC Guemes Island and Cherry Point sites had a pooled prey composition composed almost entirely of epibenthic or benthic crustaceans--gammarid amphipods (83.9 percent of total IRI), valviferan (6.7 percent) and flabelliferan isopods (1.8 percent), crabs (6.1 percent) and shrimp (1.1 percent).

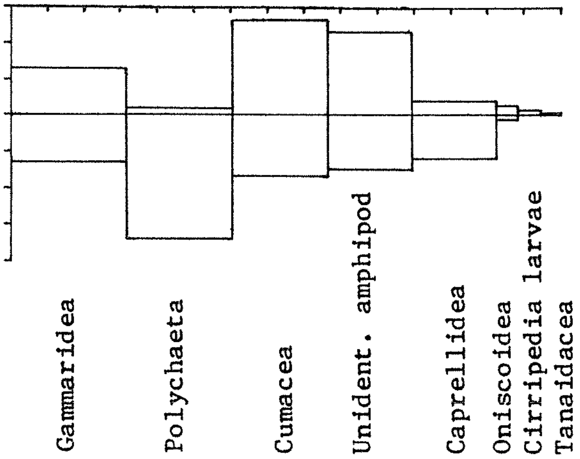

Fig. 41. Shiner perch I.R.I. Prey Spectrum (n=31).

Rhacochilus vacca, Pile Perch

Eight of the 13 pile perch collected by WWSC at the two Guemes Island and the Cherry Point sites had identifiable organisms in their stomachs. The majority of these (73.1 percent of the total IRI) were valviferan isopods, followed by bivalves (10.5 percent), crabs (9.7 percent), and gammarid amphipods (4.5 percent), all epibenthic or benthic organisms.

Trichodon trichodon, Pacific Sandfish

Adult sandfish were captured at South Beach and Village Point, and juveniles at Westcott Bay, all in August and September. Stomachs generally were a little less than half full and the contents half-digested.

Although this species has been known to burrow in sand (Hart 1973), its prey spectrum suggested pelagic feeding behavior. Pacific herring dominated the diet (74.4 percent of total IRI) with additional contributions by crab larvae (21.9 percent), euphausiids, amphipods, and the shrimp, *Crangon franciscorum.*

Lumpenus sagitta, Snake Prickleback

Snake prickleback samples originated from a Westcott Bay beach seine and a Cherry Point townet collection. Twenty percent of the stomachs were empty. A relatively broad spectrum of prey organisms characterized this species as principally a benthic feeder; bivalves composed 48.7 percent of the total IRI, tanaids and polychaetes both accounted for 21.2 percent, and gammarids amphipods contributed 7.3 percent.

Three snake prickleback adults sampled from Fidalgo Bay by WWSC had a rather different, though still benthic, diet. Oligochaetes accounted for 84.4 percent of the total IRI; gammarid amphipods, 11.0 percent; and polychaetes, 4.6 percent.

Phytichthys chirus, Ribbon Prickleback

A single ribbon prickleback retained from an August 1974 beach seine collection by WWSC had 14 gammarid amphipods in its stomach.

Apodichthys flavidus, Penpoint Gunnel

Sixteen penpoint gunnel stomachs were examined, all but one originating from the spring beach seine collections in the gravel habitat at Deadman Bay. One stomach was empty, the other 15 were half full and about half of the prey were unidentifiable.

Oniscoidean isopods and gammarid amphipods were equally important prey organisms, contributing 43.8 percent and 43.4 percent of the total IRI, respectively. Valviferan isopods contributed somewhat less (9.3 percent), followed by shrimp (1.2 percent), and several other epibenthic crustacean taxa.

Three penpoint gunnel specimens were retained by WWSC from their collections at three of their northeastern sites. Their combined prey composition was completely dominated by gammarid amphipods (93.8 percent of total IRI) with only minor contributions by gastropods (3.7 percent) and valviferan isopods (2.2 percent).

Pholis laeta, Crescent Gunnel

All but two of the 13 crescent gunnel stomach samples were from Deadman Bay seine collections. One stomach was empty; the remaining averaged between 25 percent and 50 percent full of organisms, 50 percent to 75 percent of which were identifiable.

As with the penpoint gunnel, the crescent gunnel preyed upon epibenthic and benthic organisms. Gammarid amphipods were the principal prey item, totaling 78.4 percent of total IRI. Harpacticoid copepods were less important, accounting for 10.2 percent. Tanaids made up 4.7 percent; polychaetes, 2.5 percent; valviferan isopods, 1.1 percent; and a variety of epibenthic crustaceans contributed less than 1.0 percent of the total IRI.

The crescent gunnel occurred relatively often in WWSC beach seine collections during July and August 1974. Their diet composition was quite similar to those in FRI's San Juan Island collections. Gammarid amphipods predominated (85.4 percent of total IRI), while polychaetes (8.8 percent), crab larvae (2.7 percent), and hyperiid and caprellid amphipods (each at 1.1 percent) were the less important prey.

Pholis ornata, Saddleback Gunnel

A related pholid, *P. ornata* occurred in the same habitats and had much of the same prey composition as the more common crescent gunnel, *P. laeta*. Amphipods were also the principal prey (49.7 percent of the total IRI) but oniscoidean isopods (not found in *P. laeta* stomachs) ranked a close second (32.9 percent) in importance. Polychaete annelids (7.4 percent), harpacticoid copepods (5.6 percent), cumaceans (2.0 percent), and valviferan isopods (2.0 percent) were also in these stomachs.

One crescent gunnel collected by WWSC in an August 1974 Fidalgo Bay collection had consumed four gammarid amphipods and one polychaete.

Ammodytes hexapterus, Pacific Sand Lance

Pacific sand lance were similar in occurrence and distribution to juvenile Pacific herring, being caught by both beach seine and townet in July and August. Beach seine catches of Pacific sand lance were most frequent and numerous at Eagle Cove, and townet catches, at Point George and Westcott Bay. Sixty-four percent of the total stomach samples were empty and the remaining 11 stomachs had few prey and a high stage of digestion with only traces of identifiable organisms.

Pacific sand lance were basically pelagic feeders with an even more specialized prey spectrum than juvenile Pacific herring. Calanoid copepods (88.5 percent of total IRI) and gammarid amphipods (9.0 percent) were the only prey organisms of any significance, and barnacle larvae and penaeid shrimp consituted only incidental food items. Organic detritus was also prominent numerically in the overall diet spectrum.

A large catch of Pacific sand lance was made by WWSC in July 1974 at Legoe Bay. These fish also had a high percentage of empty stomachs (27 percent) and few prey organisms in the remaining stomachs. Unlike the FRI sample, however, these fish had fed to a great degree upon copepod (harpacticoid?) eggs (85.3 percent of total IRI) and only secondarily upon calanoids (11.1 percent). Gammarid amphipods made a small contribution of 2.7 percent of the total IRI.

Anaplopoma fimbria, Sablefish

A May 1975 beach seine collection at Deadman Bay captured one adult sablefish. In its stomach (75 percent full) were 14 penaeid shrimp, five oxyrhynchid crabs, two gammarid amphipods, one valviferan isopod, and one callainassid shrimp.

Hexagrammos decagrammus, Kelp Greenling

Kelp greenling was a commonly occurring species in the gravel habitat at Deadman Bay, ranking 16th and 17th in overall occurrence in 1974-75 and 1975-76 beach seine catches, respectively. It was also the most commonly observed fish along the SCUBA transects in the rocky/kelp bed habitat.

Kelp greenling stomachs averaged between 75 percent to completely full, with no empty stomachs in the sample. The contents of the stomachs were consistently half digested (Table 18).

The prey spectrum for kelp greenling (Fig. 42) illustrated one of the most diversified, opportunistic feeding behaviors of the species studied. Amphipods, principally *Eusiroides* sp., *Amphithoides* sp., ranked as the most important (34.1 percent of total IRI) prey, followed by crabs, *Cancer magister, Pugettia gracilis, Oregonia gracilis, Telmessus cheiragonus*, and unidentified Oxyrhyncha sp. (15.2 percent), oniscoidean

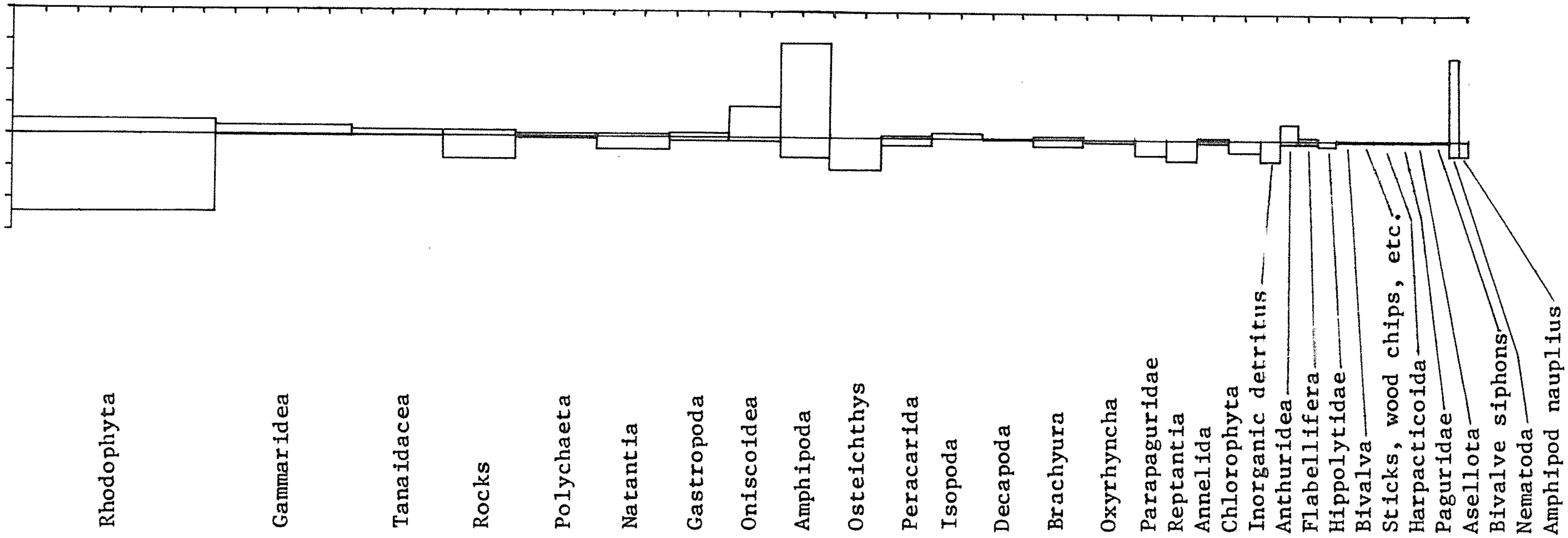

Fig. 42. Kelp greenling I.R.I. Prey Spectrum (n=31).

isopods (81.3 percent), fishes (7.2 percent), asteroids (5.1 percent), amphipod larvae (3.9 percent), gastropods (3.5 percent), polychaetes (2.6 percent), tanaids (2.3 percent), and flabelliferan isopods (2.3 percent) plus a number of even less important items. Although algae, Rhodophyta, Chlorophyta (2.0 percent) and rocks (8.8 percent) constituted measurable percentages of the total biomass, these were considered incidental items, byproducts of the feeding of kelp greenling on the predominantly benthic prey items.

Only two kelp greenling specimens originated from the WWSC sampling, these being from Legoe Bay in November 1974. Of the principal prey, gammarid amphipods accounted for 67.7 percent of the total IRI; fishes, 28.4 percent and polychaetes, 2.5 percent.

Hexagrammos stelleri, Whitespotted Greenling

The whitespotted greenling was collected mostly at Deadman Bay during beach seining. It was also collected in the rocky/kelp bed habitat, but in much smaller numbers than the kelp greenling. Of those stomachs retained for analysis (Table 18), all were judged nearly full, and the contents were considered just less than half digested.

The prey spectra of the whitespotted greenling was similar to the kelp greenling. Gammarid amphipods, especially *Eusiroides* sp., *Amphithoe* sp., constituted the most important food item, contributing 55.7 percent of the total IRI. Shrimp (*Heptacarpus stimpsoni*), with 22.4 percent, and various brachyuran crabs (*Cancer oregonensis, Pugettia gracilis*), with 11.4 percent of the total IRI, were secondary; fish and polychaete annelids provided less than 5 percent each. Incidental algae, however, was not as significant in the overall diet composition of the whitespotted greenling as the kelp greenling.

Whitespotted greenling stomach samples collected by WWSC originated from northeastern Guemes Island, Birch Bay, Cherry Point and Legoe Bay. Despite the different areas and habitats, prey composition of this sample was very similar to those from FRI's San Juan Island collections, with gammarid amphipods responsible for 61.4 percent of the total IRI; penaeid and callianassid shrimp, 25.9 percent; brachyuran crabs, 10.4 percent; and polychaetes, 2.5 percent.

Ophiodon elongatus, Lingcod

Although not significant numerically, the lingcod was commonly observed in the rocky/kelp bed habitat (57 percent frequency of occurrence during SCUBA transect observations) and constituted the major top-level carnivore in the fish assemblage characterizing that habitat. The 14 stomach samples, including eight adults and six juveniles, were obtained during trammel net, spearing, hook and line, and townet collections in the rocky/kelp bed habitat from April through July 1976. Fourteen percent of the total stomach samples were empty, the remaining averaged (with some variation) more than half full and, with a high degree of digestion, less than 50 percent of the contents was identifiable.

Lingcod proved to be primarily piscivorous, with 36.1 percent of the total IRI being fish. Although the fish were usually digested beyond recognition, rockfish (Scorpaenidae) were identified. The remaining secondary food items were benthic gastropods, siphonophores, ascidians, polychaetes, and incidental algae. Except for the fish, which may or may not be bottom oriented, all the prey items were benthic.

Although the small sample size does not permit quantitative comparisons, there was no dramatic difference evident between juvenile and adult lingcod diets, with fish being most important to both.

Sebastes brevispinus, Silvergrey Rockfish

One juvenile silvergrey rockfish collected from the rocky/kelp bed habitat had fed on calanoid copepods, crab larvae, shrimp, and chaetognaths (arrow worms), i.e., except for the shrimp, all were pelagic organisms.

Sebastes caurinus, Copper Rockfish

Copper rockfish were commonly caught during the July and August beach seine collections at Deadman Bay (gravel habitat) and had a high frequency of occurrence along all SCUBA transects in the rocky/kelp bed habitat.

On the average, copper rockfish stomachs were close to half full with 26 percent empty stomachs and a moderate stage of digestion of the contents (Table 18). Stomach samples collected by beach seine, however, were much fuller (and showed less variation in stomach fullness) and the prey less digested than samples from the rocky/kelp bed habitat (collected by spear, hook and line, or trammel net); the latter techniques may have resulted in a sampling bias due to regurgitation. Stomachs from beach seined rockfish had sample condition factor means of 4.3 ± 1.4 and 5.3 ± 0.7, whereas the fish collected by the other methods had a mean of 2.9 ± 2.1. Similarly, digestion factors averaged 3.3 ± 0.9 and 4.0 ± 0 for beach seine samples and 2.8 ± 1.9 for the other samples.

The composite prey spectrum (Fig. 43) suggests that these specimens of *S. caurinus* were opportunistic epibenthic feeders although they also consumed both benthic and pelagic organisms. General peracaridan crustaceans were the more important prey; these included gammarid amphipods (45.0 percent of total IRI), mysids (10.3 percent), shrimp (Hippolytidae, 9.6 percent), brachyuran crabs (*Cancer oregonensis, Petrolistes eriomerus* and *Scyra acutifrons*, 2.7 percent), oniscoidean (3.4 percent), and

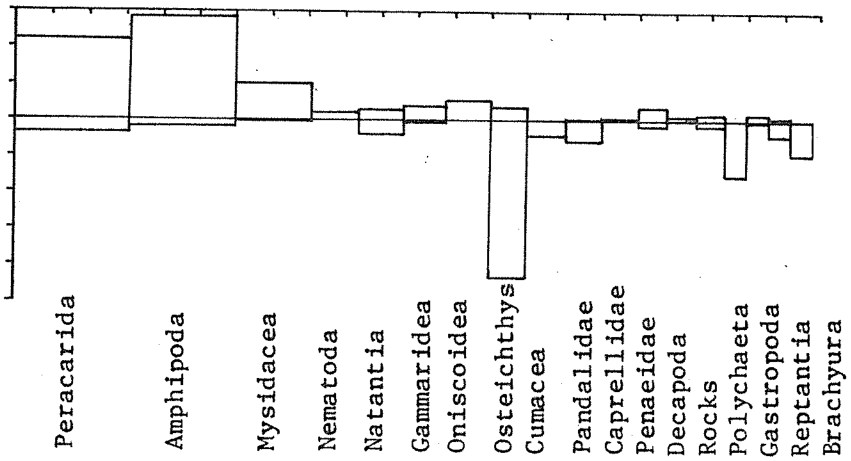

Fig. 43. Copper rockfish I.R.I. Prey Spectrum (n=52).

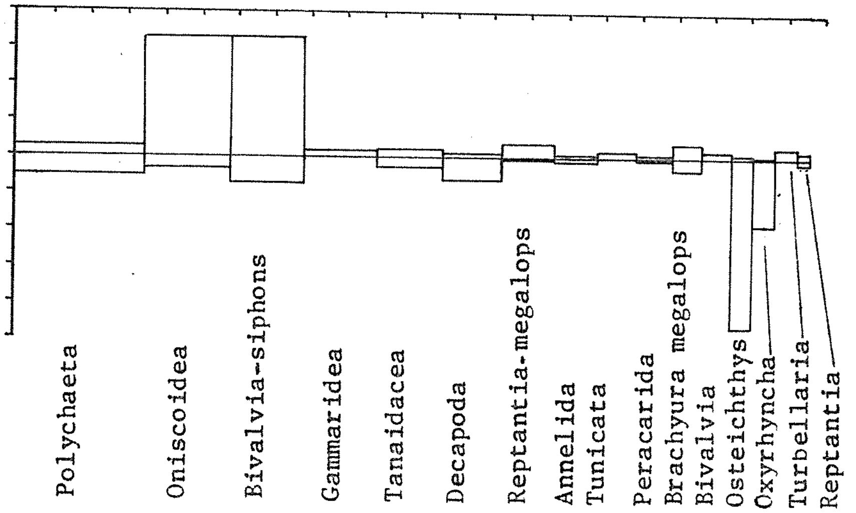

Fig. 44. Staghorn sculpin I.R.I. Prey Spectrum (n=51).

flabelliferan (1.1 percent) isopods, and cumaceans (2.4 percent). Fish (Pacific sand lance and juvenile rockfish) accounted for 16.4 percent of the total IRI, polychaetes 4.4 percent.

Six juvenile copper rockfish beach seined from Legoe Bay in July 1974 had a relatively similar diet composition based on epibenthic and pelagic prey. Shrimp (Crangonidae, Pandalidae, and Penaeidae) and gammarid amphipods predominated, with 36.1 percent and 31.8 percent, respectively, of the total IRI. Crab larvae (15.9 percent) and fish (threespine sticklebacks, 13.7 percent) formed secondary diet components.

Temporal variation in prey composition was obvious when comparing three months' of beach seine samples at Deadman Bay (Table 26). From July to August 1974 the most important prey item shifted from oniscoidean isopods and fishes to gammarid amphipods and shrimp; in June 1975, gammarid amphipods completely dominated.

Sebastes emphaeus, Puget Sound Rockfish

Puget Sound rockfish were collected only by spearing during SCUBA observations in the rocky/kelp bed habitats along San Juan channel. Unlike copper rockfish, Puget Sound rockfish had a high incidence of full or near-full stomachs and a slightly higher stage of digestion (D.F mean: 3.6 ± 1.5).

The overall prey composition indicated a relatively unspecialized planktonic feeding behavior. Calanoid copepods (57.3 percent of total IRI), siphonophores (jellyfish, 17.8 percent), and crab larvae (16.0 percent) constituted the more important prey; hyperiid amphipods (5.1 percent), and crabs (1.6 percent) were secondary in importance.

Sebastes flavidus, Yellowtail Rockfish

Although a few juvenile yellowtail rockfish were caught in the Deadman Bay beach seine, the majority originated from rocky/kelp bed collections around San Juan Island and Burrows Island. Stomachs averaged less than half full with a high degree of digestion (Table 18).

Yellowtail rockfish prey composition was similar to those of Puget Sound rickfish, emphasizing pelagic organisms. Calanoid copepods accoun accounted for the highest proportion (34.4 percent) of the total IRI mysids (20.1 percent; *Neomysis awatschensis*), fishes (17.5 percent; including Pacific sand lance), crab larvae (10.6 percent); chaetognaths (8.4 percent) hyperiid amphipods (2.1 percent), and fish larvae (1.2 percent) composed the other food items. Gammarid amphipods (usually *Pontogeneia* spp., and *Eusiroids* sp., and occasional Lyssianasid sp., *Atylus* sp., *Ischyrocerus* sp., *Eusiroides* sp., and *Photis californicus*) were not overly important.

Sebastes melanops, Black Rockfish

Adult black rockfish were commonly caught during the varied sampling of the rocky/kelp bed habitat and consituted over 15 percent of the total fish enumerated along the established transects. Juveniles were also captured during the September nighttime beach seines at Deadman Bay. As is typical with most of the rockfish stomachs collected, black rockfish had a high percentage of empty stomachs (26 percent) and only medium stomach fullness and contents digestion (Table 18).

Prey organisms were predominantly pelagic organisms. Hyperiid amphipods (79.9 percent of total IRI) were most important, followed by fishes (13.9 percent; including Pacific sand lance and tadpole sculpins), crab larvae (1.1 percent), and crabs (1.0 percent; *Cancer* sp.). Incidental items such as rocks accounted for 1.7 percent of the total IRI. Gammarid amphipods (predominantly *Eusiroides* sp., *Pontogeneia* spp., and *Atylus* sp., but also *Ischyrocerus* sp., *Hyale* sp., *Paraphoxus spinosa* (?), *Photis californica, Photis* sp., *Amphithoe lacertosa*, and *Amphithoe* sp.) were not significant in the total IRI.

Three juvenile black rockfish from WWSC's September 1974 collection at their northeastern Guemes Island site had an entirely different diet composition which emphasized epibenthic items--shrimp (73.0 percent), harpacticoid copepods (24.7 percent), and gammarid amphipods (2.2 percent).

Sebastes nigrocinctus, Tiger Rockfish

One adult tiger rockfish collected by hook and line sampling at Turn Island in July contained seven crabs--three oxyrhynchan, one *Cancer* sp., two Porcellanidae sp., and one pagurid--and a hydroid specimen.

Sebastes ruberrimus, Yelloweye Rockfish

An adult yellowtail rockfish caught in the rocky/kelp bed habitat in April 1976 had two pandalid shrimp and two nematodes in its stomach.

Artedius fenestralis, Padded Sculpin

All six padded sculpins from FRI samples originated from Deadman Bay beach seine collections. Their stomachs were typically 75 percent full and the contents relatively undigested.

Principal prey were gammarid amphipods (89.1 percent of total IRI) and several other epibenthic crustaceans--the flabelliferan isopod *Gnorimosphaeroma oregonense* (6.5 percent) and tanaidaceans (3.0 percent).

Thirteen of the 15 padded sculpin specimens collected by WWSC originated from an April 1976 sample at Legoe Bay. Benthic tunicates were the most prevalent item (47.8 percent of total IRI), followed by gammarid amphipods (16.8 percent), shrimp (13.2 percent), bivalves (6.7 percent), harpacticoid copepods (3.1 percent), and isopods (1.2 percent).

Artedius harringtoni, Scalyhead Sculpin

Scalyhead sculpins were the second most common cottid observed in the rocky/kelp bed SCUBA observations and some specimens were procured by slurp gun or spearing from the Point George and Friday Harbor vicinity. All stomachs were full, although with a moderate state of digestion (55.7 percent unidentifiable).

The variety of prey organisms consumed by scalyhead sculpins was much greater than that seen in padded sculpin stomachs. A diverse array of organisms--pelagic, epibenthic, and benthic--were included in its prey spectrum. Harpacticoid copepods, though constituting only 28.1 percent of the total IRI, were the most important prey. Chaetognaths (pelagic arrow worms) composed 19.2 percent and calanoid copepods, 12.1 percent. The remaining prey taxa all contributed less than 10 percent of the total IRI and included, in decreasing order, crabs (*Petrolisthes eriomerus*), crab larvae, mysids, shrimps, gammarid and hyperiid amphipods, fishes, euphausiids, and caprellid amphipods.

Artedius lateralis, Smoothhead Sculpin

One smoothhead sculpin, retained from a July Deadman Bay beach seine sample, had consumed one mysid, one amphipod, and one shrimp.

Artedius meanyi, Puget Sound Sculpin

A small Puget Sound sculpin included in the WWSC collection had in its stomach 25 gammarid amphipods, 19 isopods (*Exosphaeroma amplicauda* and *Gnorimosphaeroma oregonense*), four crabs (including *Pagurus hirsutiusculus*), and two gastropods.

Blepsias cirrhosus, Silverspotted Sculpin

Silverspotted sculpin commonly appeared in Deadman Bay beach seine collections from July through October; they were also encountered at Eagle Cove, though with much less frequency. The total sample included five juveniles and 15 adults.

No empty stomachs were present in the sample. Stomachs averaged almost 75 percent full and the contents were half digested.

The spectrum of prey identified from these specimens was very specialized toward epibenthic crustaceans, specifically gammarid amphipods

(50.1 percent of total IRI; including *Amphithoe* sp.), oniscoidean isopods (39.6 percent) and shrimp (9.6 percent; *Heptacarpus stimpsoni*).

Ten silverspotted sculpin specimens from WWSC's cobble and gravel habitat sites at Cherry Point, Shannon Point, and Legoe Bay were even more specialized in their diet. Gammarid amphipods comprised 32.7 percent of the total IRI, shrimp 7.2 percent.

Clinocottus embryum, Calico Sculpin

The stomachs of two calico sculpins from a WWSC sample at Fidalgo Bay in August 1974 contained 23 gammarid amphipods (90.9 percent of total IRI) and nine harpacticoid copepods (9.1 percent).

Dasycottus setiger, Spinyhead Sculpin

The stomach of one spinyhead sculpin, captured in a May Deadman Bay beach seine collection, was full of penaeid shrimp, brachyuran crabs, including *Cancer magister*, one isopod, and a rock.

Enophrys bison, Buffalo Sculpin

Four buffalo sculpins caught by FRI had in their stomachs numerous pieces of algae (ulvoid type), constituting 61.8 percent of the total IRI, accompanied by two amphipods (25.0 percent), and one partly digested fish (13.2 percent). The sample size is too small, however, to determine whether the consumption of algae is representative of the food habits.

A sample of six buffalo sculpins originating from WWSC Cherry Point collections tends to confirm the contribution of algae to this species' diet, however. Of the total IRI, 45.8 percent was contributed by algae. Nonalgae prey taxa included gammarid amphipods (13.8 percent of total IRI), insects (11.2 percent), polychaetes (9.2 percent), crabs (5.3 percent), nudibranchs (4.7 percent), pychnogonids (4.1 percent), sticks and organic debris (2.5 percent), and flabelliferan isopods (2.4 percent; *Exosphaeroma amplicauda*).

Hemilepidotus hemilepidotus, Red Irish Lord

Characteristic of the Deadman Bay demersal fish assemblage, and often found in the rocky/kelp bed habitat, the red Irish lord appeared to be an almost completely bottom oriented carnivore, having preyed upon oniscoidean isopods (42.8 percent of total IRI), brachyuran crabs (39.9 percent; *Cancer magister, C. oregonensis, C. productus, Pugettia gracilis, Mimulus* sp.), fish (13.4 percent), and shrimp (1.3 percent).

Icelinus borealis, Northern Sculpin

Two northern sculpins were SCUBA-collected, but one had an empty stomach; the remaining stomach contained a gammarid amphipod, a harpacticoid copepod, and a crab megalops. Over 94 percent of the stomach content biomass was unidentifiable. (Even if it were all identifiable, it could not be considered "representative".)

Icelinus tenuis, Spotfin Sculpin

Beach seine collections along three of the four western San Juan Island sites produced 11 softfin sculpins. Stomachs of these fish were nearly full and the contents were between 50 percent and 75 percent identifiable.

A broadly based spectrum of food taxa was dominated by gammarid amphipods (63.8 percent of the total IRI); tanaids (9.6 percent), turbellarians (8.9 percent), polychaetes (8.4 percent), cumaceans (2.4 percent), fishes (2.2 percent), oniscoidean isopods (1.9 percent), and bivalves (1.9 percent) comprised the less important prey items. The only identifiable fish prey was a juvenile rockfish.

Jordania zonope, Longfin Sculpin

The longfin sculpin was the most frequently observed cottid and third most common species over the combined SCUBA transect observations (85 percent frequency of occurrence) in the rocky/kelp bed habitat. Specimens were procured from within this habitat from April through July 1976 by spear and slurp gun.

None of the stomachs was empty, all approached fullness, and the contents were usually about half digested (Table 18).

Considering the sample size, the prey spectrum is very diverse, with a number of rare prey items included in the overall sample. Harpacticoid copepods were the most important prey, contributing 55.4 percent of the total IRI. Polychaetes (23.9 percent), crabs (8.7 percent), gammarid amphipods (5.7 percent), shrimp (1.5 percent), and crab larvae, (1.5 percent), however, were of secondary importance. Although epibenthic organisms were taken more frequently, benthic organisms made the greatest contribution to the total prey biomass.

Leptocottus armatus, Staghorn Sculpin

Staghorn sculpins were probably the most ubiquitous cottid in the shallow sublittoral region of northern Puget Sound. Although one of the dominant components of the demersal assemblages, the staghorn sculpin was also important in the townet catches at Birch Bay and Cherry Point.

Stomach specimens from 22 juveniles and 31 adults averaged over half full, with only 3 percent empty. Approximately half of the stomach contents were considered identifiable.

Considering the large sample size, the overall prey spectrum (Fig. 44) is not very diverse. Emphasis is on benthic organisms, with oniscoidean isopods (32.2 percent of total IRI), and bivalve siphons (29.6 percent) being equally important; polychaetes follow with 11.5 percent. Crabs account for 8.9 percent of the total IRI; fish, 51.7 percent; crab larvae, 4.3 percent; tanaids, 3.3 percent; gammarid amphipods (including *Atylus* sp., *Allorchestes* sp., *Paraphoxus spinosa*, and *Euhaustorius* sp., 1.3 percent; and bivalves, 0.5 percent. Although not as frequently preyed upon, fish (including juveniles and larvae of *Clupea harengus pallasi* and juvenile *Embiotoca lateralis*) and oxyrhynchan crabs actually composed the majority of the biomass ingested. Included in the decapod and general peracaridan crustacean categories were *Crangon franciscorum, Idotea resecata*, and *Cancer magister*.

Although townet catches of staghorn sculpins were generally so sporadic that sample sizes from any one collection were insufficient, samples were large enough to compare prey spectra from two adjacent sites, the sand/eelgrass habitat at Birch Bay and the cobble habitat at Cherry Point (Table 27). The Birch Bay prey composition spectrum was quite generalized with polychaetes, crabs, and fishes (Pacific herring) being the more important prey taxa; shrimp (*Crangon franciscorum*) were significantly less important. Prey organisms from staghorn sculpins caught at Cherry Point, however, were concentrated into four or five taxa; crab megalops, polychaetes, and gammarid amphipods.

Undoubtedly the most common nearshore demersal species collected by WWSC along the eastern beach seine sites, staghorn sculpins also provided the most stomachs; they occurred dominantly in collections at the Fidalgo Bay, Drayton Harbor, and Padilla Bay mud/eelgrass sites and the Birch Bay sand/eelgrass site. Overall prey composition from the eastern sites is dramatically different than those in the western area. Gammarid amphipods are much more important, providing 69.8 percent of the total IRI. Other prey taxa are rather equally represented by crabs (8.8 percent; *Hemigrapsus orgeonensis, H. nudus, Cancer magister, Pinnixa* sp., and *Paguridae*), shrimp (8.2 percent; Crangonidae, Callianassidae, including *Upogebia pugettensis*, and Penaeidae), isopods (5.7 percent; *Exosphaeroma amplicauda, E. media*), fish (3.2 percent; juvenile staghorn sculpins, shiner perch, and rockfishes), and polychaete annelids (3.2 percent).

Myoxocephalus polyacanthocephalus, Great Sculpin

One juvenile great sculpin from a November beach seine collection at Deadman Bay had two unidentifiable decapods in its stomach. Another from a WWSC beach seine collection at Guemes Island in July 1974 contained 17 gammarid amphipods, 17 benthic gastropods (*Littorina scutulata*) and a piece of algae.

Rhamphocottus richardsoni, Grunt Sculpin

A juvenile grunt sculpin captured by slurp gun during a SCUBA dive in a rocky/kelp bed habitat had a full stomach containing 42 percent harpacticoid copepods, two asellotan isopods, one gammarid amphipod, and an insect.

Scorpaenichthys marmoratus, Cabezon

Two juvenile cabezon caught by beach seine in the cobble habitat in South Beach in October 1974 had full or nearly full stomachs. Oniscoidean isopods were the most important prey (55.6 percent of total IRI). Various epibenthic decapods (41.0 percent) including a shrimp (*Heptacarpus stimpsoni*), a crab (*Cancer oregonensis*), and amphipods (mostly *Eusiroides* sp. with *Atylus* sp. and *Allorchestes* sp.), and a parapagurid hermit crab (3.4 percent) were also included in the prey spectrum.

Four cabezon, two each from northeastern Guemes Island and Legoe Bay collections by WWSC were retained for stomach analysis; two of these were empty. One Dungeness crab, *Cancer magister*, shrimp parts, and a rock were contained in the remaining two stomachs.

Agonus acipenserinus, Sturgeon Poacher

Four sturgeon poachers were retained from two of WWSC's beach seine collections at Birch Bay. The sample total IRI was rather evenly distributed among cumaceans, gammarid amphipods, shrimp (Crangonidae and Penaeidae), and harpacticoid copepods. Polychaetes and tanaids were also found in the stomachs.

Eumicrotremus orbis, Pacific Spiny Lumpsucker

WWSC beach seine collections at Cherry Point and Legoe Bay provided three Pacific spiny lumpsucker specimens for analysis of stomach contents. Gammarid amphipods supplied 56.1 percent of the total IRI, hyperiid amphipods, 36.8 percent. Caprellid amphipods (3.0 percent), valviferan isopods (3.1 percent), and cumaceans (0.6 percent) were incidental prey items.

Liparis florae, Tidepool Snailfish

A December 1975 WWSC beach seine collection at Birch Bay provided four tidepool snailfish; their diet was composed principally of gammarid amphipods (41.4 percent of total IRI), polychaetes (39.8 percent) and valviferan isopods (15.4 percent), with shrimp (Penaeidae) providing a small contribution (3.4 percent).

Eopsetta jordani, Petrale Sole

A petrale sole captured in a Deadman Bay beach seine in May 1975 had one unidentifiable fish it its stomach.

Hippoglossoides elassodon, Flathead Sole

A flathead sole from a July 1974 WWSC beach seine collection at the northeast Guemes Island sand/eelgrass site had a (numerically) diverse spectrum of benthic and epibenthic prey. The principal items included 15 polychaete annelids, 16 cumaceans, 10 gammarid amphipods, and 11 flabelliferan isopods; secondary prey included five bivalves, one tanaid, and one crab larvae.

Lepidopsetta bilineata, Rock Sole

Adult rock sole were infreqeuntly caught, usually in the summer along the cobble and sand/eelgrass habitats of southwestern San Juan Island. The six stomachs examined averaged between 25 percent full to distended; all stomach contents were considered 50 percent to 75 percent identifiable.

Considering the low sample size, the prey spectrum is extremely broad. Prey items, in descending order of importance, were oniscoidean isopods (33.6 percent of total IRI), gammarid amphipods (16.6 percent), bivalve siphons (16.2 percent), polychaetes (13.3 percent), flabelliferan isopods (6.2 percent), cumaceans (4.5 percent), bivalves (3.0 percent), brachyuran crabs (3.6 percent) and fish (2.3 percent).

Eleven rock sole were retained by WWSC from their collections at the two Guemes Island sites in 1974 and Cherry Point in 1976; one stomach was empty. Their diet was much more concentrated (numerically) upon a few prey items, principally gammarid amphipods (88.9 percent of total IRI); crabs (4.4 percent), bivalves (3.0 percent), and polychaetes (2.4 percent) were only supplemental organisms.

Parophrys vetulus, English Sole

Juvenile English sole, the most frequently caught species of the nearshore demersal assemblages, usually dominated beach seine catches at Westcott Bay (mud/eelgrass) and Eagle Cove (sand/eelgrass) from April through September.

Stomachs averaged over 75 percent full, though with considerable variation and typically half of the contents were identifiable (Table 18).

Overall, cumaceans dominated the prey spectrum with 74.8 percent of the total IRI (Fig. 45). Gammarid amphipods (11.7 percent), polychaete annelids (8.8 percent), tanaids (1.1 percent), crabs (1.0 percent), and bivalves (0.3 percent) were of secondary importance.

Prey compositions for juvenile English sole may differ considerably in different habitats as evidenced by the July 1974 samples from False Bay (sand-gravel/eelgrass) and Westcott Bay (mud/eelgrass); these indicate that gammarid amphipods, cumaceans, and harpacticoid copepods were the dominant prey for fish feeding in the sandy habitat, while polychaetes, tanaids, and bivalves were more prevalent in prey for English sole in the mud/eelgrass habitat (Table 28). This difference is also evident in the Westcott Bay and Eagle Cove samples taken in April 1976 (Table 28). Again polychaetes were the predominant prey in Westcott Bay, but bivalve siphons, gammarid amphipods, tanaids, and cumaceans were also taken in fairly equal numbers and frequency. English sole from Eagle Cove (sand/eelgrass), however, were feeding dominantly on cumaceans with lower, equal contributions by gammarid amphipods and polychaetes. The difference between juvenile English sole prey spectra in Westcott Bay between July 1974 and April 1976 suggests a more generalized diet in the spring, when gammarids and cumaceans were more available (or preferred), than later in the summer when the prey spectrum is reduced to only the three principal prey taxa. Annual variation in prey abundance would, however, bias these results.

Juvenile English sole were common in WWSC beach seine collections during August through October in sand/eelgrass and mud/eelgrass habitats. All the prey taxa were similar. Diet composition in this region was dominated by gammarid amphipods (87.7 percent of total IRI), with cumaceans (8.4 percent), polychaetes (2.0 percent), and bivalves (1.4 percent) providing lower inputs.

Platichthys stellatus, Starry Flounder

Adult starry flounder were frequently captured in beach seine collections at Eagle Cove and South Beach from July through November, though never in large numbers.

The starry flounder stomachs ranged from empty (15 percent) to full, averaging less than 25 percent full. Digestion was judged to be relatively high with less than 50 percent of the contents identifiable.

The most frequently consumed prey organisms were oniscoidean isopods which accounted for 58.9 percent of the total IRI. Fish (18.2 percent) were second in importance, followed by gammarid amphipods (8.2 percent), epicaridean isopods (4.5 percent), polychaetes (3.7 percent), gastropods (3.3 percent), and turbellarians (1.2 percent). The amphipods were primarily *Atylus* sp. but also *Eusiroides* sp. and *Amphithoe* sp. All prey, except perhaps the fish, were epibenthic or benthic organisms.

As at San Juan Island, juvenile starry flounder appeared in WWSC collections principally in sand/eelgrass (Birch Bay, East Guemes Island) and mud/eelgrass (Padilla Bay, Drayton Harbor) habitats in August through December. While isopods (primarily valviferan) were still important (30.2 percent of total IRI) in these samples, gammarid amphipods

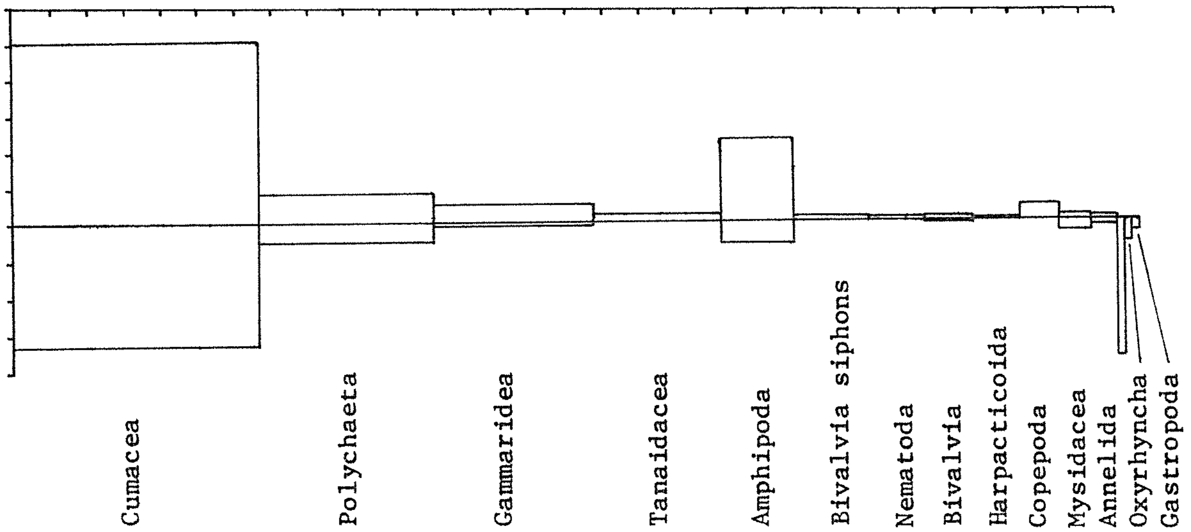

Fig. 45. English sole juveniles, I.R.I. Prey Spectrum (n=46).

Table 28. Percent of total I.R.I. contributed by dominant prey taxa of juvenile English sole at False Bay and Wescott Bay in July 1974, and Wescott Bay and Eagle Cove in April 1976

	Sample size n	Gammarid amphipods	Cuma-ceans	Harpac-ticoid copepods	Tanaids	Poly-chaetes	Bivalves	Bivalve siphons	Mysids
July 1974									
False Bay	6	60.5	35.0	< 1.0	< 0.1	0.3	0.0	0.0	0.0
Westcott Bay	10	0.1	0.1	0.5	24.3	50.0	23.8	0.0	0.0
April 1976									
Westcott Bay	10	9.5	5.5	0.6	7.5	63.2	0.0	13.5	0.0
Eagle Cove	9	20.7	60.3	0.2		14.7	< 0.1	0.1	1.6

Table 29. Nearshore epibenthic plankton pumping sites, dates, samples, and environmental conditions

Date	Location	Number of samples 209µ	Number of samples 505µ	Temperature °C	Salinity °/oo	Dissolved oxygen (% saturation)
March 3, 1976	Deadman Bay	2	2	6.6	30.0	91
	Westcott Bay	2	2	6.0	29.0	96
	Eagle Cove	1	2	6.0	29.9	99
	South Beach	0	2	6.0	29.9	99
May 30, 1976	Deadman Bay	2	2	9.5	30.8	123
	Westcott Bay	2	2	11.0	-	-
June 13, 1976	Eagle Cove	2	2	10.5	34.6	117
	South Beach	2	2	11.0	34.6	117
September 8, 1976	Deadman Bay	2	2	11.9	30.2	151
	Eagle Cove	2	4	12.3	30.3	79
	TOTAL	17	22			

(33.4 percent), barnacles (16.7 percent), and oligochaetes (11.8 percent) were much more prevalent in the diets of starry flounders on the eastern shore than at San Juan Island.

Pleuronichthys coenosus, C-O Sole

Three C-O sole were caught during beach seine collections at South Beach and Deadman Bay. Stomachs averaged half full and the prey were approximately half digested. As with the starry flounder, the principal prey items of the C-O sole were oniscoidean isopods (45.8 percent of total IRI), fish (21.4 percent), polychaetes (14.3 percent), amphipods (9.2 percent), and turbellarians (4.4 percent).

One C-O sole from a WWSC beach seine collection at southern Guemes Island in July 1974 had 12 bivalves (98.0 percent of total biomass) and 10 pieces of algae (Rhodophyta) in its stomach.

Psettichthys melanostictus, Sand Sole

One juvenile sand sole from Westcott Bay in April 1976 had a stomach full of 23 polychaetes (61.1 percent total biomass), seven bivalve siphons (27.8 percent total biomass), and seven tanaids (11.1 percent total biomass). These primary prey were all benthic organisms or parts thereof.

A large catch of juvenile sand sole at Birch Bay in December 1975 constituted a WWSC sample of 18 stomachs, two of which were empty. In this sand/eelgrass habitat, gammarid amphipods were the most important prey taxa, with 82.1 percent of the total IRI. Polychaetes supplied 8.3 percent and epibenthic organisms--tanaids (3.8 percent), cumaceans (3.4 percent), and valviferan isopods (1.3 percent)--accounted for the remaining proportion.

Summary

1. The stomach contents of approximately 1,300 specimens from 52 species of nearshore fish from FRI collections and 611 specimens of 42 species from WWSC collections were quantitatively examined for identification of prey organisms, and diet composition by abundance and biomass of prey items.

2. In general, nearshore demersal fish preyed primarily upon epibenthic invertebrates--gammarid amphipods, oniscoidean and flabelliferan isopods, brachyuran crabs, caridean shrimp, harpacticoid copepods, cumaceans, polychaetes, bivalves, mysids and tanaids. Neritic fishes preyed more on pelagic organisms--calanoid copepods, gammarid and hyperiid amphipods, decapod larvae, (drift) insects, euphausiids, and chaetognaths and fish.

3. Prey compositions were somewhat different in fish assemblages between nearshore habitats, with polychaetes, bivalves (siphons), tanaids, and cumaceans being more common to the mud/eelgrass and sand/eelgrass habitats and oniscoidean isopods, brachyuran crabs and shrimp being more representative in the diets of fishes common to the cobble and gravel habitats. Fishes occupying the rocky/kelp bed habitat preyed equally upon pelagic organisms and epibenthic crustaceans and mollusks, depending upon the species-specific feeding habits of the predator.

4. Seasonal and annual differences in diets of nearshore fishes was most evident in the neritic fishes, suggesting generally opportunistic feeding upon the temporally and spatially variable plankton community. Noteworthy occurrences of such important prey organisms to neritic fish diets include the incidence of barnacle larvae in the spring months and crab and fish larvae, insects and drift insects in the summer months.

Nearshore Epibenthic Plankton: Results

Epibenthic plankton pump collections were made at the four western San Juan Island beach seine sites two or three times from March through September 1976. Seventeen 209μ mesh samples and twenty-two 505μ mesh samples were collected (Table 29).

The numbers of organisms retained in the 505μ and 209μ plankton nets are shown in Table 30. The highest abundance of > 505μ mesh plankton was found in the gravel and mud/eelgrass in March, and the cobble site generally had the lowest. Conversely, organisms retained between 209μ and 505μ mesh were more common in the gravel and sand/eelgrass habitats in September, reaching over 11,500/378.5 liters sample at that time. In most cases the dry weight biomass of the 505μ samples (the 209μ samples were too small to attain a dry weight) increased from March to September. The only exception was the sand/eelgrass site at Eagle Cove which had the highest biomass value of .063 ± 0.83 grams/378.5 liters in June but which showed a dramatic decline to September's low of 0.02 ± 0.01 grams/378.5 liters. Distinct trends in numerical diversity were not evident though the highest diversity of both size ranges of plankton usually occurred in May and June.

Percentage composition of the plankton samples partitioned according to mesh size is included in Appendix 5 and illustrated in Figs. 46A (505μ) and 46B (209μ). The mud/eelgrass site at Westcott Bay was dominated by calanoid copepods in the 505μ category and harpacticoid copepods in the 209μ size range. Between March and May 1976, the larger plankton also shifted in dominance to harpacticoid copepods, and in the 209μ size category calanoid copepods, nematodes, and ostracods were more common.

At Deadman Bay, the gravel habitat site, harpacticoid copepods also dominated except for the 505μ plankton in the spring and fall when gammarid amphipods became more and more prevalent. Calanoid copepods in the 505μ category also declined from March to September while gastropods, cumaceans, polychaetes, and shrimps appeared more common. In the 209μ

Table 30. Abundance, biomass, and diversity of epibenthic plankton per 378.5 liter (100 gal) samples taken at four nearshore habitats along western San Juan Island

Site	No. Organisms/Sample		Dry Weight Biomass/Sample	Shannon-Wiener Diversity Index, H' (abundance)	
	505 µ	209 µ	505 µ	505 µ	209 µ
Westcott Bay (mud/eelgrass)					
March 3, 1976	2045.0±816.0	2108.0±1304.0	0.08±0.01	2.07	0.28
May 30, 1976	268.5±202.9	2972.0±1508.0	0.16±0.22	2.58	2.10
Deadman Bay (gravel)					
March 3, 1976	2376.0±305.5	3132.0± 640.0	0.09±0.01	1.70	1.65
May 30, 1976	385.0±284.3	1948.0±1332.0	0.35±0.13	2.90	2.66
September 8, 1976	207.0± 96.2	11588.0±4500.0	0.61±0.01	2.44	0.44
Eagle Cove (sand/eelgrass)					
March 3, 1976	809.0± 25.5	452.0± 180.0	0.57±0.76	1.83	1.78
June 13, 1976	353.0±321.0	3092.0±2332.0	0.63±0.83	2.30	2.29
September 8, 1976	866.0±342.2	11540.0±1640.0	0.02±0.01	3.31	1.35
South Beach (cobble)					
March 3, 1976	594.5± 77.1	--	0.09±0.02	1.92	--
June 13, 1976	323.0±200.8	792.0± 216.0	0.34±0.16	1.24	2.70

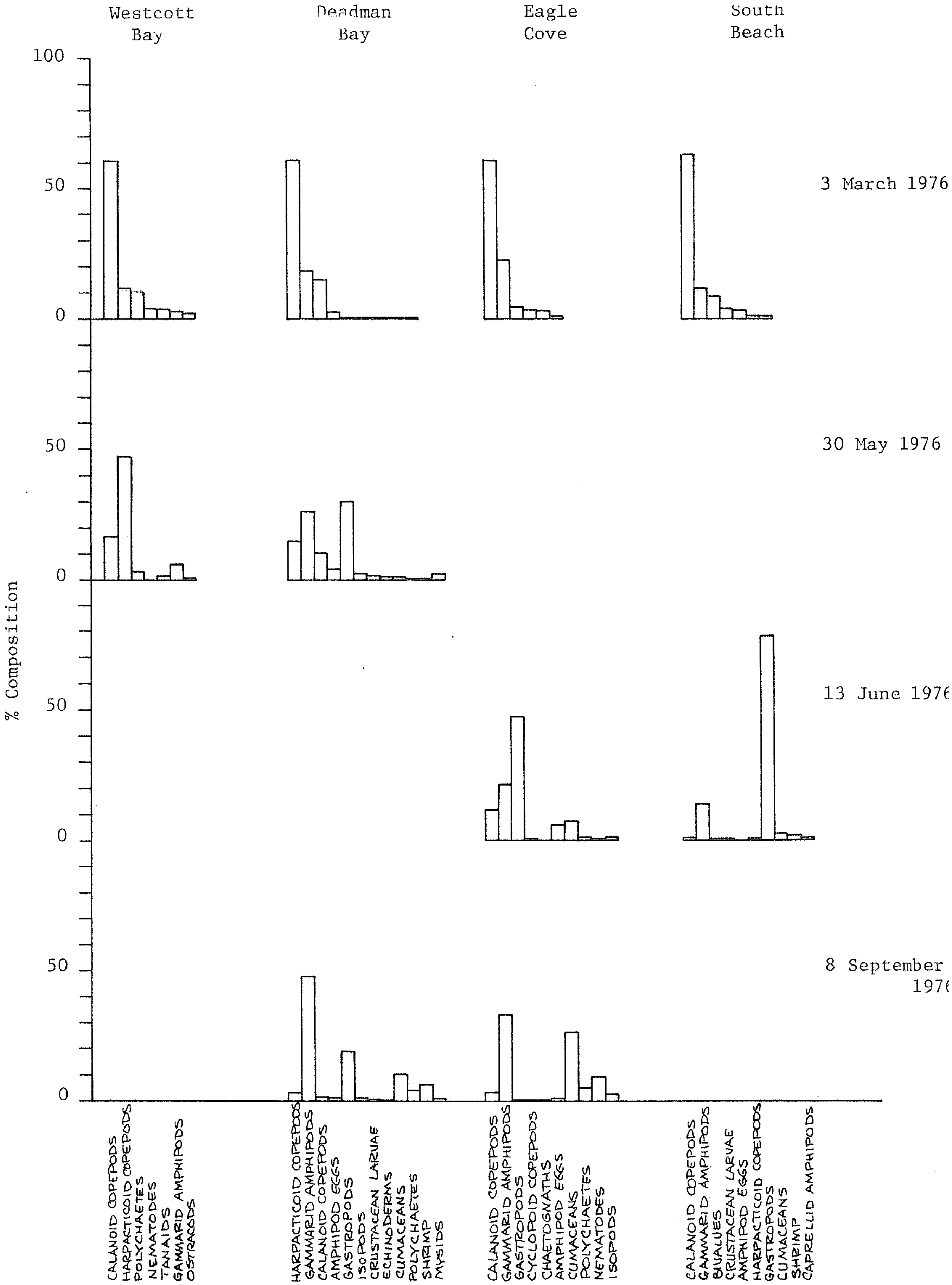

Fig. 46-A. Percent composition of dominant epibenthic plankton retained in 505μ net during sampling at four nearshore habitats, western San Juan Island, March - September, 1976.

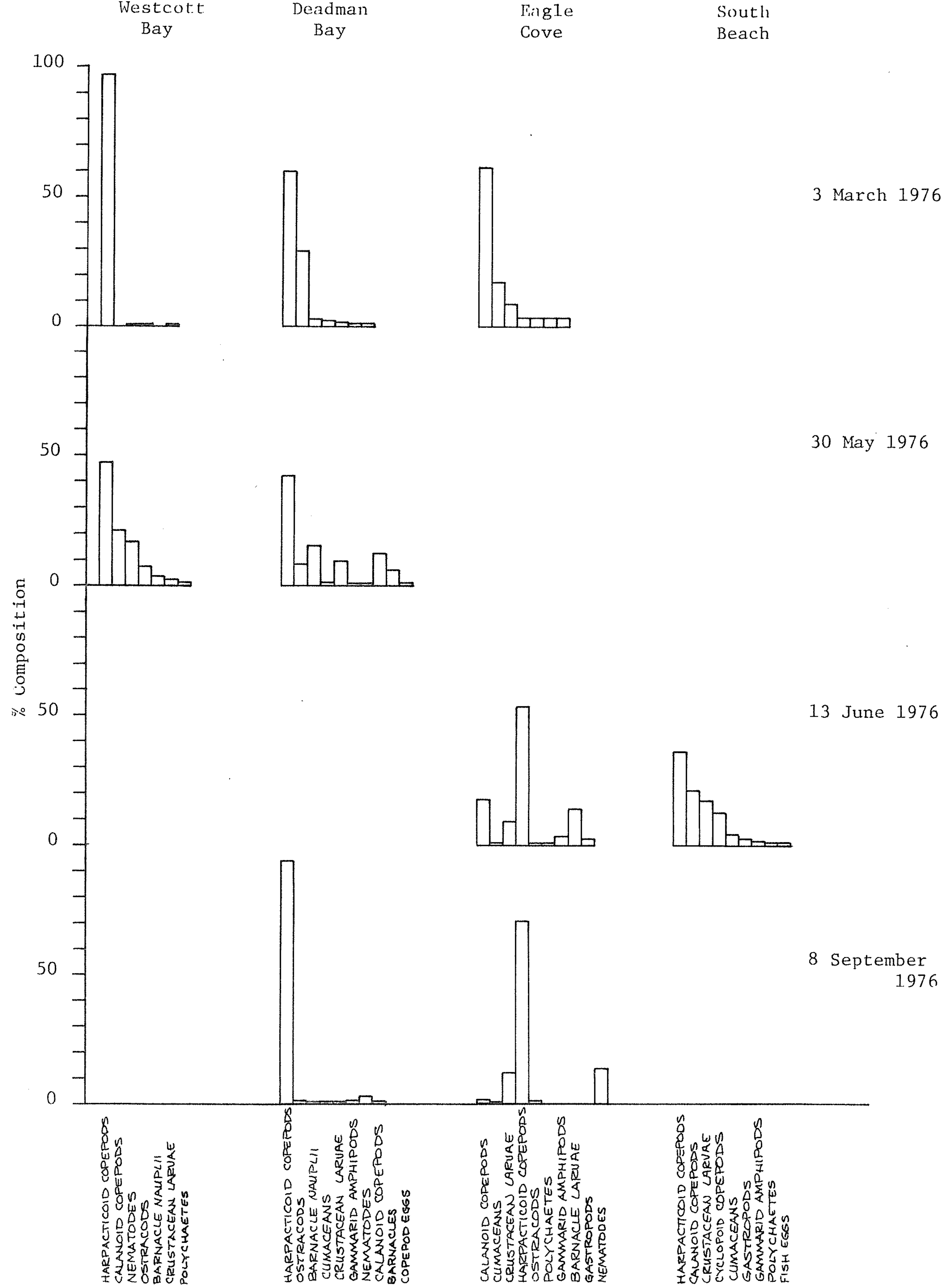

Fig. 46-B. Percent composition of dominant epibenthic plankton retained in 209µ net during sampling at four nearshore habitats, western San Juan Island, March-September, 1976.

plankton, only harpacticoids and ostracods were common in March. By May the epibenthic plankton had diversified considerably with the appearance of barnacle (cypris) nauplii, crustacean larvae, calanoid copepods, and juvenile barnacles. In September, harpacticoid copepods had again become the numerically dominant epibenthic organism.

The sand/eelgrass site at Eagle Cove showed some of the same trends in plankton composition as the other sites. The larger plankton was composed primarily of calanoid copepods and gammarid amphipods, with a few gastropods, cyclopoid copepods and chaetognaths (arrow worms), in March. By June, the calanoids had declined and gastropods were most numerous; amphipod eggs and cumanceans also appeared in significant numbers at this time. In September, the > 505μ plankton was mostly gammarid amphipods and cumaceans; polychaetes, nematodes, and isopods were of secondary importance. In the 209μ range, however, harpacticoid copepods became more and more dominant with time as the calanoid copepods declined. And as > 505μ cumaceans were increasing, those cumaceans retained in the 209μ mesh were gradually declining. Crustacean larvae were equally represented at all sampling times, barnacle nauplii were common during June, and nematodes were abundant only in September.

Epibenthic plankton composition at South Beach, site of the cobble habitat, was very similar to that of Eagle Cove. Calanoid copepods dominated the > 505μ plankton in March, with nominal contributions by gammarid amphipods, bivalves (*Lacuna* sp.), crustacean larvae, and amphipod eggs (probably detached from egg-bearing amphipods in the sample). By June, dominance had completely shifted to harpacticoid copepods; the percentage of gammarid amphipods remained approximately the same. Only the June 1976, 209μ sample was obtained from South Beach; composition was diversely apportioned between harpacticoid copepods, calanoid copepods, crustacean larvae, and cyclopoid copepods.

As the epibenthic pump sampling technique is just in a development stage, quantitative estimates tend to be extremely variable. But, in order to provide some estimates of approximate plankton density values, epibenthic plankton taxa--harpacticoid copepods, calanoid copepods, and gammarid amphipods--are shown according to sampling data in Figs. 47-49, respectively. Harpacticoid copepods tended to be more abundant in the mud/eelgrass and gravel habitats in the later winter; by early September the sand/eelgrass and gravel indicated the highest densities, with a maximum of almost 290 copepods/liter of water sampled at Deadman Bay. In all cases the majority of the harpacticoids were < 505μ in size with the highest incidence of > 505μ copepods being present in March and the smaller (juveniles) being prevalent in the summer.

Calanoid copepods, which tend to be more pelagic than epibenthic, showed a general decline in density from March to September. As with the harpacticoids, calanoids > 505μ were generally more abundant than those between 505μ and 209μ during March; by June the smaller calanoids were present in higher densities. There is little evidence for distinct differences in calanoid densities in the four habitats. The March sample in the mud/eelgrass habitat provided the highest overall density

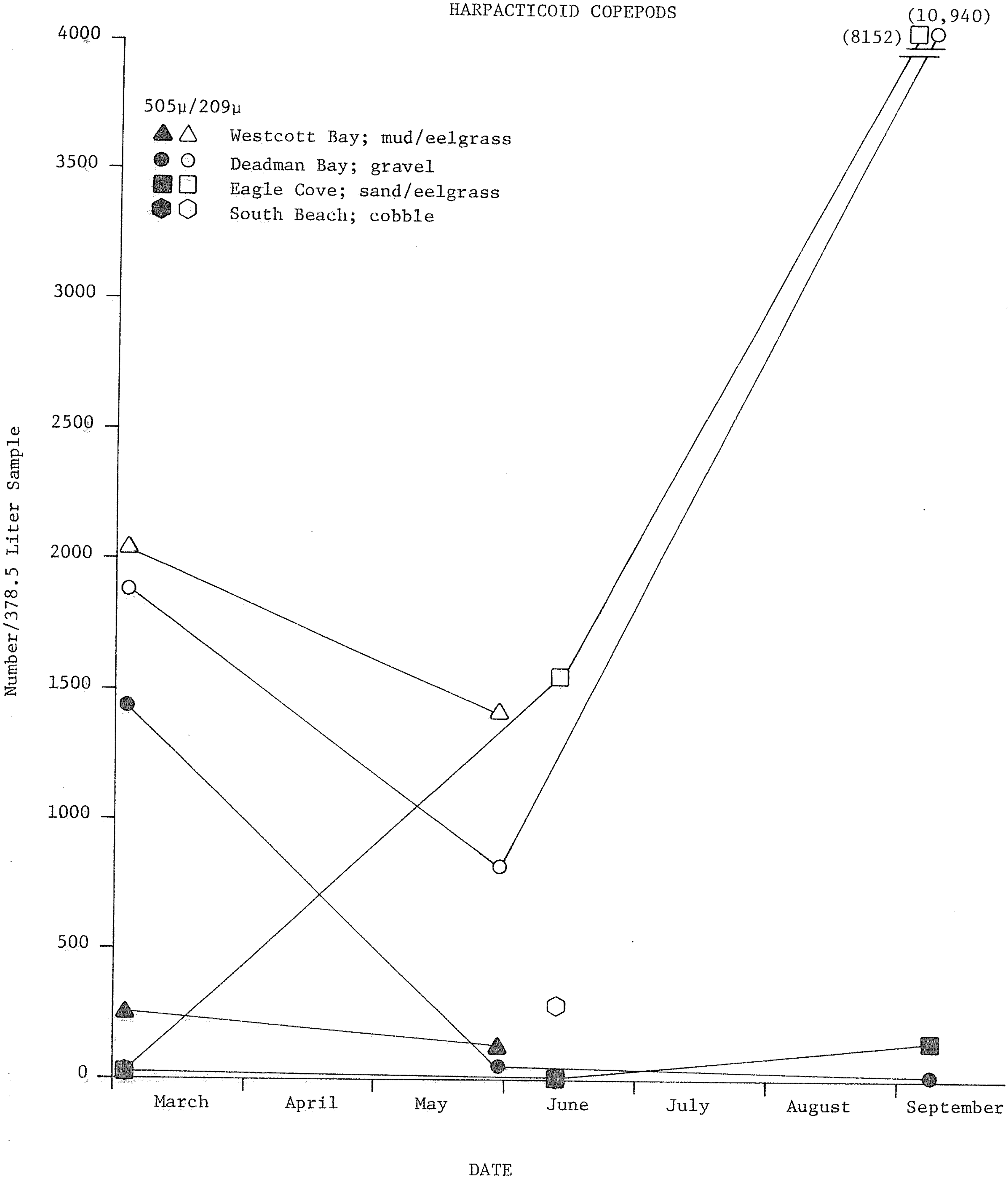

Fig. 47. Densities (number/378.5-liter sample) of epibenthic harpacticoid copepods at four nearshore habitats, western San Juan Island, March-September, 1976.

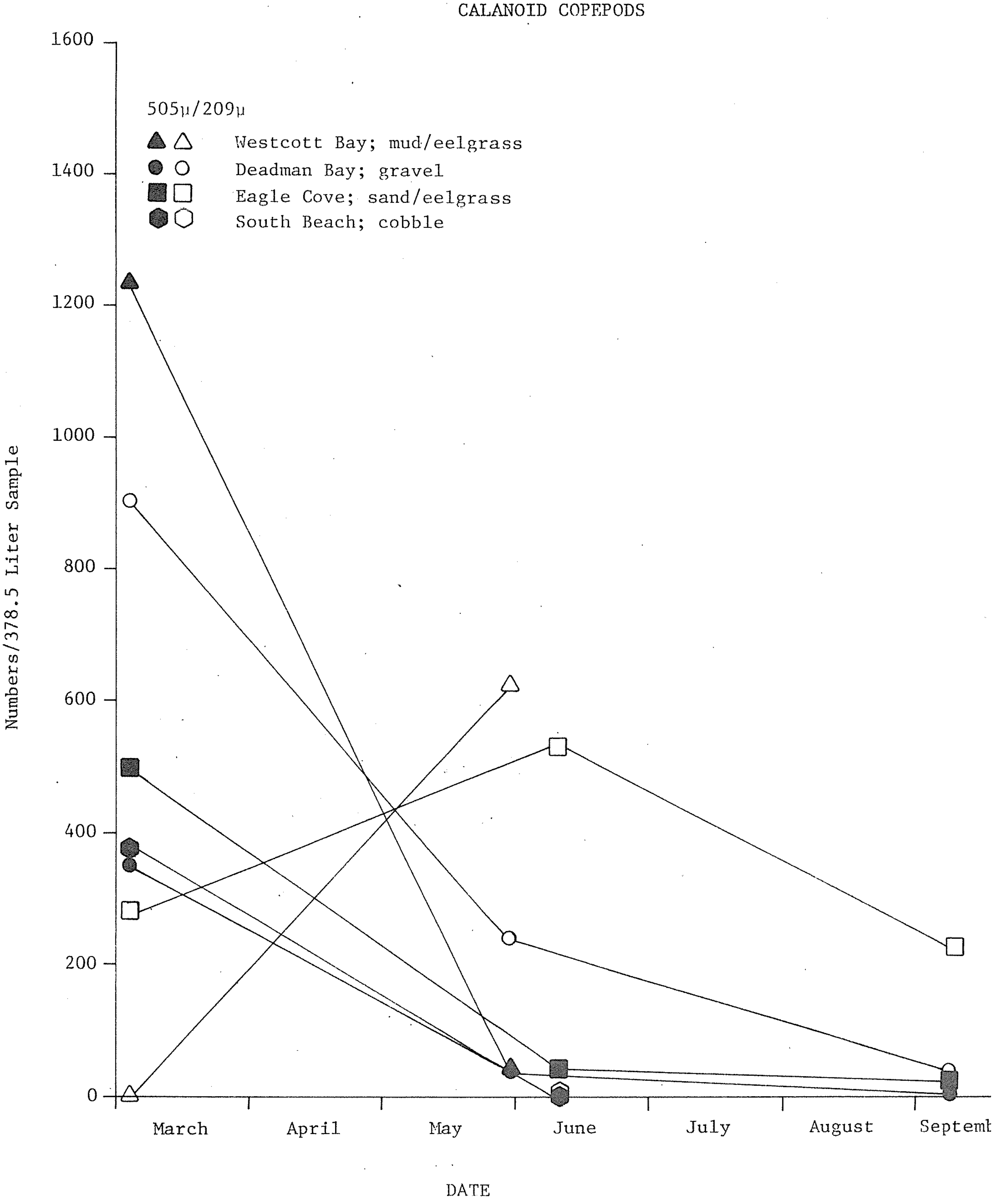

Fig. 48. Densities (number/378.5-liter sample) of epibenthic calanoid copepods at four nearshore habitats, western San Juan Island, March-September, 1976.

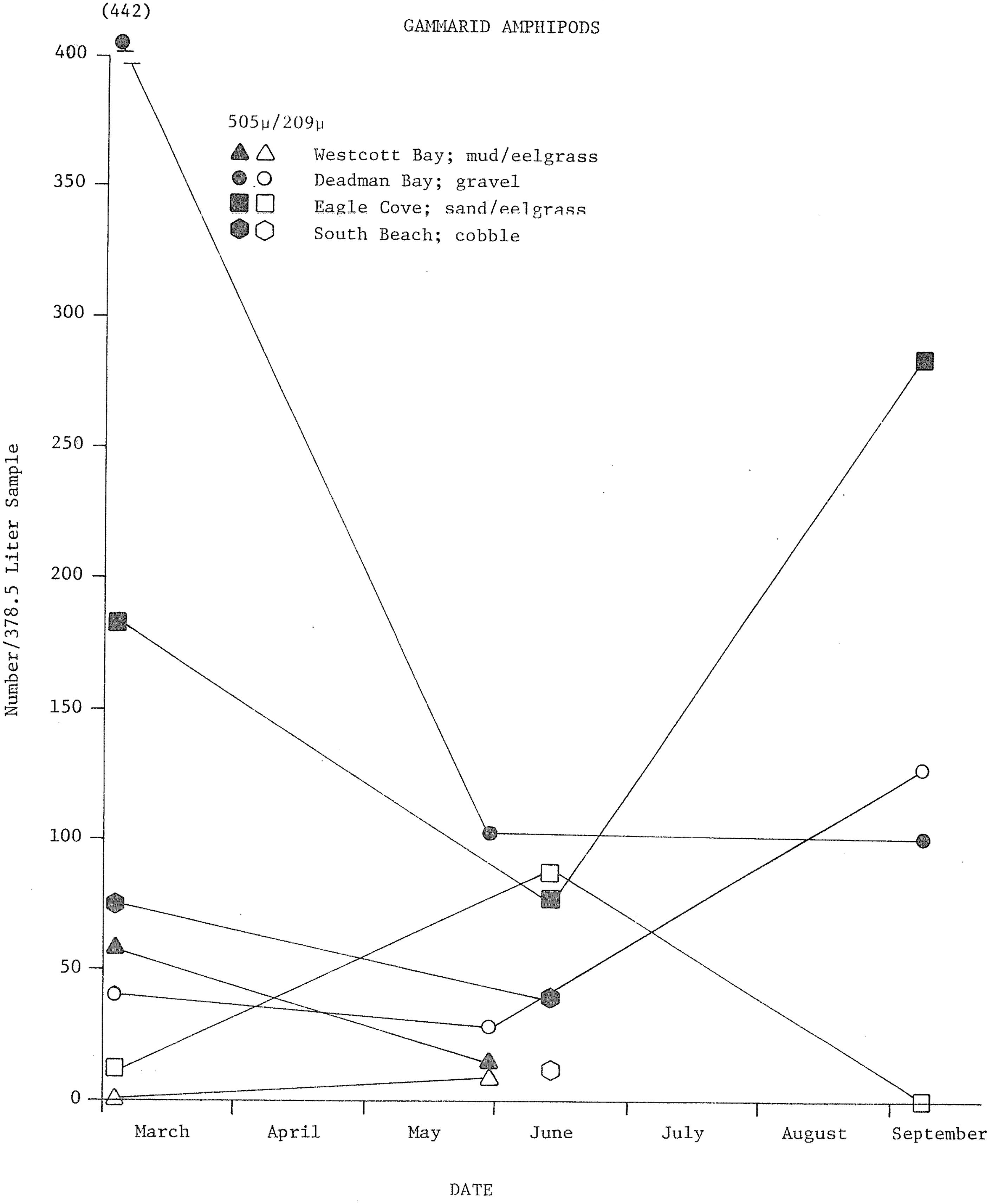

Fig. 49. Densities (number/378.5-liter sample) of epibenthic gammarid amphipods at four nearshore habitats, western San Juan Island, March-September, 1976.

of just over 3.4 calanoids/liter and this habitat also had the highest density in the May-June sampling period. Although relatively low in March, densities in the sand/eelgrass habitat remained somewhat constant through the sampling period.

Overall, gammarid amphipods were undoubtedly the most important prey organism of the nearshore fish assemblages in northern Puget Sound. Gammarids were most dense in the gravel and sand/eelgrass habitats; the maximum density was in March at the Deadman Bay gravel habitat where 1.17 gammarids were sampled. And, except for the September sample at Deadman Bay, the majority of the gammarids were > 505μ in size. A general decline in density is evident between March and May-June at Eagle Cove and Deadman Bay.

Although not frequent enough to graph, several other organisms were dense in particular habitats at certain times of the sampling period--polychaete annelids (> 505μ) in March at Westcott Bay at a density of 0.57/liter; gastropods (mostly *Lacuna* sp.) in May and June at Deadman Bay (0.30/liter), Eagle Cove (0.44/liter), and South Beach (0.67/liter); and cumaceans at Eagle Cove in September (0.61/liter).

Nearshore Epibenthic Plankton: Discussion

The epibenthic plankton present in different nearshore habitats are an important element of the nearshore invertebrate communities utilized as food by nearshore fishes. Unfortunately, quantitative sampling of the epibenthos has not been adequately developed and thus we have little information concerning the actual availability of prey organisms. The epibenthic plankton pump samples utilized in this preliminary study illustrated that epibenthic plankton are both seasonally and spatially (habitat) variable, which may account for the changes in prey composition seen in many epibenthic-feeding nearshore fishes such as juvenile English sole and sand sole, juvenile salmonids, shiner perch, some rockfish species, kelp greenling, whitespotted greenling, and several sculpin species. In addition, epibenthic organisms which are associated with distinct habitats may explain the presence of species during a certain period in their life history. For example, juvenile chum salmon or English sole prey rather specifically upon small harpacticoid copepods and cumaceans which are prevalent in sand/eelgrass and gravel habitats during the spring and summer and this is where we find the maximum concentrations of these species in the nearshore environs. In order to evaluate the "importance" of any food item to a species' trophic demands, it is necessary to document the spectrum of organisms available in the environment as compared to those eaten by the predator and to know how the composition of the prey community changes with time and space.

The data collected during the preliminary epibenthic plankton pump experiments are by no means adequate to describe the relative availability of plankton to nearshore fish. Because the variances associated with the density estimates and percentage composition were extremely high, it is apparent that the technique should be standardized further and the amount of contamination from adjacent zones reduced. This could be accomplished by pumping from within a smaller, confined cylinder rather than just over a hoop. There is the further question about the pumping efficiency and extinction rate of plankton during one sample, e.g., whether or not the pump is removing a high percentage of the available epibenthic plankton at an equal rate or is severely biased toward slower moving organisms. The extent of this bias can only be determined by a series of experiments whereby samples with different volumes over uniform substrates would be taken.

Finally, the present data indicated that, even considering the sampling biases, epibenthic plankton communities vary considerably in composition, diversity, and abundance over time. Three data points over 7 months cannot provide even an approximation of the changes which take place. Sampling should take place at least biweekly with a diel series (sample every 3 hours) performed every month.

These studies, though preliminary, suggest that an epibenthic pump is a useful tool for sampling the epibenthic plankton community, but revision and expansion of technique and sampling design will be necessary before an accurate measure of the actual availability of organisms can be related to their exploitation by an epibenthic-feeding fish.

Nearshore Fish Food Web Relationships: Discussion

Previous discussions in this report have described fish assemblages characterizing northern Puget Sound's nearshore habitats, including the food habits of the dominant species within these assemblages. While fish assemblages and prey composition vary considerably with season, time of day, exposure, and oceanographic conditions, generalized food webs can be drawn to indicate critical prey groups. If it can be assumed that the sum of these critical prey groups represents the optimum food resources for the fish assemblage as a whole, loss or reduction of these resources due to acute or chronic pollution could significantly reduce the carrying capacity of the habitat. The effect upon the fishes would depend on the degree or longevity of the pollution event but could include forced changes in food habits to suboptimal prey or abandonment of the habitat area for another area. Thus, we consider these food webs, though preliminary, as important illustrations of the critical food web components and linkages in the biological energy flow characterizing the nearshore regions of north Puget Sound. While the top-level predators may not be directly affected by a pollutant, the effect of a pollutant upon typically more sensitive lower trophic levels could cause concomitant changes in their predators, many of which are economically or recreationally important to man.

The food web linkages leading to neritic fishes were diagrammed in Fig. 50. Here and in the following figures the different arrows represent the trophic importance of prey taxa (measured as the percentage of the total IRI for the fish as they occur in the various nearshore habitats) contributing to the prey spectrum of each predator. Pelagic calanoid

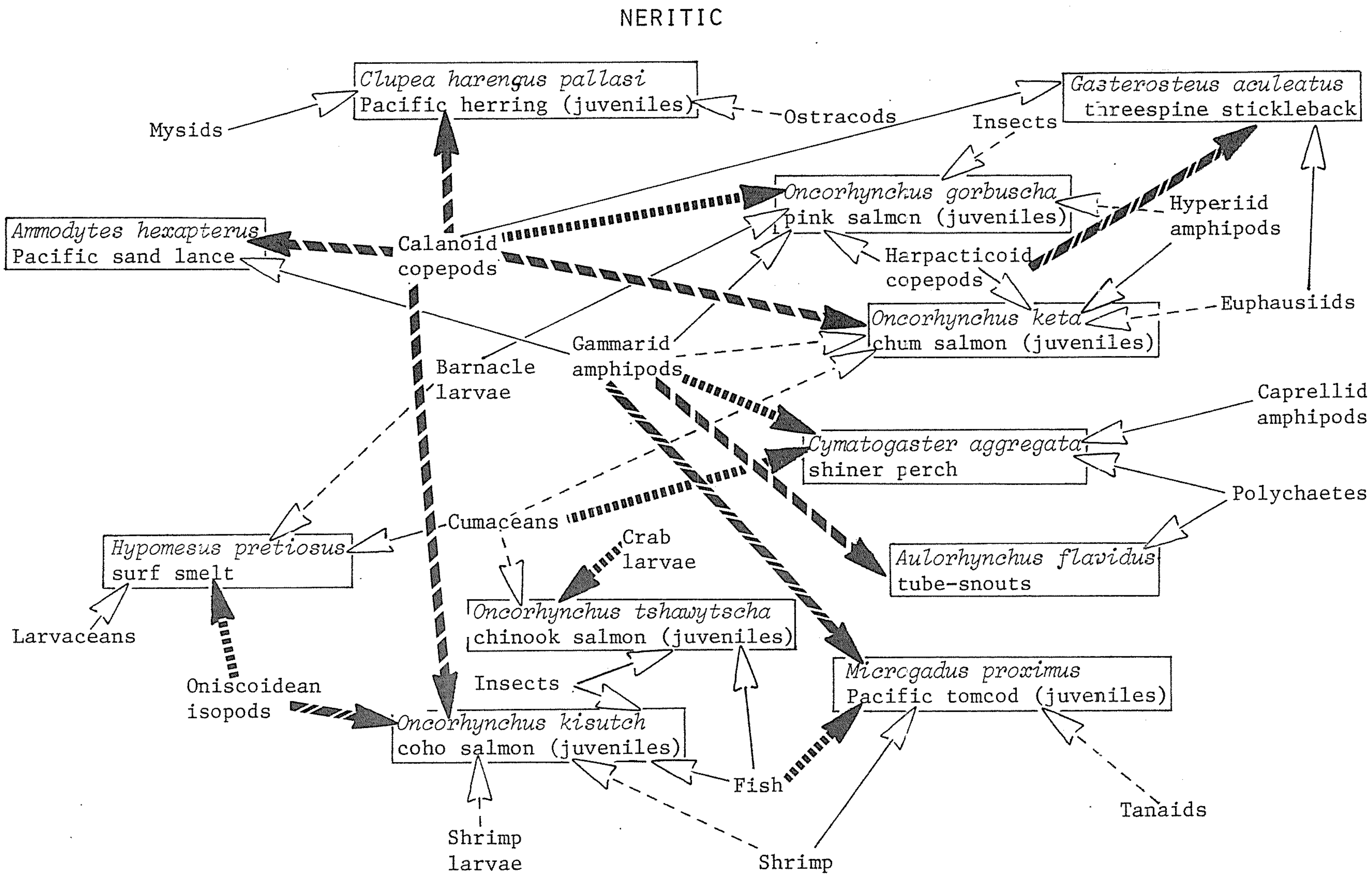

Fig. 50. Food web linkages to neritic fishes of northern Puget Sound. Arrows represent percentages of total I.R.I. contributed by a predator's principal prey taxa, where ➡ = 76-100%, ➡ = 51-75%, ➡ = 26-50%, ——▷ = 6-25%, and - - ▷ = 1-5%.

copepods and epibenthic gammarid amphipods were universally the most important prey for neritic fishes; other fishes (usually larvae), epibenthic oniscoidean isopods and cumaceans were less important. The schooling, far-ranging pelagic species--juvenile Pacific herring and Pacific sand lance--almost exclusively exploited calanoid copepods and were not dependent upon the more uniquely nearshore prey organisms. Their presence in the nearshore environs may not have been specifically involved so much with feeding (although the neritic waters may be highly productive in pelagic prey organisms) as with seeking refuge from predation or for spawning. Pelagic organisms were the dominant prey of juvenile salmonids occupying the neritic waters during their migration to oceanic feeding grounds, but epibenthic prey organisms were also important. In shallow neritic waters early in their marine residence, prey composition of juvenile pink and chum salmon was made up almost exclusively of epibenthic organisms such as harpacticoid copepods. Surf smelt, when in neritic waters during their spawning period, utilized epibenthic isopods. The other more resident neritic species fed almost exclusively upon epibenthic crustaceans. When these neritic species were captured during beach seining by WWSC, their prey compositions tended to be more oriented to epibenthic organisms (Appendix 4) and pelagic prey included significantly more crustacean larvae than in the same predators from the San Juan Island region.

The seven dominant species in northern Puget Sound's rocky/kelp bed fish assemblage exploited three types of prey organisms (Fig. 51), but no single prey taxon dominated the food web. Three rockfish--Puget Sound, black, and yellowtail--generally fed upon pelagic organisms, consuming calanoid copepods, hyperiid amphipods, pelagic fish, crustacean larvae, euphausiids, and chaetognaths (arrow worms); epibenthic mysids and shrimp were less important as prey. The copper rockfish and longfin sculpin, on the other hand, fed upon epibenthic forms--principally shrimp, crabs, harpacticoid copepods, mysids, and gammarid amphipods. Only one of the dominant fishes in the assemblage, the kelp greenling, could be considered benthophagous; its principal prey organisms usually included benthic forms--sea cucumbers and chitons--and fewer epibenthic prey--crabs, shrimp, gammarid isopods, harpacticoid copepods, and asellutan isopods. Lingcod, the top-level predator of the assemblage, was entirely piscivorous.

Because of the general overlap in species and the absence of significant stomach samples from cobble assemblage fishes, the assemblages characterizing the cobble and gravel habitats have been combined (Fig. 52). Epibenthic crustaceans accounted for most of the food web linkages to the dominant gravel-cobble habitat demersal fishes. Gammarid amphipods were the most important, providing 25 percent or more of the total IRI to seven of the 10 dominant species. Oniscoidean isopods, shrimp, crabs, mysids, and harpacticoid copepods also contributed more than 25 percent of the total IRI of at least one species. The only benthic organisms in any of the diet spectra were gastropods and polychaetes, neither one of much importance to the overall food web.

ROCKY/KELP BED

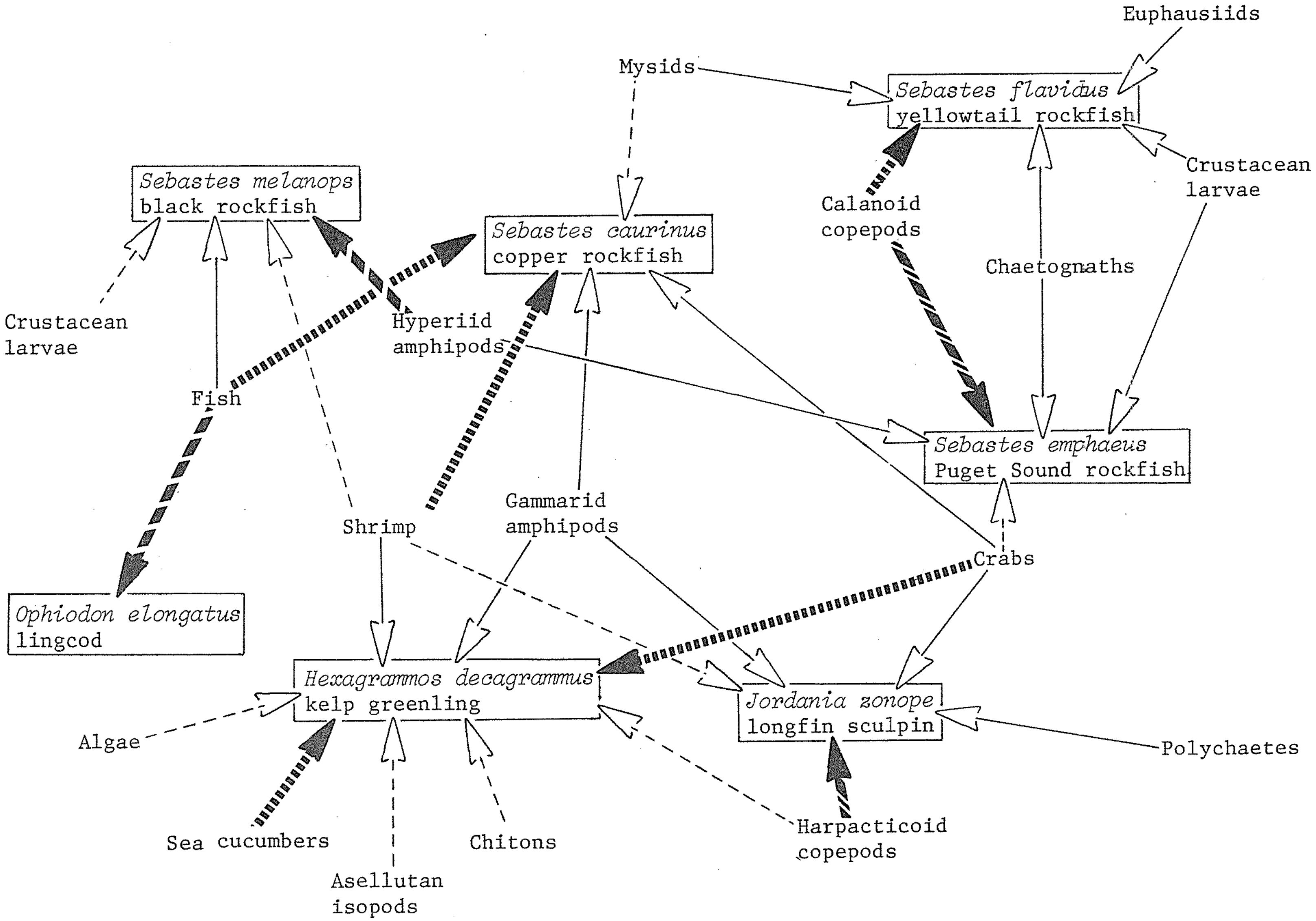

Fig. 51. Food web linkages to rocky/kelp bed fish of northern Puget Sound. Arrows represent percentages of total I.R.I. contributed by a predator's principal prey taxa, where ▬▬➡ = 76-100%, ▨▨➡ = 51-75%, ▪▪▪➡ = 26-50%, ——▷ = 6-25%, and - - -▷ = 1-5%.

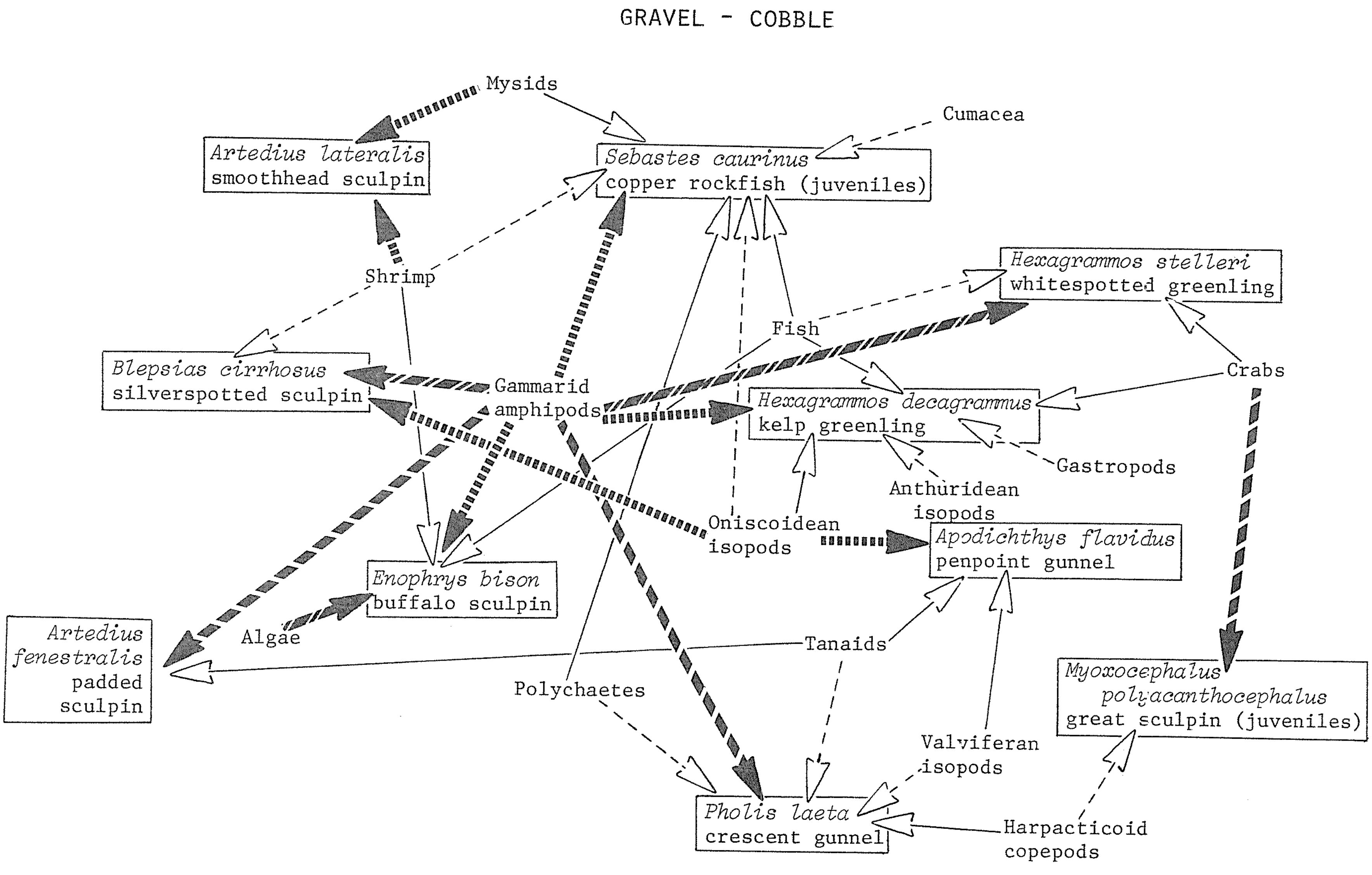

Fig. 52. Food web linkages to gravel and cobble habitat fishes of northern Puget Sound. Arrows represent percentages of total I.R.I. contributed by a predator's principal prey taxa, where ➤ = 76-100%, ➤ = 51-75%, ➤ = 26-50%, ⟶ = 6-25%, and ⇢ = 1-5%.

The food web relationships of these species in the eastern shore area were basically similar with perhaps a slightly greater utilization of gammarid amphipods (Appendix 4).

Important prey resources of fishes composing the sand/eelgrass habitat (Fig. 53) consisted of epibenthic crustaceans--gammarid amphipods, oniscoidean isopods, cumaceans--or benthic organisms such as polychaetes and bivalves (siphons). The only significant pelagic prey were shrimp larvae; they represented less than 5 percent of the total IRI of the staghorn sculpin. Dominant flatfish species each utilized a different taxon for major food items. Juvenile English sole fed mostly upon cumaceans, sand sole upon polychaetes, and starry flounder upon oniscoidean isopods and gammarid amphipods. The food web relationships for flatfish species along the eastern shore were appreciably different; there, the flatfishes were much more dependent upon gammarid amphipods.

Although six species were identified as dominant members of the mud/eelgrass assemblage, only the staghorn sculpin, juvenile English sole, and snake prickleback are included in the food web (Fig. 54). The small number of tidepool sculpin, sharpnose sculpin, and starry flounder collected for stomach samples (because of small fish size or low abundance) did not permit their inclusion in a generalized food web. Staghorn sculpin in the a mud/eelgrass habitat fed mostly upon epibenthic organisms. Juvenile English sole in the mud/eelgrass habitat tended to be more benthophagous than those in sand/eelgrass habitats. Snake prickleback also fed predominantly upon benthic organisms, i.e., bivalves. In the eastern shore region these species had similar spectra of prey organisms, except snake prickleback which utilized oligochaetes as their principal food.

These generalized food webs indicated that epibenthic crustaceans--gammarid amphipods, isopods, mysids, harpacticoid copepods, tanaids, cumaceans, shrimp, and crabs--dominated the important linkages to nearshore fishes of north Puget Sound. Pelagic organisms--calanoid copepods, euphausiids, larvae of barnacles and other crustaceans, and larvaceans--were important to but a few species, principally in the neritic and rocky/kelp bed fish assemblages. Benthic prey, such as polychaetes, bivalves (bivalve siphons), holothurians, and chitons, were important to only a few species in the mud/eelgrass, sand/eelgrass, and rocky/kelp bed assemblages. Thus, except for six fish species of the neritic assemblage and three species of the rocky/kelp bed assemblage, the predominant nearshore fish species fed upon prey organisms which were uniquely nearshore, i.e., generally restricted to the epibenthic and benthic fauna of the shallow sublittoral and littoral regions.

Possible reasons for this preference for feeding upon nearshore prey are many and interrelated, including: 1) Generally higher base productivity in the nearshore area, especially for populations of crustaceans which utilize detritus; 2) protection from predators inhabiting deeper waters; 3) protective or food-related associations with certain

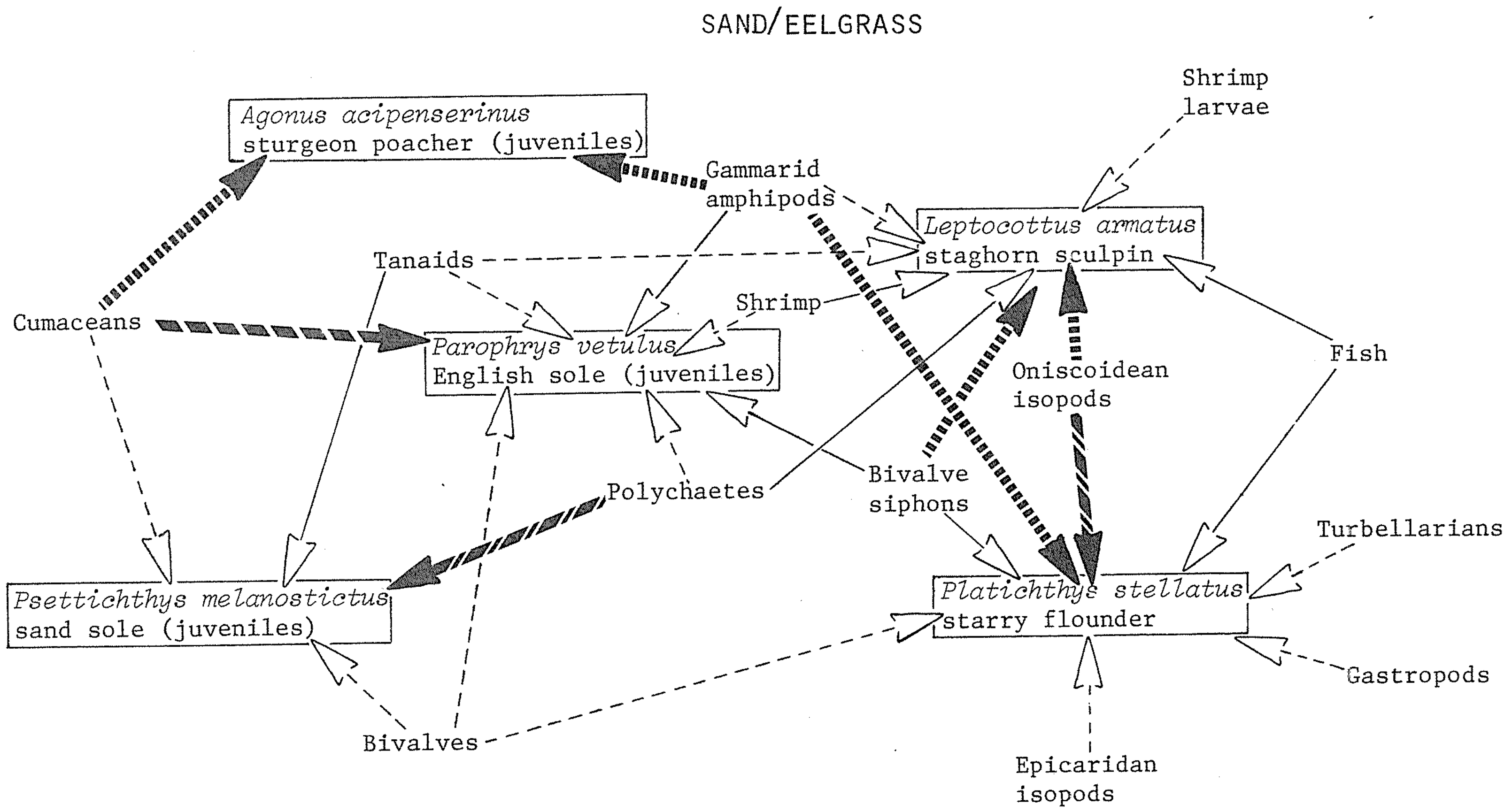

Fig. 53. Food web linkages to sand/eelgrass habitat fishes of northern Puget Sound. Arrows represent percentages of total I.R.I. contributed by a predator's principal prey taxa, where ▰▰▶ = 76-100%, ▱▱▶ = 51-75%, ▪▪▪▶ = 26-50%, ——▷ = 6-25%, and - - -▷ = 1-5%.

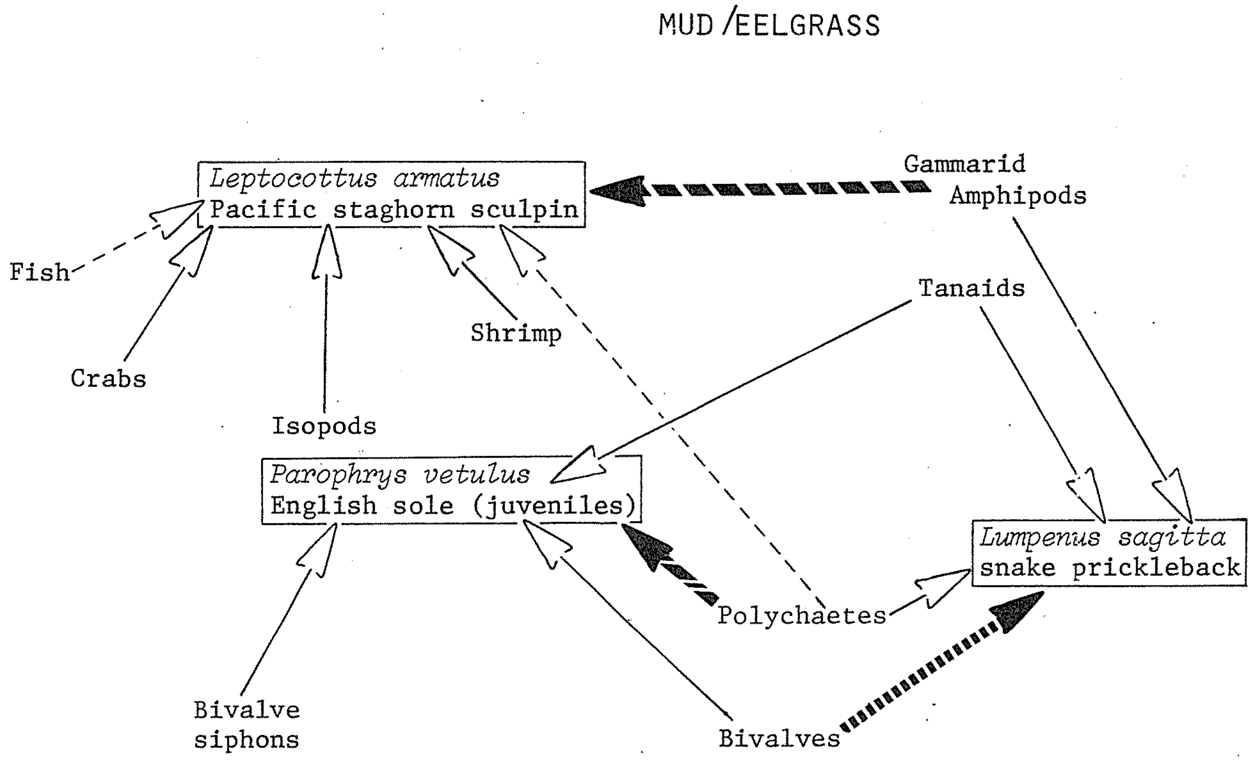

Fig. 54. Food web linkages to mud/eelgrass habitat fishes of northern Puget Sound. Arrows represent percentages of total I.R.I. contributed by a predator's principal prey taxa, where ▰▰➤ = 76-100%, ➤ = 51-75%, ┅┅➤ = 26-50%, ——▷ = 6-25%, and - - -▷ = 1-5%.

substrates, algae, and sea grasses which are restricted to nearshore habitats; and 4) physiochemical conditions which are preferential or optimal for growth and survival.

Predictions or evaluations of the effects of pollutants in north Puget Sound, especially the effects of spilled petroleum hydrocarbons, must consider the structure of these food webs characterizing the predominant habitats. It is through these trophic pathways that the more subtle community changes may occur, eventually resulting in the reduction of economically or recreationally important fish species, or transfer of pollutants to the ultimate predator at the top of the trophic structure, man.

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APPENDICES

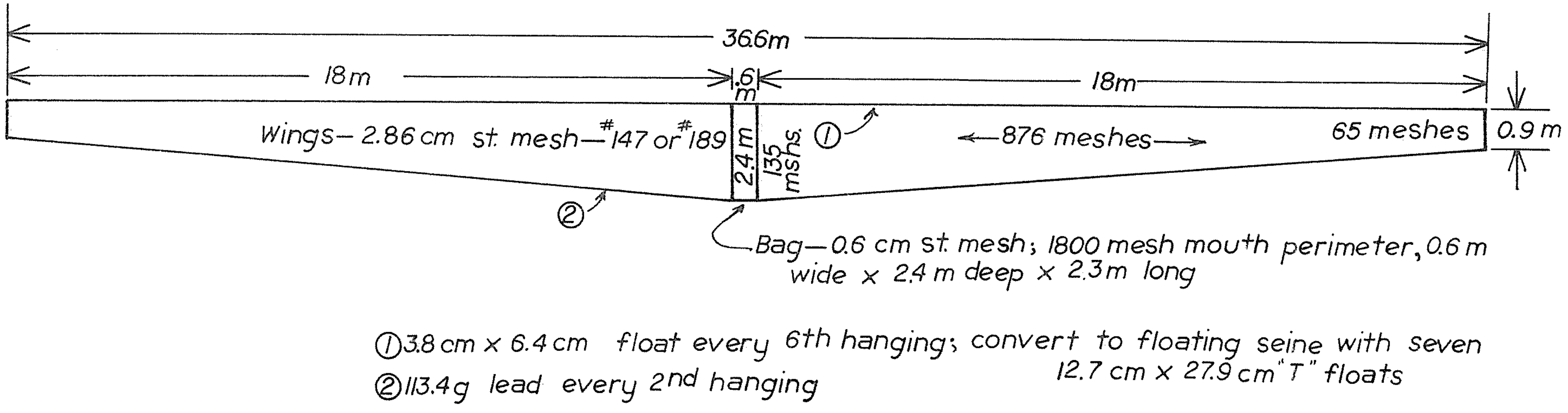
APPENDIX 1

Sampling Gear Descriptions

A. Beach Seine

B. Townet

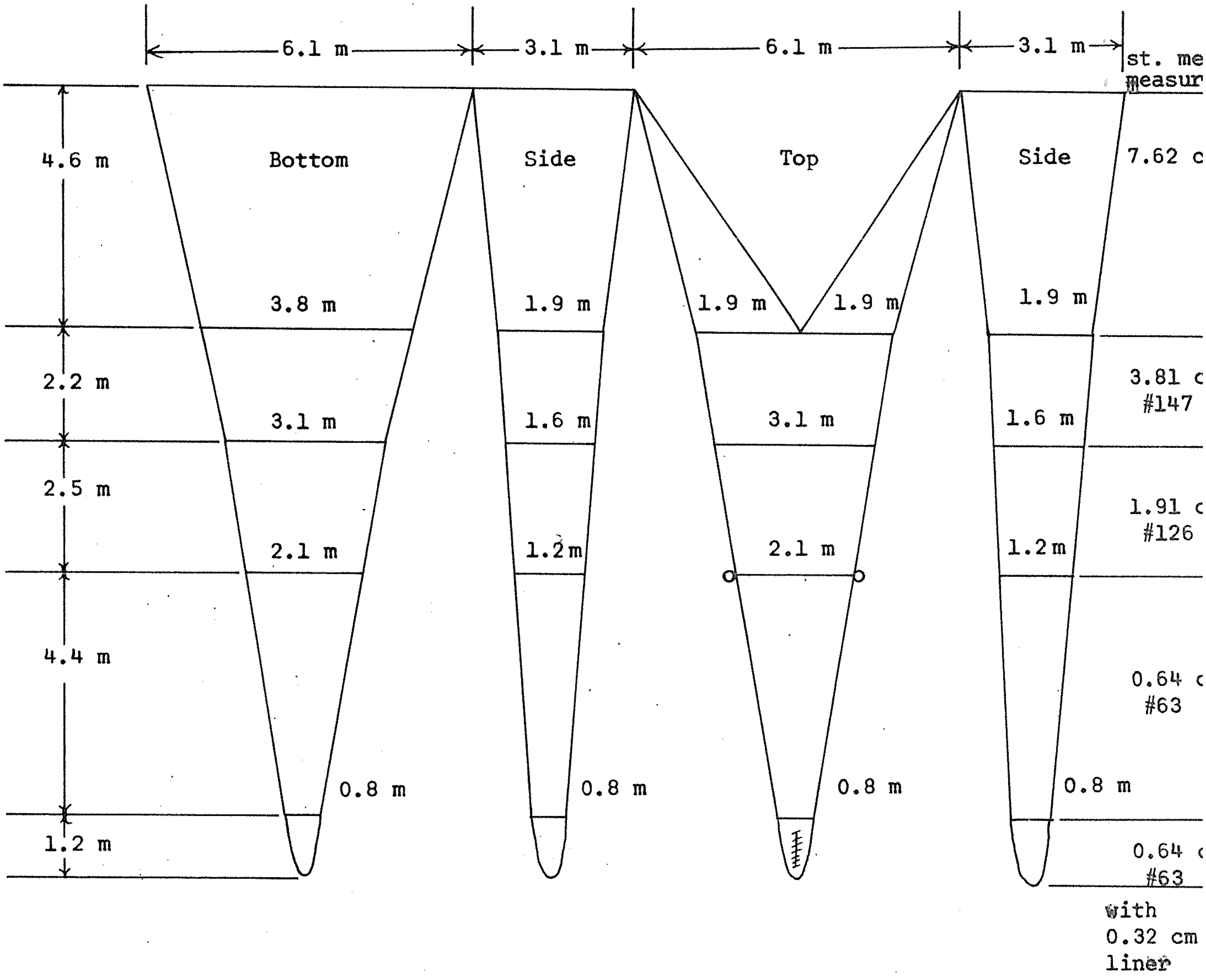
C. Trammel Net



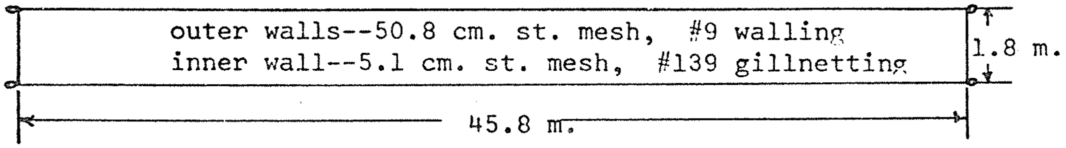
Appendix 1a. Convertible beach seine utilized during Nearshore Fish Survey, July 1974 - June 1975.

Appendix 1b. Surface tow net utilized during Nearshore Fish Survey, July 1974 - June 1975.

Surface Trawl - 2.1 m x 3.1 m mouth
15 m long



All seams of 3.81 cm and smaller mesh reinforced with heavy 2.54 cm nylon tape including center lines of bottom and top panels. Rib-lines of 0.95 cm diameter polypro on four corner seams full length. Mouth of net double twine and hung on 0.35 cm polypro single braid with mimbles at each corner. A 0.9 m nylon coil zipper shall be sewn into cod-end and liner in the top panel. Six 4-oz. leads shall be spaced evenly along the foot line. 5.08 cm rings shall be sewn on top panel at 1.91 cm - 0.64 cm seam.



floatline: 1.3 cm. polycore with one B-2 float every 7th hanging
leadline: 34 kg. leadcore

Appendix 1c. Trammel net used in Nearshore Fish Survey.

APPENDIX 2

Nearshore Fish Survey Data Forms

A. Collection Form, S240.0

B. Catch Summary Form, S240.1

C. Fish Examination Form, S240.2

D. Stomach Analysis Forms, S240.3 and S240.4

S240.0
COLLECTION FORM

ECOLOGY AND DISTRIBUTION OF PUGET SOUND FISHES
COLLEGE OF FISHERIES / FISHERIES RESEARCH INSTITUTE
UNIVERSITY OF WASHINGTON

COLLECTION NUMBER ☐☐☐☐☐ 5 HAUL NUMBER ☐☐ 7 DATE DAY ☐☐ 9 MONTH ☐☐ 11 YEAR ☐☐ 13

LOCATION ____________________ CODE SUBAREA ☐☐ 15 SITE ☐☐☐ 18

LATITUDE ____________ LONGITUDE ____________

HABITAT TYPE ____________________ CODE ☐☐ 20

BOTTOM TYPE ____________ CODE ☐ 21 EXPOSURE ____________

BOTTOM DEPTH ☐☐☐☐ 25 *meters* COLLECTION DEPTH ☐☐☐☐ 29 *meters*

GEAR TYPE ____________ CODE ☐☐☐ 32

LINE OUT ______ *m.* WIRE ANGLE ______ ° SPEED ____________ *km/hr*

DISTANCE FISHED ☐☐☐☐ 36 *meters* TIME: START ☐☐☐☐ 40 *hours* DURATION ☐☐☐☐ 44 *minutes*

AREA FISHED ☐☐☐☐ 48 *meters*^{2} VOLUME STRAINED ☐☐☐☐☐☐ 54 *meters*^{3}

WEATHER: WIND SPEED ______ *km/hr* DIRECTION ______ VISIBILITY ____________ *kilometers*

% CLOUD COVER ______ PRECIPITATION ____________

AIR TEMPERATURE ______ °*C*

SEA: SURFACE TEMPERATURE ☐☐.☐ 57 °*C* TIDE: STAGE ______ ☐ 58 HEIGHT ☐☐.☐ 61 *meters*

VISIBILITY (SECCHI) @ ______ *m.* DEPTH ☐.☐ 64 *meters* SEA STATE ____________

COLOR ______ CURRENT: DIRECTION ____________ VELOCITY ______ *km/hr*

WATER SAMPLES: DEPTH ______ *m.* TEMPERATURE ☐☐.☐ 67 °*C*

DEPTH ______ *m.* SALINITY ☐☐.☐ 70 °/₀₀ BOTTLE NUMBER ______

DEPTH ______ *m.* O_2 ☐☐☐ 73 *% sat.* BOTTLE NUMBER ______

PERSONNEL ____________________

____

HANDLING OF FISH CATCH ____________________ CODE ☐ 74

____

REMARKS ____________________

____

____

____

FORM TYPE 0 77

REVISED S240.1
CATCH SUMMARY FORM

ECOLOGY AND DISTRIBUTION OF PUGET SOUND FISHES
COLLEGE OF FISHERIES / FISHERIES RESEARCH INSTITUTE
UNIVERSITY OF WASHINGTON

COLLECTION		DATE		
Number	Hl	Day	Mo.	Yr.
5	7	9	11	13

	SPECIES	SPECIES CODE	TOTAL NUMBER	TOTAL WEIGHT *grams*	DATA	REMARKS	SPECIES	SPECIES CODE	TOTAL NUMBER	TOTAL WEIGHT *grams*	DATA	REMARKS	FORM TPE.
		17	22	27	28			32	37	42	43		77
1													1
2													1
3													1
4													1
5													1
6													1
7													1
8													1
9													1
10													1
11													1
12													1
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17													1
18													1
19													1
20													1
21													1
22													1
23													1
24													1

REMARKS ______________________________

ECOLOGY AND DISTRIBUTION OF PUGET SOUND FISHES
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REVISED S240.2
FISH EXAMINATION FORM
11/14/74

Species

COLLECTION		DATE			SPECIES	NORMAL/ ABNORMAL	PRES. METHOD	LENGTH TYPE	LENGTH mm	ROUND WEIGHT grams	SEX	MATURITY	AGE METHOD	AGE	L.H. STAGE	FIN ROT							TOTAL AEN TUMORS	AEN		TOTAL EP TUMORS	EP		EXT. NEMATODES	(individual remarks)	SPECIMEN NUMBER	FORM TYPE		DATA SOURCE
NUMBER	HL.	DAY	MO.	YR.												dsl.	anal	cdl.	E.pt.	B.pt.	E.vtl	B.vtl		eyed side	blind side		eyed side	blind side						
5	7	9	11	13	16	18	19	20	24	30	31	32	33	35	36	37	38	39	40	41	42	43	45	47	49	51	53	55	56		76	77		80
				1																												2		
				2																												2		
				3																												2		
				4																												2		
				5																												2		
				6																												2		
				7																												2		
				8																												2		
				9																												2		
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				19																												2		
				20																												2		
				21																												2		
				22																												2		
				23																												2		
				24																												2		
				25																												2		

REMARKS

Ecology and Distribution of Puget Sound Fishes
College of Fisheries
University of Washington

Form S240.3
Stomach Examination

	Collection		Date			Specimen Number	Species			Condition Fac.	Digestion Fac.	Total Contents	1			2			3			Form Type		Continuation
	Number	Haul	Day	Month	Year		Code	L.H.Stg				Weight *grams*	Food Organism Code	No.	Weight *grams*	Food Organism Code	No.	Weight *grams*	Food Organism Code	No.	Weight *grams*			
	5	7	9	11	13	15	18	19		22	23	28	37	40	44	53	56	60	69	72	76	77		80
1																								
2																								
3																								
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Remarks: ______________________________

ECOLOGY AND DISTRIBUTION OF PUGET SOUND FISHES
College of Fisheries/Fisheries Research Institute
University of Washington

Form 324.0.4
Stomach exam.-prey freq.

Collection		Date		
Number	Haul	Day	Month	Year
5	7	9	11	13

Species ____________________

Specimen Number	Species Code	L.H.stage
15	18	19

Prey organism taxa (initial sorting) ____________________

Organism code				L.H.stage
Phylum Class	Order Family	Genus	Species	
21	23	25	27	28

Prey species (final determination)	Organism code				L.H.stage	Number		Continuation
	Phylum Class	Order Family	Genus	Species				
							40	
							52	
							64	
							76	☐ 80
						4	77	
							40	
							52	
							64	
							76	☐
						4	77	
							40	
							52	
							64	
							76	☐ 80
						4	77	
							40	
							52	
							64	
							76	☐ 80
						4	77	
							40	
							52	
							64	
							76	☐ 80
						4	77	

APPENDIX 3

Ichthyoplankton Catches

Appendix Table 3A. Burrows Island bongo net catches (number/100 m^3), 1976.

Date	20 Feb.	20 Mar.	7 May	14 June	11 Aug.
Mesh size (μ)	505	505	333	505	505
Tow type	Surface	Surface	Surface	Surface	Surface
Volume filtered (m^3)	297.8	311.0	200.1	254.1	262.7
Species or Family					
Eggs					
Eopsetta jordani		0.3			
Pleuronichthys sp.			1.0	0.4	
Psettichthys melanostictus or *Isopsetta isolepis*	10.1	33.4	2.0	0.8	2.3
Unidentified		0.6	0.5	0.8	
Total number/100 m^3	10.1	34.3	3.5	2.0	2.3
Number of species	1	3	3	3	1
Larvae					
Clupea harengus pallasi		0.6	4.5	2.8	
Engraulis mordax				0.4	
Osmeridae				6.3	
Stenobrachius leucopsarus	0.3				
Gadus macrocephalus or *Theragra chalcogramma*		3.5	1.0		
Anoplarchus sp.		6.1			
Lumpenus sagitta	0.3	1.6			
Xiphister atropurpureus		1.6			
Ammodytes hexapterus	0.3	1.0	1.5		
Sebastes sp.		1.6	1.5		0.4
Hexagrammos sp.	0.3				
Leptocottus armatus		0.6			
Cottidae	0.9				
Agonidae		2.3			
Isopsetta isolepis				0.4	
Parophrys vetulus		0.3			
Platichthys stellatus			2.0		
Unidentified	0.3	0.3		0.8	
Total number/100 m^3	2.4	19.5	10.5	10.7	0.4
Number of species	6	11	5	5	1

Appendix Table 3B. Point George bongo net catches (numbers/100 m^3) during 1976.

Date	24 Feb.	21 Mar.	10 Apr.	10 Apr.	10 Apr.	10 May	10 May	18 June	18 June
Mesh size (μ)	505	505	333	505	505	505	505	505	505
Tow type	Surface	Surface	Surface	Surface	Oblique	Surface	Oblique	Surface	Oblique
Volume filtered (m^3)	288.1	244.3	248.4	248.4	321.0	77.5	148.3	85.8	42.9
<u>Species or Family</u>									
<u>Eggs</u>									
Citharichthys sp.							0.7		
Eopsetta jordani		2.5		10.5					
Glyptocephalus zachirus or *Lyopsetta exilis*				1.6					
Glyptocephalus zachirus or *Microstomus pacificus*				0.8					
Hippoglossoides elassodon				0.4	4.2				
Pleuronichthys sp.			0.8			1.3	3.4	12.8	9.3
Psettichthys melanostictus or *Isopsetta isolepis*	5.9	22.5	5.2	2.8	2.1				
Unidentified		3.3	12.8	1.2	8.4		1.3	11.7	2.3
Total number/100 m^3	5.9	28.3	18.8	17.3	14.7	1.3	5.4	24.5	11.6
Number of species	1	3	3	6	3	1	3	2	2
<u>Larvae</u>									
Clupea harengus pallasi		0.8	1.5	6.4	8.4	14.2	4.7		4.7
Spirinchus thaleichthys	1.4								
Osmeridae					2.1			12.8	673.4
Gadus macrocephalus or *Theragra chalcogramma*	0.3	5.3	2.3	3.6	33.5	14.2	6.7		
Anoplarchus sp.		4.1	2.3	2.8	2.1				
Chirolophis sp.	0.3								
Lumpenus sagitta		0.4							
Pholis sp.					2.1				
Gobiidae								1.2	
Ammodytes hexapterus	4.5	9.4	3.0	0.8			1.3		
Sebastes sp.	0.3	4.1	6.0	24.2	27.2	6.5	12.8		
Ophiodon elongatus	0.7	0.4		0.4					
Leptocottus armatus				0.4					

Appendix Table 3B, cont'd

Date Mesh size (μ) Tow type Volume filtered (m^3)	24 Feb. 505 Surface 288.1	21 Mar. 505 Surface 244.3	10 Apr. 333 Surface 248.4	10 Apr. 505 Surface 248.4	10 Apr. 505 Oblique 321.0	10 May 505 Surface 77.5	10 May 505 Oblique 148.3	18 June 505 Surface 85.8	18 June 505 Oblique 42.9
Larvae cont'd									
Cottidae		5.7	0.8	7.2	35.6	2.6	2.0	1.2	4.7
Agonus acipenserinus						1.3			
Agonidae		0.8							
Cyclopteridae									2.3
Isopsetta isolepis						2.6	0.7		
Parophrys vetulus				0.8			2.0		
Platichthys stellatus						2.6	0.7		
Psettichthys melanostictus				0.4		1.3	0.7		
Pleuronectidae		0.4		0.4	2.1				9.3
Unidentified					6.3			1.2	
Total number/100 m^3	7.5	31.4	15.9	47.4	119.4	45.3	31.6	16.4	693.4
Number of species	6	10	6	11	9	8	9	4	5

Appendix Table 3C. Cherry Point bongo net catches (numbers/100 m^3) during 1976

Date Mesh size (μ) Tow type Volume filtered (m^3)	20 Feb. 505 Surface 143.8	7 April 333 Surface 254.7	11 Apr. 505 Oblique 260.2	9 May 333 Surface 37.1	9 May 505 Oblique 41.6	16 June 505 Surface 91.5	16 June 505 Oblique 58.4	10 Aug. 505 Surface 104.3	10 Aug. 505 Oblique 58.6
<u>Species or family</u>									
<u>Eggs</u>									
Citharichthys sp.						3.3	1.7	9.6	15.3
Glyptocephalus zachirus or *Microstomus pacificus*		4.6							
Hippoglossoides elassodon		10.8	37.5	2.7	4.8				
Pleuronichthys sp.		1.5		37.7	7.2				
Psettichthys melanostictus or *Isopsetta isolepis*	787.9	1490.0	1903.1		14.4	22.9	15.4	6.7	6.8
Unidentified						2.2	5.1		
Total number/100 m^3	787.9	1506.9	1940.6	40.4	26.4	28.4	22.2	16.3	22.1
Number of species	1	4	2	2	3	3	3	2	2
<u>Larvae</u>									
Clupea harengus pallasi		23.2	70.3	86.2	1428.9	39.3	39.4		
Osmeridae		10.8	4.7		7.2	44.8	58.2		
Gadus macrocephalus or *Theragra chalcogramma*		6.2	46.9		21.6				
Gasterosteus aculeatus	2.1								1.7
Anoplarchus sp.		13.9	32.8						
Chirolophis sp.	6.3								
Lumpenus sagitta			0.4						
Xiphister atropurpureus	36.2								
Pholis sp.		3.1							
Gobiidae						1.1	1.7		
Ammodytes hexapterus	9.0	41.8	56.3	32.3	2.4				
Sebastes sp.					2.4				
Ophiodon elongatus	8.3								
Gilbertidia sigalutes		1.5	0.4						

Appendix Table 3C, cont'd

Date	20 Feb.	7 April	11 Apr.	9 May	9 May	16 June	16 June	10 Aug.	10 Aug.
Mesh size (μ)	505	333	505	333	505	505	505	505	505
Tow type	Surface	Surface	Oblique	Surface	Oblique	Surface	Oblique	Surface	Oblique
Volume filtered (m^3)	143.8	254.7	260.2	37.1	41.6	91.5	58.4	104.3	58.6
Larvae, cont'd									
Leptocottus armatus	4.2			2.7	2.4				
Myoxocephalus polyacanthocephalus			0.4						
Psychrolutes paradoxus			10.5						
Cottidae		1.5			7.2	1.1	1.7		
Agonus acipenserinus				2.7					
Agonidae					2.4				
Isopsetta isolepis						1.1			
Parophrys vetulus				2.7	4.8				
Platichthys stellatus		13.9		24.2	79.2				
Psettichthys melanostictus				5.4	14.4				
Pleuronectidae		3.0	206.3				3.4		
Unidentified			2.7	9.6	1.1				
Total number/100 m^3	66.1	118.9	431.7	165.8	1572.9	87.4	104.4	0	1.7
Number of species	6	10	11	8	12	5	5	0	1

Appendix Table 3D. South Beach bongo net catches (number/100 m^3) during 1976.

Date	24 Feb.	21 Mar.	9 April
Mesh size (μ)	505	505	505
Tow type	Surface	Surface	Surface
Volume filtered (m^3)	250.2	195.2	208.2
Species or Family			
Eggs			
Glyptocephalus zachirus or *Lyopsetta exilis*			3.3
Pleuronichthys sp.			0.8
Psettichthys melanostictus or *Isopsetta isolepis*	5.2	23.6	7.3
Unidentified		1.0	2.4
Total number/100 m^3	5.2	24.6	13.8
Number of species	1	2	4
Larvae			
Clupea harengus pallasi		1.0	0.8
Osmeridae		0.5	1.6
Gadus macrocephalus or *Theragra chalcogramma*		1.0	8.1
Anoplarchus sp.		2.0	1.6
Chirolophis sp.	1.2		
Lumpenus sp.		0.5	
Xiphister atropurpureus		0.5	
Ammodytes hexapterus	0.4	11.8	18.7
Sebastes sp.		1.0	10.6
Ophiodon elongatus	0.4		0.8
Leptocottus armatus			0.8
Scorpaenichthys marmoratus			0.8
Cottidae		1.5	8.1
Agonidae			0.8
Pleuronectidae			1.6
Total number/100 m^3	2.0	19.8	54.3
Number of species	3	9	12

Appendix Table 3E. Guemes I. (south) bongo net catches (numbers/100 m^3) during 1976.

Date	20 Feb.	20 Mar.	8 April	7 May	7 May	11 Aug.	11 Aug.
Mesh size (μ)	505	505	333	333	333	505	505
Tow type	Surface	Surface	Surface	Surface	Oblique	Surface	Oblique
Volume filtered (m^3)	287.9	261.9	253.1	104.4	11.1	154.2	101.4
Species or Family							
Eggs							
Citharichthys sp.							1.0
Hippoglossoides elassodon			1.6	1.0	9.0		
Pleuronichthys sp.				2.8	99.0		
Psettichthys melanostictus or *Isopsetta isolepis*	5.2	199.3	69.5	4.8	126.0	1.9	2.0
Unidentified		0.8				0.6	2.0
Total number/100 m^3	5.2	200.1	71.1	8.6	234.0	2.5	5.0
Number of species	1	2	2	3	3	2	3
Larvae							
Clupea harengus pallasi			3.2	14.4	27.0		
Osmeridae				1.0			
Gadus macrocephalus or *Theragra chalcogramma*		6.5	0.8	4.8	27.0		
Anoplarchus sp.		0.8					
Lumpenus sagitta	1.0	4.6					
Xiphister atropurpureus	0.3	2.7					
Ammodytes hexapterus	1.4	1.5					
Sebastes sp.		1.9	5.9				2.0
Gilbertidia sigalutes					27.0		
Myoxocephalus polyacanthocephalus		0.8					
Psychrolutes paradoxus			0.4				
Scorpaenichthys marmoratus		3.4					
Cottidae		1.9		3.8	18.0		
Parophrys vetulus				1.9			
Platichthys stellatus					9.0		
Pleuronectidae					9.0		
Unidentified		0.4	1.6	2.8			1.0
Total number/100 m^3	2.7	24.5	11.9	28.7	117	0	3.0
Number of species	3	10	5	6	6	0	2

Appendix Table 3F. Deadman Bay bongo net catches (number/100 m^3) during 1976.

Date	24 Feb.	21 Mar.	10 Apr.	10 Apr.
Mesh size (μ)	505	505	333	505
Tow type	Surface	Surface	Surface	Surface
Volume filtered (m^3)	240.9	298.7	233.8	233.8
<u>Species or Family</u>				
<u>Eggs</u>				
Eopsetta jordani			5.1	
Glyptocephalus zachirus or *Lyopsetta exilis*				0.9
Glyptocephalus zachirus or *Microstomus pacificus*			0.9	
Glyptocephalus zachirus		0.3	0.4	0.4
Hippoglossoides elassodon				0.4
Pleuronichthys sp.			0.4	
Psettichthys melanostictus or *Isopsetta isolepis*	1.2	4.7	2.1	4.3
Unidentified		1.3		6.4
Total number/100 m^3	1.2	6.3	8.9	12.4
Number of species	1	3	5	5
<u>Larvae</u>				
Clupea harengus pallasi			5.6	2.6
Spirinchus thaleichthys	4.6			
Osmeridae		0.3		
Gadus macrocephalus or *Theragra chalcogramma*	0.4	0.3	3.4	4.3
Anoplarchus sp.		38.5		4.3
Chirolophis sp.	5.8			
Lumpenus sagitta	1.2	0.3		
Xiphister atropurpureus		0.7		
Ammodytes hexapterus	27.8	52.6	3.0	2.6
Sebastes sp.	0.4	0.7	6.8	4.7
Ophiodon elongatus	4.6	1.7		
Zaniolepis latipinnis		0.3		
Gilbertidia sigalutes	0.8			
Cottidae	1.2	3.3	0.9	0.9
Cyclopteridae			0.4	
Parophrys vetulus			0.4	
Platichthys stellatus		0.3		
Psettichthys melanostictus			0.4	
Pleuronectidae	3.3	0.3		0.8
Total number/100 m^3	50.1	99.3	20.9	20.2
Number of species	10	12	8	7

Appendix Table 3G. Birch Bay bongo net catches (numbers/100 m^3) during 1976.

Date	20 Feb.	19 Mar.	7 April	11 Apr.	8 May	9 May	15 June	9 Aug.
Mesh size (μ)	505	505	333	505	505	505	505	505
Tow type	Surface	Surface	Surface	Oblique	Surface	Surface	Surface	Surface
Volume filtered (m^3)	354.3	266.7	190.8	209.9	12.5	20.6	57.9	116.4
Species or Family								
Eggs								
Engraulis mordax								2.6
Citharichthys sp.						20.8		737.8
Hippoglossoides elassodon				6.6	8.0			
Pleuronichthys sp.					303.3	135.7		0.9
Psettichthys melanostictus or *Isopsetta isolepis*	1161.9	1574.7	5238.0	638.4	39.9		31.1	
Unidentified							10.4	244.8
Total number/100 m^3	1161.9	1574.7	5238.0	645.0	351.2	156.5	41.5	986.1
Number of species	1	1	1	2	3	2	2	4
Larvae								
Clupea harengus pallasi		1.9	12.1	50.4	5619.6	2846.9	8.6	
Spirinchus thaleichthys			17.3					
Osmeridae				6.6			1.7	
Gadus macrocephalus or *Theragra chalcogramma*			0.5	26.3				
Anoplarchus sp.		0.4		2.2				
Lumpenus sagitta			1.0					
Pholis sp.				4.4				
Gobiidae						10.7	1.7	1.7
Ammodytes hexapterus	4.5	4.1	20.8	6.6	39.9	73.2		
Sebastes sp.				6.6				
Ophiodon elongatus			1.0					
Enophrys bison			0.5					
Leptocottus armatus		0.7	5.8		79.8	73.2		
Psychrolutes paradoxus				1.0				
Scorpaenichthys marmoratus					8.0			
Cottidae	0.3		2.1	8.8	23.9			
Agonidae			1.0	0.5				

Appendix Table 3G, cont'd

Date	20 Feb.	19 Mar.	7 April	11 Apr.	8 May	9 May	15 June	9 Aug.
Mesh size (μ)	505	505	333	505	505	505	505	505
Tow type	Surface	Surface	Surface	Oblique	Surface	Surface	Surface	Surface
Volume filtered (m^3)	354.3	266.7	190.8	209.9	12.5	20.6	57.9	116.4
Larvae (cont'd)								
Parophrys vetulus				4.4	55.9	62.5		
Platichthys stellatus			30.7		159.6	114.9		
Psettichthys melanostictus					151.7	114.9		
Pleuronectidae				2.2				
Unidentified			2.1	26.3				0.9
Total number/100 m^3	4.8	7.1	94.9	146.3	6138.4	3296.3	12.0	2.6
Number of species	2	4	12	13	8	7	3	2

Appendix Table 3H. Eagle Cove bongo net catches (number/100 m^3) during 1976.

Date	24 Feb.	21 Mar.	9 April	10 May	10 May	17 June	17 June	12 Aug.	12 Aug.
Mesh size (μ)	505	505	333	505	505	505	505	505	505
Tow type	Surface	Surface	Surface	Surface	Oblique	Surface	Oblique	Surface	Oblique
Volume filtered (m^3)	442.0	312.3	320.3	75.1	70.0	53.9	44.1	88.5	57.8
Species or Family									
Eggs									
Citharichthys sp.						5.6	2.3	4.5	8.6
Glyptocephalus zachirus		0.3	0.6						
Microstomus pacificus		1.0	0.3						
Pleuronichthys sp.			1.9	25.3	18.6	7.4	20.4		5.2
Psettichthys melanostictus or *Isopsetta isolepis*	6.6	39.8	0.3	1.3	1.4				
Unidentified		1.3	0.9	4.0	1.4		4.5	12.4	12.1
Total number/100 m^3	6.6	42.4	4.0	30.6	21.4	13.0	27.2	16.9	25.9
Number of species	1	4	5	3	3	2	3	2	3
Larvae									
Clupea harengus pallasi		27.5		1.3	20.0	51.9	31.8		
Spirinchus thaleichthys	0.2								
Osmeridae							65.8	1.1	
Gadus macrocephalus or *Theragra chalcogramma*	1.6	0.3			1.4		2.3		
Brosmophycis marginata								1.1	
Anoplarchus sp.	3.4	199.1							
Chirolophis sp.	3.6	10.1							
Lumpenus sagitta			0.3						
Xiphister atropurpureus		1.0							
Gobiidae				2.7					
Ammodytes hexapterus	17.9	181.7		1.3	1.4				
Sebastes sp.			0.6	2.7	1.4	1.9	2.3	35.0	57.1
Ophiodon elongatus	0.5	8.8	15.9						
Myoxocephalus polyacanthocephalus		0.6							
Cottidae	1.4	0.3			2.8		2.3		

Appendix Table 3H, cont'd

Date Mesh size (μ) Tow type Volume filtered (m^3)	24 Feb. 505 Surface 442.0	21 Mar. 505 Surface 312.3	9 April 333 Surface 320.3	10 May 505 Surface 75.1	10 May 505 Oblique 70.0	17 June 505 Surface 53.9	17 June 505 Oblique 44.1	12 Aug. 505 Surface 88.5	12 Aug. 505 Oblique 57.8
Larvae, cont'd									
Agonus acipenserinus				1.3					
Cyclopteridae							2.3		
Parophrys vetulus					2.9				
Platichthys stellatus					2.9	5.6			
Psettichthys melanostictus							2.3		
Pleuronectidae	0.2			5.3			2.3		
Unidentified		2.0					6.8		
Total number/100 m^3	28.8	431.4	16.8	14.6	32.8	59.4	118.2	37.2	57.1
Number of species	8	10	3	6	7	3	9	3	1

Appendix Table 3I. Lummi Bay bongo net catches (number/100 m^3) during 1976.

Date Mesh size (μ) Tow type Volume filtered (m^3)	20 Feb. 505 Surface 273.5	20 Mar. 505 Surface 197.8	8 April 333 Surface 182.4	15 June 505 Oblique 59.0	16 June 505 Oblique 65.9	16 June 505 Surface 91.4	10 Aug. 505 Surface 83.7	10 Aug. 505 Oblique 58.5
Species or Family								
Eggs								
Engraulis mordax				5.1		7.7		
Citharichthys sp.					25.8	15.3	65.7	
Eopsetta jordani			7.9					
Glyptocephalus zachirus			2.6					
Hippoglossoides elassodon		1.5	7.9					
Pleuronichthys sp.			2.6	1.7		1.1		
Psettichthys melanostictus or *Isopsetta isolepis*	364.1	1312.0	1962.8	5.1	37.9	212.3	11.9	12.0
Unidentified				1.7			8.4	15.4
Total number/100 m^3	364.1	1313.5	1983.8	13.6	63.7	236.4	86.0	27.4
Number of species	1	2	5	4	2	4	3	2
Larvae								
Clupea harengus pallasi		1.5	13.1	11.9	16.7	5.5		
Engraulis mordax						1.1		
Clupea or *Engraulis*						1.1		
Osmeridae			2.6	11.9	4.6	4.4		
Gadus macrocephalus or *Theragra chalcogramma*		2.0	2.6					
Gasterosteus aculeatus							2.4	
Anoplarchus sp.		18.2						
Xiphister atropurpureus		0.5						
Pholis sp.			5.3		1.5			
Gobiidae				1.7	1.5	3.3		
Ammodytes hexapterus		2.5	10.5		1.5			
Sebastes sp.		1.5						
Ophiodon elongatus	0.7							
Leptocottus armatus	1.5	3.0	5.3					
Psychrolutes paradoxus	0.4			1.7				

Appendix Table 3I, cont'd

Date Mesh size (μ) Tow type Volume filtered (m^3)	20 Feb. 505 Surface 273.5	20 Mar. 505 Surface 197.8	8 April 333 Surface 182.4	15 June 505 Oblique 59.0	16 June 505 Oblique 65.9	16 June 505 Surface 91.4	10 Aug. 505 Surface 83.7	10 Aug. 505 Oblique 58.5
Larvae cont'd								
Scorpaenichthys marmoratus		1.0		1.7				
Cottidae		1.0		5.1		1.1		
Agonidae				1.7				
Platichthys stellatus			7.9					
Psettichthys melanostictus				1.7				
Pleuronectidae				1.7				
Unidentified			13.1		1.5	2.2		
Total number/100 m^3	2.6	31.2	60.4	39.1	27.3	18.7	2.4	0
Number of species	3	9	8	9	6	7	1	0

Appendix Table 3J. Padilla Bay bongo net catches (number/100 m^3) during 1976.

Date	16 Feb.	20 Mar.	8 April	12 Apr.
Mesh size (μ)	505	505	333	333
Tow type	Surface	Surface	Surface	Oblique
Volume filtered (m^3)	394.3	273.7	360.9	321.0
Species or Family				
Eggs				
Glyptocephalus zachirus			1.3	
Hippoglossoides elassodon				10.1
Pleuronichthys sp.				2.0
Psettichthys melanostictus or *Isopsetta isolepis*	6.6	24.5	568.2	70.7
Unidentified			2.5	4.0
Total number/100 m^3	6.6	24.5	572.0	86.8
Number of species	1	1	3	4
Larvae				
Clupea harengus pallasi				4.0
Spirinchus thaleichthys	0.8			8.1
Osmeridae			6.3	
Gadus macrocephalus or *Theragra chalcogramma*	0.3	0.7		8.1
Anoplarchus sp.	0.3	3.7	2.5	
Chirolophis sp.	0.3	0.7		
Lumpenus sagitta	0.3			
Xiphister atropurpureus		6.9		
Ammodytes hexapterus	20.5	2.6		4.0
Sebastes sp.		1.1	2.5	24.3
Ophiodon elongatus	0.8	1.8		
Leptocottus armatus	0.5	1.1		
Myoxocephalus polyacanthocephalus		1.1		
Psychrolutes paradoxus				2.0
Scorpaenichthys marmoratus		5.1		
Cottidae		0.4	3.8	12.1
Pleuronectidae			1.3	
Unidentified				4.0
Total number/100 m^3	23.8	25.2	16.4	66.6
Number of species	8	11	5	8

Appendix Table 3K. Westcott Bay bongo net catches (number/100 m^3) during 1976.

Date	24 Feb.	21 Mar.	10 Apr.	9 May	16 June	11 Aug.
Mesh size (µ)	505	505	505	505	505	505
Tow type	Surface	Surface	Surface	Surface	Surface	Surface
Volume filtered (m^3)	252.1	231.9	230.3	61.8	17.4	97.7
<u>Species or Family</u>						
<u>Eggs</u>						
Pleuronichthys sp.				1.6		
Psettichthys melanostictus or *Isopsetta isolepis*	1.2	62.5				
Unidentified	15.4	0.9				
Total number/100 m^3	16.6	63.4	0	1.6	0	0
Number of species	2	2	0	1	0	0
<u>Larvae</u>						
Clupea harengus pallasi	85.3	35.6	1.7	11.3	11.5	
Hypomesus pretiosus	5.9					
Osmeridae			0.4		57.5	
Gadus macrocephalus or *Theragra chalcogramma*		0.4	0.4			
Anoplarchus sp.	1.2	14.3				
Chirolophis sp.	0.8	0.9				
Lumpenus sagitta			3.0			
Xiphister atropurpureus	3.2	5.0				
Gobiidae						1.0
Ammodytes hexapterus	6.3	51.5				
Sebastes sp.			2.2			
Ophiodon elongatus		21.4				
Leptocottus armatus	1.6	0.9				
Myoxocephalus polyacanthocephalus		0.9				
Scorpaenichthys marmoratus	1.6					
Cottidae	0.4		0.4	1.6		
Unidentified					5.7	
Total number /100 m^3	106.3	130.9	8.1	12.9	74.7	1.0
Number of species	9	9	6	2	3	1

APPENDIX 4

Nearshore Fish Food Habits I.R.I. Summary

PERCENTAGE
TOTAL I.R.I.
+ < 1%
✥ 1-5%
○ 6-25%
✚ 26-50%
● 51-75%
■ 76-100%

PREY TAXA

PREDATOR	Algae	Porifera	Cnidaria	Hydroida	Siphonophora	Anthozoa	Ctenophora	Platyhelminthes: Turbellaria	Nemertea	Nematoda	Trematoda: Diogeneidae	Amphineura	Gastropoda	Gastropoda eggs	Gastropoda larvae	Bivalvia	Bivalvia larvae	Bivalvia siphons
Artedius harringtoni				+														
A. lateralis																		
Blepsias cirrhosus FRI																		
" WWSC	+																	
Enophrys bison FRI	●																	
" WWSC	✚																	
Hemilepidotus hemilepidotus	+																	
Icelinus borealis																		
I. tenuis								○					+			✥	+	
Jordania zonope	+								+	+			+		+			+
Leptocottus armatus FRI	+							+	+							+		✚
" WWSC	+									+	+	+	+			+		+
Myoxocephalus FRI																		
polyacanthocephalus WWSC	✚												✚					
Rhamphocottus richardsoni																		
Scorpaenichthys marmoratus FRI																		
" WWSC																		
Eopsetta jordani																		
Lepidopsetta bilineata FRI										+			+			✥		○
WWSC	+									+						✥		+
Parophrys vetulus FRI	+									+			+			✥		○
WWSC			+													+		+
Platichthys stellatus FRI	+							✥					✥			✥		
WWSC										+						+		+
Pleuronichthys coenosus FRI								✥					✥					
" WWSC	○															■		
Psettichthys melanostictus FRI																✥		○
" WWSC																		+
Sebastes brevispinus																		
Anoplopoma fimbria																		

PREDATOR	Polychaeta	Oligochaeta	Sipuncula	Pycnogonida	Cladocera	Ostracoda	Calanoida	Harpacticoida	Harpacticoida eggs	Cyclopoida	Caligoida	Copepoda egg	Leptostraca	Cirripedia	Cirripedia larvae	Mysidacea	Mysidacea larvae
Artedius harringtoni	+						○	✚								✥	
A. lateralis																✚	
Blepsias cirrhosus FRI	+					+											
" WWSC																+	
Enophrys bison FRI																	
" WWSC	○			✥													
Hemilepidotus hemilepidotus																	
Icelinus borealis								○									
I. tenuis	○															+	
Jordania zonope	○							●			+			+	+	+	
Leptocottus armatus FRI	○	+															
" WWSC	✥	+	+		+							+					
Myoxocephalus FRI								✥									
polyacanthocephalus WWSC																	
Rhamphocottus richardsoni								●									
Scorpaenichthys marmoratus FRI																	
" WWSC																	
Eopsetta jordani																	
Lepidopsetta bilineata FRI	○																
WWSC	✥																
Parophrys vetulus FRI	✥					+	+	+								+	
WWSC	○													+			
Platichthys stellatus FRI	✥																
WWSC	✥						+					+		○			
Pleuronichthys coenosus FRI	○																
" WWSC																	
Psettichthys melanostictus FRI	●					✥											
" WWSC	○																
Sebastes brevispinus							●										
Anoplopoma fimbria																	

PREDATOR	Cumacea	Tanaidacea	Isopoda	Asselota	Oniscoidea	Valvifera	Flabellifera	Anthuridea	Epicaridea	Gammaridea	Hyperiidae	Caprellidea	Amphipoda larvae	Euphausiacea	Euphausiacea larvae
Artedius harringtoni		+		+						✥	✥	✥		✥	
A. lateralis										○					
Blepsias cirrhosus FRI		+			✚					●		+			
" WWSC										■					
Enophrys bison FRI										✚					
" WWSC							✥			○					
Hemilepidotus hemilepidotus					✚					+					
Icelinus borealis										○					
I. tenuis	✥	○			✥		+			●		+			
Jordania zonope	+	+		+						○	+				
Leptocottus armatus FRI	+	✥	+		✚	+	+			✥		+			
" WWSC	+	+	○			+	+			●		+			
Myoxocephalus FRI															
polyacanthocephalus WWSC										✚					
Rhamphocottus richardsoni				○						○					
Scorpaenichthys marmoratus FRI					●										
" WWSC															
Eopsetta jordani															
Lepidopsetta bilineata FRI	✥	+			✚		○			○					
WWSC							+			■					
Parophrys vetulus FRI	●	✥	+		+					○					
WWSC	○	+	+							■					
Platichthys stellatus FRI					●			+	✥	✚					
WWSC		✥	✚			+				○					
Pleuronichthys coenosus FRI					✚					○					
" WWSC															
Psettichthys melanostictus FRI	✥	○													
" WWSC	✥	✥				✥				■	+				
Sebastes brevispinus															
Anoplopoma fimbria						✥				○					

PREDATOR	Natantia	Natantia larvae	Reptantia	Reptantia larvae	Insecta	Insecta larvae	Echinoidea	Chaetognatha	Larvacea	Ascidiacea (Tunicates)	Thaliacea	Osteichthys	Osteichthys eggs	Osteichthys larvae	Sticks, wood, organic detritus, etc.	Rocks	n, sample size
Artedius harringtoni	✥		○	○				○				✥					7
A. lateralis	✚																1
Blepsias cirrhosus FRI	✥																20
" WWSC	○											+					10
Enophrys bison FRI			○									○					4
" WWSC					○										✥		6
Hemilepidotus hemilepidotus	✥		✚									○				✥	8
Icelinus borealis			●														1
I. tenuis			+									✥					11
Jordania zonope	✥		○	✥	+		+						+				22
Leptocottus armatus FRI	+		○	✥	+					+		○		+	+	+	51
" WWSC	○		○				+					✥			+	+	91
Myoxocephalus FRI			■														1
polyacanthocephalus WWSC																	1
Rhamphocottus richardsoni					○												1
Scorpaenichthys marmoratus FRI			✚														2
" WWSC	✚		●													○	2
Eopsetta jordani												■					1
Lepidopsetta bilineata FRI			✥									✥					6
WWSC			✥	+						+							10
Parophrys vetulus FRI	+		✥														46
WWSC			+														12
Platichthys stellatus FRI			+									○			+		17
WWSC	✥		+							+					✥		22
Pleuronichthys coenosus FRI	✥											○					3
" WWSC																	1
Psettichthys melanostictus FRI																	1
" WWSC	+																16
Sebastes brevispinus	✥			○				○									1
Anoplopoma fimbria	●		✚														1

Appendix 4. Relative percent contributions to total I.R.I. values of nearshore fish diet items.

PERCENTAGE
TOTAL I.R.I.
+ < 1%
✙ 1-5%
○ 6-25%
✚ 26-50%
● 51-75%
■ 76-100%

PREY TAXA

PREDATOR	Algae	Porifera	Cnidaria	Hydroida	Siphonophora	Anthozoa	Ctenophora	Platyhelminthes: Turbellaria	Nemertea	Nematoda	Trematoda: Diogeneidae	Amphineura	Gastropoda	Gastropoda eggs	Gastropoda larvae	Bivalvia	Bivalvia larvae	Bivalvia siphons	Polychaeta	Oligochaeta	Sipuncula	Pycnogonida
Cymatogaster aggregata FRI													+			+			○			
" WWSC						+										✙						
Embiotoca lateralis FRI																			■			
" WWSC																						
Trichodon trichodon																						
Lumpenus sagitta FRI								+								✚			○			
" WWSC																			✙	■		
Apodichthys flavidus FRI	+									+			+						+			
" WWSC	+												✙									
Pholis laeta FRI	+															+			✙			
" WWSC										+									○			
P. ornata FRI																+			○			
WWSC																			○			
Ammodytes hexapterus FRI																						
" WWSC																						
Sebastes caurinus FRI	+									✙			+						✙			
" WWSC																						
S. emphaeus					+					+												
S. flavidus					+														+			
S. melanops FRI			+		+		+						+									
" WWSC																						
S. nigrocinctus				✙																		
S. ruberrimus										✚												
Hexagrammos decagrammus FRI	✙	+											✙			+		+	✙			
" WWSC										✙									✙			
H. stelleri FRI	+																		✙			
" WWSC	✙																		✙			
Ophiodon elongatus	+				+								+									
Artedius fenestralis FRI										+									+			
" WWSC								+									+	○	+			

PREDATOR	Cladocera	Ostracoda	Calanoida	Harpacticoida	Harpacticoida eggs	Cyclopoida	Caligoida	Copepoda egg	Leptostraca	Cirripedia	Cirripedia larvae	Mysidacea	Mysidacea larvae	Cumacea	Tanaidacea	Isopoda	Asselota	Oniscoidea	Valvifera	Flabellifera	Anthuridea	Epicaridea
Cymatogaster aggregata FRI		+	+		+						+			✚	+	+		+				
" WWSC			✙					+	+							✙			+	+		
Embiotoca lateralis FRI																						
" WWSC																			○			
Trichodon trichodon											✙											
Lumpenus sagitta FRI		+												+	○							
" WWSC																						
Apodichthys flavidus FRI											+				○	+		✚	○	+		
" WWSC																			✙			
Pholis laeta FRI			+	○										+	✙				✙	+		
" WWSC			+							+										+		
P. ornata FRI				○										✙				✚	✙			
WWSC																						
Ammodytes hexapterus FRI			■								+											
" WWSC			○	+				■														
Sebastes caurinus FRI			+							+		○		✙		+			+	✙		
" WWSC																				✙		
S. emphaeus			●									+							+			
S. flavidus	+		✚	+								○							+			
S. melanops FRI			+									+								+		
" WWSC				○																		
S. nigrocinctus																						
S. ruberrimus																						
Hexagrammos decagrammus FRI			+	+											✙	✙	+	○		✙		+
" WWSC																						
H. stelleri FRI												+								+		
" WWSC															+				+			
Ophiodon elongatus																			+			
Artedius fenestralis FRI															✙							
" WWSC				✙											+	✙				✙		

PREDATOR	Gammaridea	Hyperiidae	Caprellidea	Amphipoda larvae	Euphausiacea	Euphausiacea larvae	Natantia	Natantia larvae	Reptantia	Reptantia larvae	Insecta	Insecta larvae	Echinoidea	Chaetognatha	Larvacea	Ascidiacea (Tunicates)	Thaliacea	Osteichthys	Osteichthys eggs	Osteichthys larvae	Sticks, wood, organic detritus, etc.	Rocks	n, sample size
Cymatogaster aggregata FRI	✚		○						+	+								+					31
" WWSC	■						+																51
Embiotoca lateralis FRI																							1
" WWSC	■		+				✙		○														6
Trichodon trichodon	+						+			○								●					8
Lumpenus sagitta FRI	○		+	+																	+		12
" WWSC	○																						3
Apodichthys flavidus FRI	✚		+				✙					+									+	+	15
" WWSC	■																						3
Pholis laeta FRI	■		+				+			+								+					12
" WWSC	■	✙								✙													11
P. ornata FRI	✚																						4
WWSC	■																						1
Ammodytes hexapterus FRI	○	+						+													✙		11
" WWSC	✙									+													8
Sebastes caurinus FRI	✚		+		+		○		✙							+		○		+		✙	21
" WWSC	✚						✚			○								○					4
S. emphaeus	+	○			+		+		✙	○				○				+		+			11
S. flavidus	+	✙			✙		+		+	○				○				○		✙			15
S. melanops FRI	+	■	+		+		+		✙	✙	+			+				○		+	+	✙	19
" WWSC	✙						■																3
S. nigrocinctus									■														1
S. ruberrimus							●																1
Hexagrammos decagrammus FRI	✚		+	✙	+				○				○					✙			✙	○	31
" WWSC	●																	✚					2
H. stelleri FRI	●						○		○									✙					13
" WWSC	●				+		✚		○												+		13
Ophiodon elongatus																+		■					12
Artedius fenestralis FRI	■								+													+	6
" WWSC	○						○		+													+	15

Appendix 4. Relative percent contributions to total I.R.I. values of nearshore fish diet items, cont'd.

PERCENTAGE
TOTAL I.R.I.
\+ < 1%
✙ 1-5%
○ 6-25%
✚ 26-50%
● 51-75%
■ 76-100%

PREY TAXA

PREDATOR	Algae	Porifera	Cnidaria	Hydroida	Siphonophora	Anthozoa	Ctenophora	Platyhelminthes: Turbellaria	Nemertea	Nematoda	Trematoda: Diogeneidae	Amphineura	Gastropoda	Gastropoda eggs	Gastropoda larvae	Bivalvia	Bivalvia larvae	Bivalvia siphons	Polychaeta	Oligochaeta	Sipuncula	Pycnogonida	Cladocera	Ostracoda	Calanoida	Harpacticoida	Harpacticoida eggs	Cyclopoida	Caligoida	Copepoda egg	Leptostraca	Cirripedia	Cirripedia larvae	Mysidacea	Mysidacea larvae	Cumacea	Tanaidacea	Isopoda	Asselota	Oniscoidea	Valvifera	Flabellifera	Anthuridea	Epicaridea	Gammaridea	Hyperiidae	Caprellidea	Amphipoda larvae	Euphausiacea	Euphausiacea larvae	Natantia	Natantia larvae	Reptantia	Reptantia larvae	Insecta	Insecta larvae	Echinoidea	Chaetognatha	Larvacea	Ascidiacea (Tunicates)	Thaliacea	Osteichthys	Osteichthys eggs	Osteichthys larvae	Sticks, wood, organic detritus, etc.	Rocks	n, sample size
Squalus acanthias FRI													○																							✙			+			+			✚								○									○					8
" WWSC																			○																										■																						1
Hydrolagus colliei								○			+		✙			✙			✙						+												+	○		+		+			○	○					+		○									○				○	8
Clupea harengus pallasi FRI	+		+					+			+		+			+			+					✙	■	+		+		+			+	○	+						+				✙		+		+			+	+	+					+			+		+			115
" WWSC																			+		+			+	+	■				+						+		+		+	+	+			✙	+	+				+	○							+							+	81
Engraulis mordax											+		✙												○	○							✙			+									✙				✙			✙		○	○							✚		○			31
Oncorhynchus gorbuscha											+			+					+			+		+	✚	○							○	+		○		+							○	✙	+						+	+	✙							+	+				38
O. keta FRI								+			+													+	■	✙							+	+		✙	+				+				✙	○	+	+	✙			+	+	+	+							+					34
" WWSC																										○										○									■																						2
O. kisutch								+		+									+					+	+									+		+	+	+		●		+			○	+			+		✙		+	✙	○							○		+			149
O. nerka FRI																									✙	+							+												✙	✙			✚		+	✚	+	✙	+							○					39
" WWSC							✙																		○									+								+			●	+													○								6
O. tschawytscha FRI								+		+	○										+			+	+	+						+		+		✙	+			+									+		+			✚	○							○		+	+		131
" WWSC												✙									+																				+				✙		+							■	○												13
Salmo gairdneri																																		●																				✚													1
Salvelinus malma																								✙																					✙								■		○												1
Hypomesus pretiosus FRI							+	+			+								+					+	○	+							✙	+		○	+	+		✚	+				+	+	+		+	+	+	+	+	+	+				○			+	+	+		+	56
" WWSC										○									+					+	○	○								+		+		+							○	+	✚				+	✙	+						✚			+	✙		+	✙	42
Spirinchus thaleichthys FRI																									✚									○	+										+	✙								✚													3
" WWSC																																													✙										■												1
Gadus macrocephalus																																													■																						1
Microgadus proximus FRI																																				+	✙								●						○		+									✚					3
" WWSC																			+						○	+								+		✙	+	+			+	+			✚				+		✚		✙	+								+			+		46
Theragra chalcogramma FRI																																								○													■														1
" WWSC																			+						✙													✙			○	+			●	✙			+		✙																20
Lycodes palearis																		✙	○	○																	✚								○																						1
Aulorhynchus flavidus FRI										+									○					+	+													+							■		+							+										+			8
" WWSC																									✚	✚								✙											○				✙																		6
Gasterosteus aculeatus FRI								✙											✙						○	●														+					+	+	+		○										+								14
" WWSC											○									+				+	+	○						+				✙	+								●		+							✙					+								15

Appendix 4. Relative percent contributions to total I.R.I. values of nearshore fish diet items, cont'd.

PERCENTAGE
TOTAL I.R.I.
+ < 1%
✙ 1-5%
○ 6-25%
✚ 26-50%
● 51-75%
■ 76-100%

PREY TAXA

PREDATOR	Algae	Porifera	Cnidaria	Hydroida	Siphonophora	Anthozoa	Ctenophora	Platyhelminthes:	Turbellaria	Nemertea	Nematoda	Trematoda: Diogeneidae	Amphineura	Gastropoda	Gastropoda eggs	Gastropoda larvae	Bivalvia	Bivalvia larvae	Bivalvia siphons	Polychaeta	Oligochaeta	Sipuncula	Pycnogonida	Cladocera	Ostracoda	Calanoida	Harpacticoida	Harpacticoida eggs	Cyclopoida	Caligoida	Copepoda egg	Leptostraca	Cirripedia	Cirripedia larvae	Mysidacea	Mysidacea larvae	Cumacea	Tanaidacea	Isopoda	Asselota	Oniscoidea	Valvifera	Flabellifera	Anthuridea	Epicaridea	Gammaridea	Hyperiidae	Caprellidea	Amphipoda larvae	Euphausiacea	Euphausiacea larvae	Natantia	Natantia larvae	Reptantia	Reptantia larvae	Insecta	Insecta larvae	Echinoidea	Chaetognatha	Larvacea	Ascidiacea (Tunicates)	Thaliacea	Osteichthys	Osteichthys eggs	Osteichthys larvae	Sticks, wood, organic detritus, etc.	Rocks	n, sample size
Dasycottus setiger																																							○													●		✚														✙	1
Syngnathus griseolineatus WWSC																																							■							○																						2
Rhacochilus vacca WWSC														+			○														+		+									●				✙								○														8
Phytichthys chirus WWSC																																														■																						1
Artedius meanyi WWSC														✙																													●			✚								○														2
Clinocottus embryum WWSC																											○																			■																						2
Agonus acipenserinus WWSC																				+							○										✚	+								✚						✚																4
Eumicrotremus orbis WWSC																																					+		✙			✙				●	✚	✙																		+		3
Liparis florae WWSC																				✚																						○				✚						✙																4
Hippoglossoides elassodon WWSC																	○			●																	○	+					○			○									+													1

Appendix 4. Relative percent contributions to total I.R.I. values of nearshore fish diet items, cont'd.

APPENDIX 5

Epibenthic Plankton Data

Appendix 5. Percent composition of epibenthic plankton sampled at four nearshore habitats on west cost of San Juan Island, March through September 1976.

	Hydroida	Anthozoa	Turbellaria	Nematoda	Nemertea	Trematoda	Gastropoda	Bivalvia	Polychaeta	Oligochaeta	Ostracoda	Calanoida	Harpacticoida	Cyclopoida	Copepoda eggs	Leptostraca	Cirripedia	Cirripedia larvae	Mysidacea	Cumacea	Tanaidacea	Isopoda	Asselota	Valvifera	Flabellifera	Gammaridea	Hyperiidae	Caprellidea	Amphipoda eggs	Natantia	Reptantia	Crustacea larvae	Insecta	Echinodermata	Chaetognatha	Osteichthys eggs	Branchiura
Westcott Bay 3 March 1976 505μ:		0.05		3.94			0.17	0.34	10.61		2.52	60.39	12.54					0.10	0.10	0.93	3.67		0.51			2.86		0.05			0.02	0.85		0.10	0.24		
209μ:				0.63							0.63		96.84												0.63	0.63						0.63					
30 May 1976 505μ:	0.19			0.37			4.28		3.54			16.57	47.30					0.19	2.79	1.86	2.05		0.74		0.63	0.63			12.10	0.19		1.31		0.19			
209μ:				17.04					1.12		7.40	21.08	47.53					2.91		0.22	0.22					0.22						2.24					
Deadman Bay 3 March 1976 505μ:	0.25		0.02		0.02		0.36	0.04	0.32	0.02	0.11	15.05	60.80	0.29					0.51	0.40	0.02	0.13		0.02	0.04	18.60			2.48	0.34	0.06	0.04			0.06		
209μ:				1.06			0.21		0.42		0.85	28.94	60.00					2.55		2.34						1.28					0.85	1.49					
30 May 1976 505μ:				0.52			29.48	0.39	1.56		0.52	10.39	15.06	0.78				0.39	0.13	0.78	0.65	2.60				26.88	0.13	0.13	4.29	0.78	0.13	2.08	0.39	1.43		0.52	
209μ:				0.68			0.34		0.34		7.88	12.33	42.81		1.37		5.82	15.41		1.03	0.34					1.37						9.59	1.02				
8 September 1976 505μ:				0.48			19.08	0.72	4.35			1.24	3.14						2.17	10.39		1.21				48.79			0.97	6.77	0.48		0.24				
209μ:				2.70		0.06			0.12		0.63	0.35	94.42		0.17			0.06		0.12			0.06			1.09						0.23					
Eagle Cove 3 March 1976 505μ:				0.56			4.76		0.12		0.12	60.82	2.10	3.28				0.06		0.93		0.12		0.12		22.50			1.42			0.31			2.72		0.66
209μ:									2.94		2.94	61.76	2.94							17.65						2.94						8.82					
13 June 1976 505μ:				0.28			47.17		0.85			12.46	0.71	0.14					0.57	7.65		0.42				21.67			6.23	0.85		0.85				0.14	
209μ:							2.37		0.43	0.22	0.65	17.24	52.80					14.44		0.43						2.88						8.66					
8 September 1976 505μ:				9.70			0.12	1.56	5.08		0.29	3.46	16.92			0.06		0.06	0.06	26.45	0.06	2.42	0.06			32.96			0.52	0.17		0.06					
209μ:				13.58					0.23		1.16	1.96	70.65					0.06		0.23												12.13					
South Beach 3 March 1976 505μ:							1.60	8.66	0.84		0.08	63.75	1.77					0.08		0.08	0.08	0.38				12.53			3.45			4.04				0.03	
13 June 1976 505μ:				0.15			78.48					0.54	0.38							2.48		0.15				14.39		1.08		2.07	0.15	0.15					
209μ:							2.52		0.84			21.01	36.13	12.61				0.84		4.20						1.68						16.81				0.84	