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TROPHIC RELATIONSHIPS OF OUTMIGRATING CHUM  
SALMON IN HOOD CANAL, WASHINGTON, 1977

by

Charles A. Simenstad and William J. Kinney

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October 1, 1977-March 31, 1978  
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Prepared for

Washington State Department of Fisheries  
115 General Administration Building  
Olympia, Washington 98504

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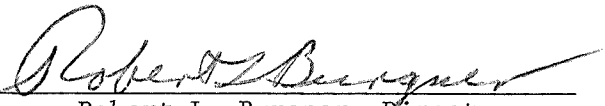
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Robert L. Burgner, Director  
Fisheries Research Institute

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## INTRODUCTION

Hood Canal, a fjord-like extension of northern Puget Sound, provides one of the most important passageways and nursery areas for chum salmon, *Oncorhynchus keta*, in Washington State, accounting for approximately a quarter of the State's total chum return (Fiscus 1969, Morrill 1974). A significant proportion of Hood Canal's chum salmon stocks originate from hatcheries; in 1977 the three major hatcheries (Quilcene, U.S. Fish and Wildlife (USF&W); Hoodspout and George Adams, Washington State Department of Fisheries (WDF)) released a total of 20 million chum fry. More important, proposed chum salmon enhancement destined for Hood Canal by the WDF includes fry releases to result in harvest of an additional 2 million returning adults.

Estimates of marine survival rates for chum salmon range widely, from 0.02 to 2.8 percent (Koski 1975) but little or nothing is known about the component variables determining the overall survival to return. It is becoming increasingly apparent, however, that the period of early marine residence, from entry into estuary to oceanic migration, is a critical stage, especially as related to the availability of optimum food resources (Wickett 1958, Mason 1974, Healey et al. 1976). Shallow sublittoral epibenthic organisms (e.g., harpacticoid copepods, gammarid amphipods, cumaceans, mysids) have generally been shown to be the principal food organisms of juvenile chum salmon (Kaczynski et al. 1973, Feller and Kaczynski 1975, Simenstad 1977, Schreiner et al. 1977) during their first 2 to 3 months (< 55 mm in total length) of outmigration. Chum fry may in fact selectively feed upon harpacticoids during a specific period in their ontogeny and residence in the estuary, despite an

abundance of alternative prey organisms. Predation by juvenile chums during this time may, in fact, be intense enough to depress local harpacticoid populations (Feller and Kaczynski 1975). Healey and Sibert (Pacific Biological Station (PBS), Nanaimo, British Columbia, personal communication) have documented highly specific predation by chum fry in the Nanaimo River estuary, where the chum fry fed principally upon one species of harpacticoid (a different species in different years) until these copepod populations declined to the point that the chum fry left the estuary. Upon attaining a certain size ( $> 55$  mm) the outmigrating chums move into the neritic zone farther offshore, there feeding upon larger, planktonic organisms such as calanoid copepods, hyperiid amphipods, larvaceans and fish larvae (Simenstad 1977, Schreiner et al. 1977). It would appear that these juvenile salmonids have evolved an early life history period in the shallow sublittoral environs which, until they have acquired a more advantageous size, provide high abundances of preferred epibenthic prey (Feller and Kaczynski 1975) and refuge from predation (Parker 1971).

One significant problem associated with interpreting the feeding behavior of chum salmon during their early estuarine residence is the general lack of information on the relative availability of epibenthic prey organisms. Core samples and epibenthic sleds either do not sample the true epibenthos or are difficult to use in the shallow sublittoral region. Feller and Kaczynski (1975) have provided one of the few comparisons between juvenile chum stomach contents and quantitative epibenthic prey sampled with a suction pump. Their data, though encompassing a limited time series, indicated positive electivity for smaller fractions

of harpacticoid copepods than were represented in the prey community. Possible relationships between such selective behavior and residence times and survival prompted us to conduct more detailed sampling throughout the period of chum fry outmigration through Hood Canal.

Since 1976 Fisheries Research Institute (FRI) investigators have been monitoring the outmigration of juvenile chum salmon in the vicinity of the U.S. Navy's Trident submarine base, presently under construction in northern Hood Canal (Schreiner et al. 1977, Snyder and Bax, in press). One aspect of these studies was to examine the trophic dynamics of juvenile salmonids as they passed through the shoreline area affected by construction activities (e.g., dredging) and placement of pier structures. Documentation of the prey community available to the juvenile salmon was considered a necessary component of these studies if we were to properly interpret alterations in food habits as the salmon fry migrated through the study area. The role of other juvenile salmonids and nearshore fish as predators was also considered an important aspect of these studies.

Preliminary plankton pump sampling was conducted during 1976 to test the feasibility of quantifying the abundance of epibenthic prey organisms. The plankton pump system was originally developed for sampling nearshore zooplankton in the Aleutian Islands (Burgner et al. 1969) and had been adapted for epibenthic sampling during nearshore fish community studies in northern Puget Sound (Miller et al. 1977). The system design as used in the initial Hood Canal investigations was described in a 1976 fish food habits workshop (Simenstad 1977), and was subsequently modified to reduce contamination from plankton outside the immediate sampling area. The following paper describes the results of the 1977

studies, comparing the taxonomic and size composition and relative abundance of epibenthic plankton with the prey organisms of juvenile chum salmon during the period of their migration through northern Hood Canal. Potential competition and predation by other salmonids and marine fishes are also discussed.

We thank the WDF Research and Development Division, especially Drs. Rick Cardwell and Chuck Wolke, and the U.S. Navy's OICC Trident for their cooperative support of these studies. Dr. Ernest O. Salo (Principal Investigator), Bruce Snyder and the staff of the Big Beef Research Station provided valuable support, facilities and guidance. Jeff Cordell assisted in the sample analysis.

## MATERIALS AND METHODS

### Predator Collection

Juvenile chum salmon and associated fishes were collected at or just offshore of four beaches in the vicinity of the Bangor Annex area of Hood Canal (Fig. 1) by a 36.6-m floating beach seine with a 0.6-cm mesh bag, and a surface trawl (towsnet) which had a 3- x 6-m net opening and mesh sizes grading from 76 mm at the opening to 6 mm at the bag. The net was towed at approximately 3 feet/second behind two diesel-powered boats for 10 minutes/sample, as close to shore as possible.

Chum samples of three to five fish were injected with and preserved whole in 10 percent buffered formalin at the time of capture.

### Stomach Analysis

Stomach contents were identified and enumerated at Big Beef Creek Station, using a systematic, standardized procedure which provides the

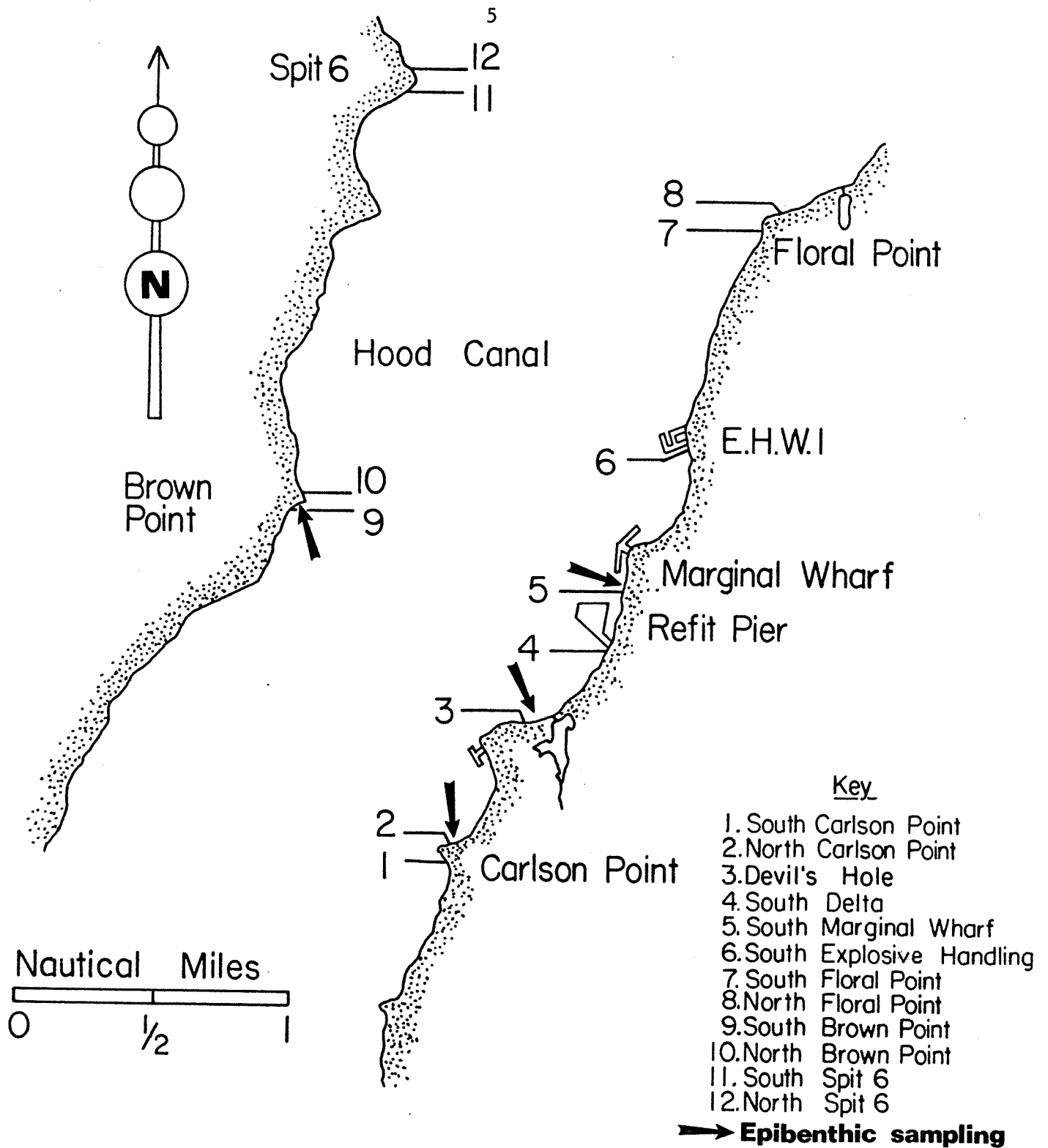


Fig. 1. Beach seine sampling stations for shoreline salmonid out-migration studies January through July 1977, in Hood Canal, Washington.

numerical and gravimetric composition of prey organisms contained in the stomach, the degree of fullness of the stomach, and the state of digestion of its contents.

#### Epibenthic Prey Collection

Shallow, sublittoral epifauna at the four sites was sampled in replicate using a suction-pump system. The pump system (Fig. 2) consisted of a self-priming, gasoline-powered, 5.1-cm (2-inch) centrifugal pump which drew water and associated planktors through a 25.4-cm (10-inch) conical expander into a 5.1-cm flexible plastic hose. Once through the pump, the water sample passed through a sealed-register, totalizing flowmeter into a double stainless steel cylinder in which two nested, conical nets were suspended. The nets were of 505- $\mu$  mesh sizes with area/aspect ratios of 1:2.5 and 1:5.3, respectively. The epibenthic organisms were retained in standard net buckets with window screen of appropriate mesh size.

The pumping system was operated from a 26-foot whaleboat maneuvered to stations at approximately the -1 foot tidal line and anchored. SCUBA equipped divers randomly placed a 1-m<sup>2</sup> round sampling cylinder on the substrate, then proceeded to "vacuum" the area within by moving the expander cone systematically 10 cm above the surface of the benthos, this distance maintained by a ring (which did contact the substrate) extended from the expander zone. Two nested nets were dropped into place within the sampling tank and removed after 378.5 liters (100 gallons) had been filtered. Organisms retained in the nets were removed and preserved in 5 percent buffered seawater formalin in labeled PVC

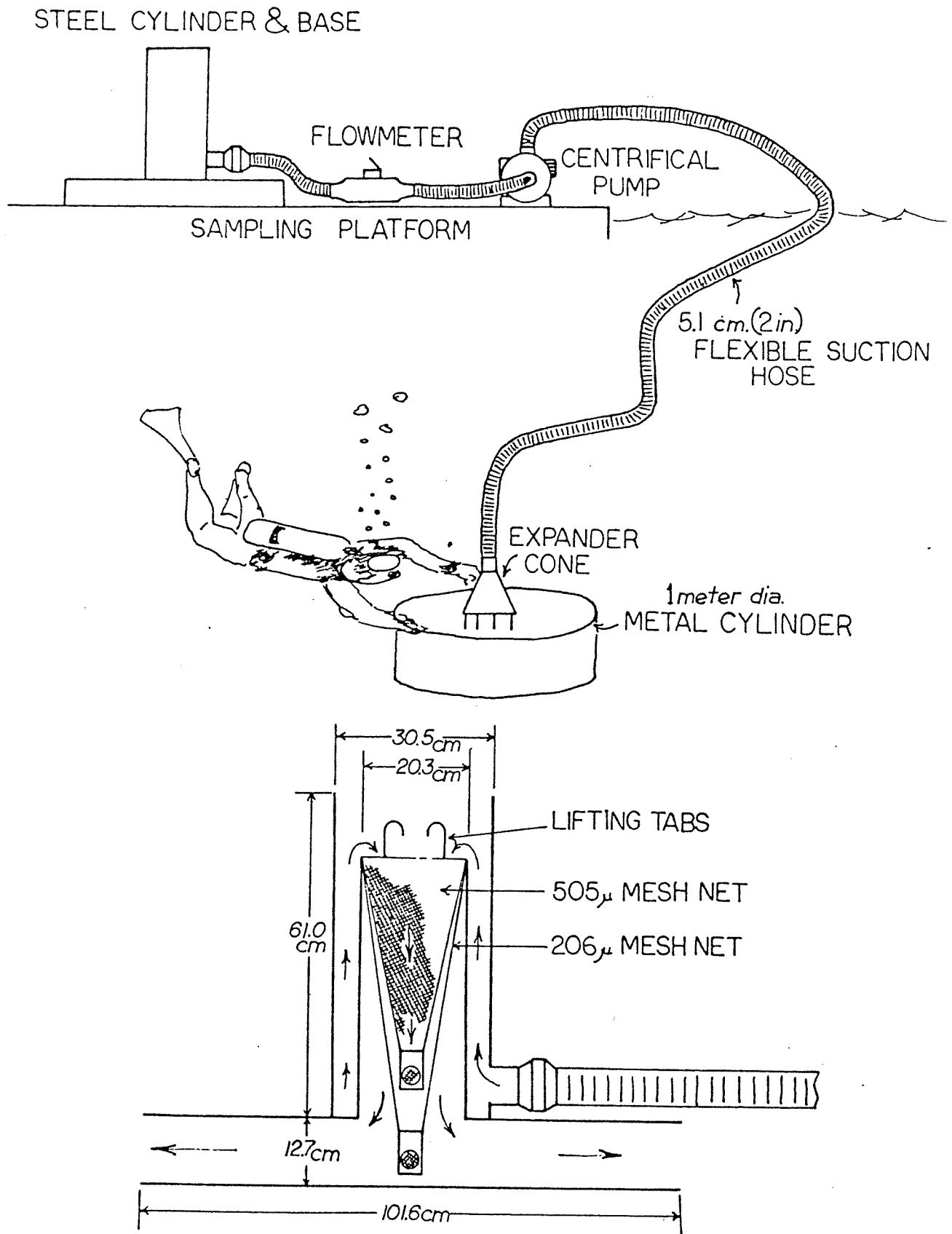


Fig. 2. Overall system design and construction detail of epibenthic pump sampling system.

jars. The sampling process was performed twice at each site after replacement of the sampling cylinder upon nearby, similar substrate.

#### Laboratory Analysis

After 2 days of fixation, epibenthic samples were rinsed, transferred with field tags to vials, and preserved with 37 percent isopropanol, with 8 percent glycerol. The smaller (209- $\mu$ ) fractions were also dyed with Rose Bengal.

The 505- $\mu$  fractions of each replicate were completely identified and enumerated. Gammarid amphipods and the remainder of this fraction were rinsed with isopropanol and water to remove glycerol, and dried at 70° C for 24 hours, then weighed separately to 0.001 g on a top-loading Mettler balance. The two weights were combined to form the total sample weight.

The 206- $\mu$  fractions of each replicate required panning to remove sand, and subsampling to accommodate the very large numbers of organisms. Subsampling was found to be most consistent when using a stoppered, 10-cc glass syringe with a 2-mm orifice, and a 250-cc flask. Into the flask was placed the sample and preservative to the 200-cc level. When settled, the syringe was inserted and slowly filled with the fluid. The fluid was then forcibly expelled back into the flask to agitate the sample, and one of five 2-cc subsamples was quickly withdrawn.

Identification of epibenthic organisms was taken as far as possible, given time constraints and the present state of the taxonomic literature. Samples of gammarid amphipods were identified by Helmut Koch, Western Washington University. Some harpacticoid copepod samples were identified by Beverly Kask, PBS, Nanaimo, British Columbia.

Laboratory results were recorded on MESA/EDS format forms, which included prey code, life history state, count, wet weight, total contents weight and remarks. These raw results were processed statistically.

Approximately 100 specimens of gammarid amphipods and harpacticoid copepods from selected epibenthic and chum salmon samples were lengthed, in order to determine the size-frequency of these abundant taxa utilized by juvenile salmonids. Total length minus antennae and setae was measured to the nearest 0.1 mm on amphipods, and to the nearest 0.025 mm on harpacticoids. Each measurement was made using a dissecting microscope with a calibrated reticle micrometer.

#### Trophic Diagrams

In the presentation of the food habit data, a modification of Pinkas et al. (1971) "Index of Relative Importance" (IRI) was used to rank the importance of prey organisms. The IRI values for prey taxa are displayed both graphically and in tabular form where justified by sample size ( $n > 10$ ). The three-axis IRI graphs illustrate frequency of occurrence (the proportion of stomachs containing a specific prey organism) plotted sequentially on the horizontal axis, and percentage of total abundance and percentage of total biomass plotted above and below the horizontal axis, respectively (Fig. 3). Prey taxa in differing stages of digestion (e.g., partly digested shrimp, "Natantia-unidentified," as opposed to family, "Pandalidae," or species, "*Pandalus borealis*") are graphed separately.

All prey groups, including those assigned to a broad taxonomic level (family, order, class) because of advanced digestion, have been arranged from left to right by decreasing frequency of occurrence.

The IRI value was computed as follows:

$$\text{IRI} = \% \text{ frequency of occurrence}_i \left[ \% \text{ numerical composition}_i + \% \text{ gravimetric composition}_i \right]$$

and is equivalent to the area encompassed by the bar for each prey category  $i$  composing the IRI diagrams. In order to compare the IRI values between prey spectra with different sample sizes, the overall importance of general prey taxa (e.g., all shrimp, including "unidentified Natantia" and those identified to family and species, added together) has been discussed as a percentage of the total combined IRI (areas) of the different prey taxa. Table 1 illustrates an example of the IRI values and percentages of total IRI generated from the data diagrammed in Fig. 3. The advantage of the IRI value is that numerically rare but high biomass prey (e.g., prey<sub>8</sub>, Fig. 3), infrequently occurring but abundant or high biomass (when eaten) taxa, and numerically abundant or frequently occurring taxa (but which contribute little in the way of trophic input, e.g., prey<sub>1</sub>, Fig. 3) do not dominate the more representative prey.

## RESULTS

### Epibenthic Plankton Community

Forty-five major taxa of epibenthic organisms were represented in the plankton pump collections (Table 2). The most diversely represented groups included the harpacticoid copepods, polychaete annelids, gammarid amphipods, shrimp and bivalves.

Between December 30, 1976 and July 22, 1977 the abundance of epibenthic organisms varied between a minimum of  $7,625.0 \pm 2,322.1/1,000$  liters

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM

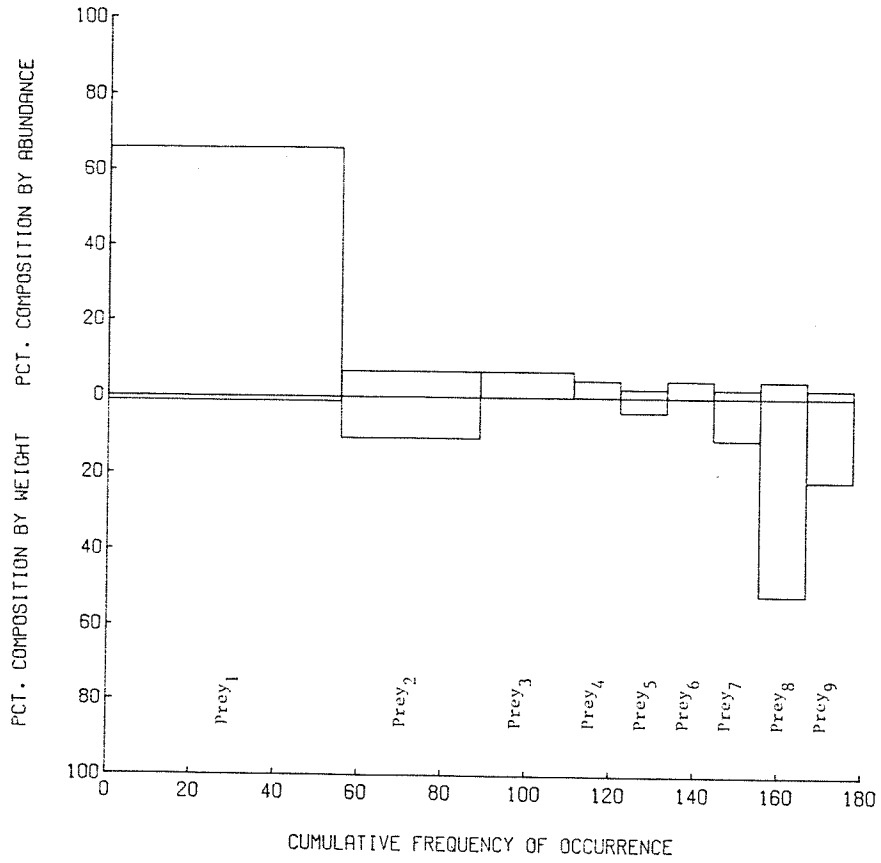


Fig. 3. Example IRI (Index of Relative Importance) diagram.

Table 1. Example computation of IRI values and percentages of total IRI from data illustrated in Fig. 3.

Prey Category	% Freq. of occurrence	% Numerical composition	% Gravimetric composition	Prey IRI	% Total IRI
1	55.56	65.91	1.22	3729.5	65.76
2	33.33	6.82	10.69	583.7	10.29
3	22.22	6.82	0.04	152.5	2.69
4	11.11	4.55	< 0.01	50.5	0.89
5	11.11	2.27	3.84	67.9	1.20
6	11.11	4.55	0.12	51.8	0.91
7	11.11	2.27	10.89	146.3	2.58
8	11.11	4.55	51.67	624.6	11.01
9	11.11	2.27	21.52	264.4	4.66

Table 2. Taxa of Epibenthic Organisms Collected in Shallow Sublittoral Zone of Northern Hood Canal, Washington, 1977. A = adult, J = juvenile, L = larvae, U = unknown.

Species	Life History Stages
Platyhelminthes	A,
Nemertea	A, J
Polychaeta	A, J, L
Polynoidae	A, J
Phyllodocidae	A, J
<i>Anaitides</i> sp.	A
<i>Eteone longa</i>	A
<i>Ophiodromus pugettensis</i>	A
Pillargiidae	U
Syllidae	A, J
<i>Exogone</i> sp.	
Nereidae	A, J
<i>Nereis</i> sp.	A
<i>Platynereis bicanaliculata</i>	A
<i>Hemipodus borealis</i>	A
Spionidae	A
Cirratulidae	A
<i>Armandia brevis</i>	A
Serpulidae	J
Oligochaeta	A
Tubificidae	A
Gastropoda	L, U
Prosobranchia	J, L
Acmaeidae	J
<i>Margarites pupillus</i>	J
<i>Lirularia lirulatus</i>	J
<i>Lacuna</i> sp.	A, J, L
<i>Littorina</i> sp.	J
<i>Alvinia</i> sp.	A
<i>Barleeia</i> sp.	A
<i>Thais</i> sp.	J

Table 2. Continued.

Species	Life History Stages
Opisthobranchia	J
Cephalaspidea	A, J
Sacoglossa	A, J
<i>Olea hansineensis</i>	A, J
Nudibranchia	A, J
<i>Melibe leonina</i>	J
Bivalvia	A, J
Mytilidae	J
<i>Mytilus edulis</i>	J
<i>Modiolus</i> sp.	J
<i>M. rectus</i>	J
<i>Turtonia minuta</i>	A
<i>Pododesmus</i> sp.	J
Veneroida	J
<i>Kellia</i> sp.	J
<i>Mysella tumida</i>	A
<i>Clinocardium nuttalli</i>	J
<i>Transennella tantilla</i>	A
<i>Protothaca staminea</i>	J
Halicaridae	A, J
Pycnogonida	U
Crustacea	J, L, U
Lightiellidae	A, J
Cladocera	
Myodocopa	A
Podocopa	A, J
Calanoida	A, J, L
<i>Calanus plumchrus</i>	A
<i>Scaphocalanus</i> sp.	U
<i>Acartia clausi</i>	A

Table 2. Continued.

Species	Life History Stages
Harpacticoida	A, J, L
Tegastidae	A
Porcellidiidae	A
Canuellidae	
<i>Scottolana canadensis</i>	
Ectinosomidae	A
Harpacticidae	A
<i>Zaus</i> sp.	A, J
<i>Harpacticus</i> sp.	A, J
Tisbidae	A
<i>Tisbe</i> sp.	A
Tachidiidae	A
<i>Microarthridion littorale</i>	A
Ameiridae	A
Diosaccidae	A
<i>Amonardia</i> sp. ( <i>purtubata</i> ?)	A
<i>Amphiascopsis</i> sp.	
<i>A. cinctus</i>	A
<i>Amphiascus</i> sp.	
<i>Diosaccus spinatus</i>	
Canthocamptidae	A
Thalestridae	A
<i>Dactylopodia</i> sp.	A
<i>Diarthrodes</i> sp.	A
<i>Parathalestris</i> sp.	A
<i>P. californica</i>	
Laophontidae	A
Cyclopoida	A
<i>Corycaeus</i> sp.	A
<i>Oithona</i> sp.	A
Caligoida	A
<i>Argulus</i> sp.	J

Table 2. Continued.

Species	Life History Stages
Balanomorpha	A, J, L
Balanidae	J
<i>Balanus</i> sp.	A
<i>Nebalia bipes</i>	A
<i>N. pugettensis</i>	A
Mysidae	A, J
<i>Acanthomysis</i> sp.	A
<i>A. macropsis</i>	A
<i>Mysis</i> sp.	A
Cumacea	A, J
<i>Lamprops</i> sp.	A, J
<i>Cumella</i> sp.	A, J
Tanaidacea	A, J
Tanaidae	A
<i>Leptochelia dubia</i>	A, J
Sphaeromatidae	A, J
<i>Gnorimosphaeroma oregonensis</i>	A, J
<i>Exosphaeroma media</i>	A, J
Valvifera	A, J
<i>Idotea</i> sp.	A, J
Asellota	A, J
<i>Munna ubiquita</i>	A, J, L
Epicaridea	A
Cryptoniscidae	A
Bopyridae	J
Gammaridea	A, J, L
<i>Allorchestes augustus</i>	A
<i>Ampithoe</i> sp.	J
<i>Aoroides columbiae</i>	A
<i>Anisogammarus pugettensis</i>	A
<i>Pontogeneia</i> sp.	A, J

Table 2. Continued.

Species	Life History Stages
Calliopidae	A
<i>Calliopiella pratti</i>	A, J
<i>Calliopi</i> sp.	A, J
Isaeidae	A
<i>Podoceropsis</i> sp.	A
<i>Paraphoxus spinosus</i>	A
<i>Photis brevipes</i>	A
<i>Synchelidium shoemakeri</i>	A
Hyperiidea	A, J
Caprellidea	A, J
<i>Tritella</i> sp.	A
<i>Caprella</i> sp.	A, J
Euphausiacea	J
Decapoda	L
Natantia	J, L
Hippolytidae	J
Pandalidae	J
<i>Pandalus</i> sp.	J
Crangonidae	A, J
<i>Crangon</i> sp.	J
Callianassidae	J
Paguridae	J
Majidae	L
Cancridea	L
Pinnotheridae	A, L
Collembola-Arthropleona	J, L
Diptera	A
Cheilostomata-Ascophora	A
<i>Barentisia</i> sp.	A, J
Ophiuroida	A, J
Holothuroidea	A
Chaetognatha	J

Table 2. Continued.

Species	Life History Stages
Urochordata	J
Teleostei	L
Unidentified	J, L

\* Notes: In some cases, larval designation includes eggs.

occurring on February 17, and a maximum of  $99,344 \pm 15,020.4/1,000$  liters occurring on April 21. The average density over the 27-week period was  $28,902.0 \pm 28,399.6/1,000$  liters (Fig. 4). The numerically prevalent organisms were harpacticoid copepods, followed by (in decreasing order of overall percent composition) gammarid amphipods, crustacean eggs, ostracods, calanoid copepods, asselotan isopods, nematodes, barnacle nauplii and cyprides, prosobranch larvae, juvenile shrimp and cumaceans (Table 3). Of the harpacticoid copepods, the prevalent species were *Harpacticus* sp., *Amphiascopsis cinctus*, and a species of the family Laophontidae (Table 4); the most common gammarids were an undescribed *Pontogeneia* sp., *Calliopius* sp., *Calliopiella pratti* (?) and *Anisogammarus pugettensis* (Table 5).

Densities of epibenthic organisms at the three principal sampling sites followed a similar seasonal trend (Fig. 5), all showing maximum densities occurring from mid-April to early May. Harpacticoid copepod densities tended to be more variable; Devil's Hole delta typically had the highest densities and Carlson Point showed more frequent and extreme fluctuations than the other sites (Fig. 6). Gammarid amphipod densities varied considerably between sites, especially at Brown Point (Fig. 7). Specific taxa composition was quite variable for the dominant harpacticoids occurring at three sites (Table 4) with different genera or species predominating at each of the three sites. Percent composition of gammarids occurring at Brown Point over time (Table 5) illustrated one species, the undescribed *Pontogeneia* sp., to predominate and three other species to vary in their relative importance.

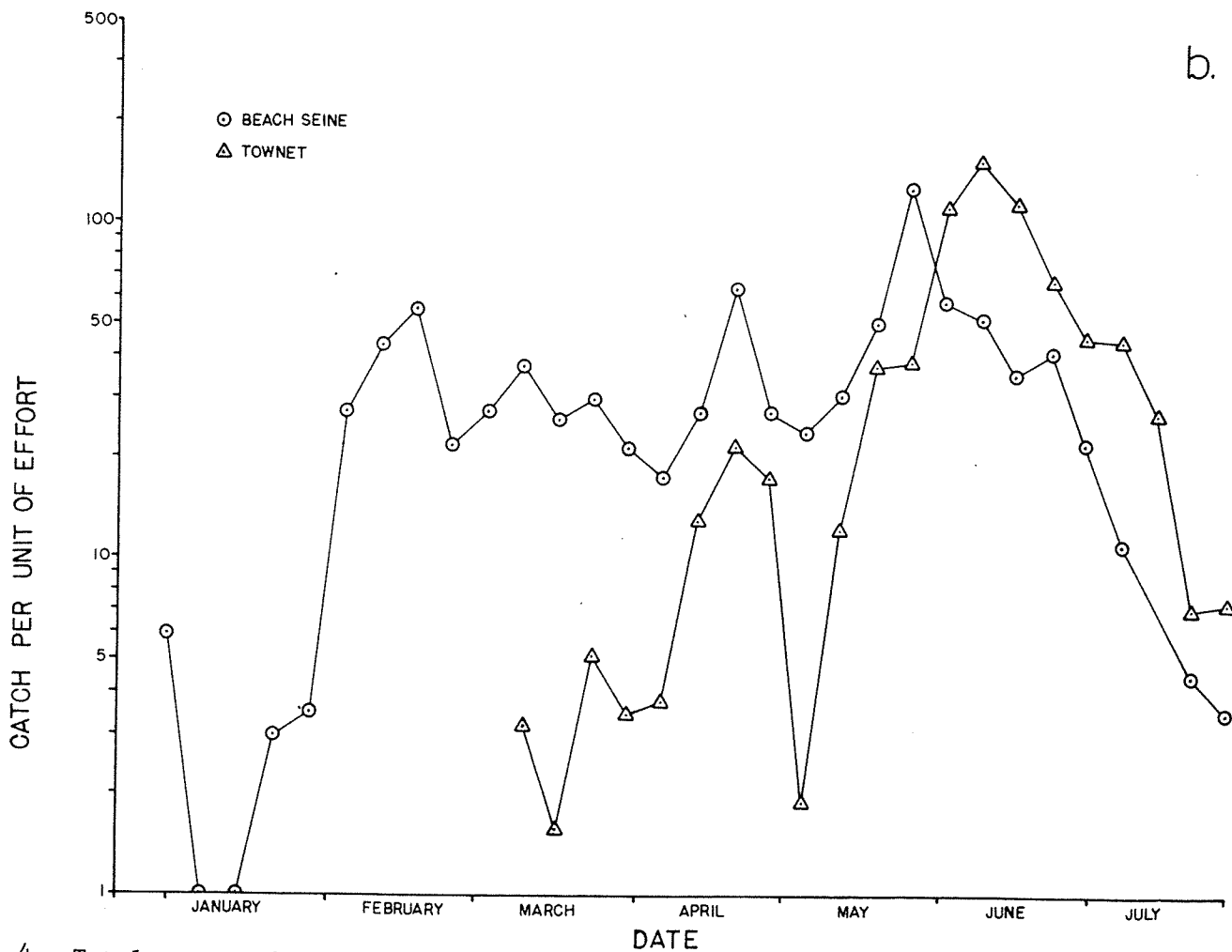
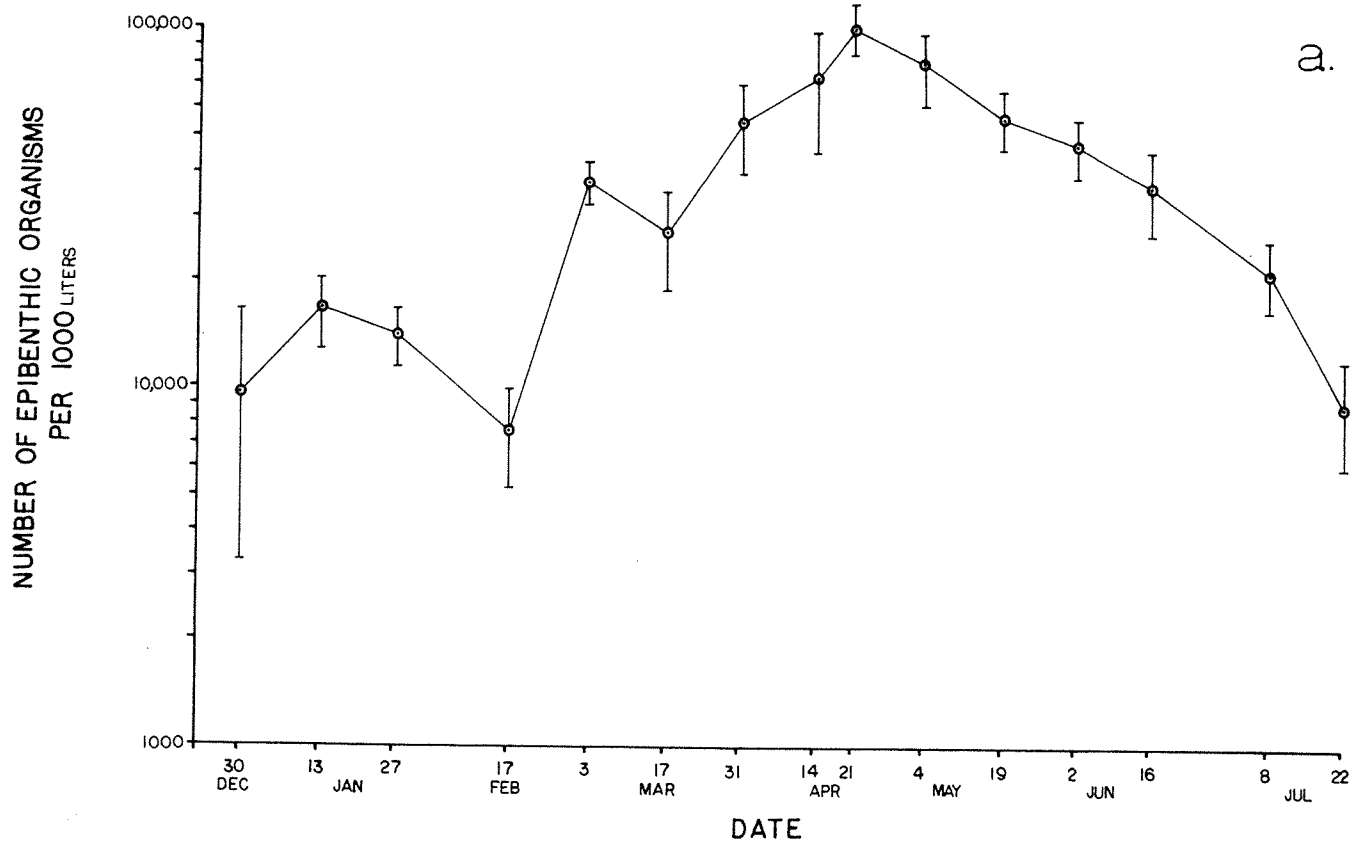


Fig. 4. Total mean number of shallow sublittoral epibenthic organisms per 1000 liters (a) and catch-per-unit-of effort of chum salmon (b) in Hood Canal, Washington, 1977. Bars represent  $\pm 1$  S.D.

Table 3. Relative quantitative composition and life history stages of epibenthic plankton samples, expressed as sum of mean number/1000 liters, at three shallow sublittoral sites, Hood Canal, Washington, December 30, 1976 through July 22, 1977.

Major Taxonomic Groups	Life History Stages				$\bar{x}$ no's/kl	$\Sigma \bar{x}$ no's/kl	$\bar{x}$ no's/kl	$\Sigma \bar{x}$ no's/kl
	Larvae	Juv.	Adult	Juv. or Ad.				
					Brown Pt.	Carlson Pt.	Devil's Hole	Three Sites Combined
Hydroida			x			4.3		1.5
Platyhelminthes			x			.2	1.4	.4
Nemertea		x	x				1.5	.5
Nematoda			x		693.5	697.7	651.6	682.0
Polychaeta*		x	x		81.1	150.0	98.6	111.0
Polynoidae		x	x		23.8	85.1	26.6	46.5
Phyllodocidae		x	x		2.1	5.2	5.7	4.5
Hesionidae			x				.1	.0
Pillargiidae				x		1.7		.6
Syllidae		x	x		18.0	2.5	38.1	18.7
Nereidae		x	x		.2	1.8	3.2	1.7
Glyceridae			x		.1			.0
Spionidae			x	x	7.2	8.6	12.8	9.4
Cirratulidae			x				.1	.0
Ophediidae			x	x	.2		.2	.2
Serpulidae		x					1.3	.4
Oligochaeta			x	x	12.3	3.9	5.4	7.2
Tubificidae			x	x	3.0	.7	4.5	2.6
Gastropoda*	x	x			10.4	14.4	11.1	11.9
Prosobranchia*	x	x			103.6	236.5	165.5	168.2
Acmaeidae		x				.1	5.7	1.8
Trochidae		x				.2		.1
Lacunidae	x	x	x		134.8	161.0	246.5	178.9
Littorinidae		x					.2	.1
Rissiodae			x	x	.8	1.3	.8	1.0
Thaididae		x				.1		.0
Opisthobranchia*		x		x	2.1	23.7		10.2
Cephalaspidea		x	x				.3	.1
Sacoglossa		x	x		.4	25.3	14.7	13.7
Nudibranchia		x	x		1.0	.1	40.1	12.8
Bivalvia*		x	x		18.2	12.5	13.1	14.6
Mytilidae		x			.6	7.3	4.4	4.2
Pinnidae			x				2.3	.7
Anomiidae				x			.3	.1
Veneroidea		x		x	11.3	2.8	.1	4.3
Kelliidae		x				.1		.0
Montacutidae			x		.4	.5	1.0	.7
Cardiidae		x			.3	.1	.5	.3
Veneridae		x	x		.6		2.2	.9
Halicardae		x	x		29.2	89.5	185.8	99.2
Pycnogonida				x	1.8		2.8	1.5

Table 3. continued

Major Taxonomic Groups	Life History Stages				$\bar{x}$ no's/kl	$\Sigma \bar{x}$ no's/kl	$\bar{x}$ no's/kl	$\Sigma \bar{x}$ no's/kl	
	Larvae	Juv.	Adult	Juv. or Ad.					
					Brown Pt.	Carlson Pt.	Devil's Hole	Three Sites Combined	
Crustacea*	x	x			3.8	39.6	25.2	23.2	
Lightiellidae		x	x			.6		.2	
Cladocera			x				1.4	.4	
Ostracoda		x	x		2,017.2	1,064.5	2,608.3	1,861.1	
Copepoda*	x	x	x		1,052.5	221.4	251.8	507.9	
Calanoida	x	x	x		1,005.5	1,021.8	1,350.4	1,117.3	
Harpacticoida	x	x	x		24,818.1	16,625.5	34,585.3	24,190.9	
Cyclopoida			x		9.1	23.0	25.9	19.3	
Argulidae		x				1.7		.6	
Balanomorpha	x	x	x		437.0	780.5	439.7	560.3	
Nebaliidae			x	x	.2	1.9		.7	
Mysidae		x	x		29.2	4.8	1.3	11.9	
Cumacea*		x	x		52.7	13.6	65.1	46.0	
Lampropidae					100.7	34.7	197.1	107.0	
Nannastasidae					129.7	53.4	396.1	185.1	
Tanaidacea		x	x		35.1	29.2	595.8	207.4	
Isopoda									
Sphaeromatidae		x	x		51.0	342.2	61.1	157.8	
Valvifera					.5	8.6	.9	3.4	
Asellota	x	x	x		126.9	677.9	1,397.6	717.7	
Epicaridae		x	x		10.0	45.1	30.9	28.9	
Gammaridae	x	x	x		1,438.6	4,135.9	2,353.5	2,683.6	
Hyperiididae		x	x		16.4	13.9	.1	10.4	
Caprellidae		x	x		10.8	132.4	85.0	77.1	
Euphausiacea		x					6.4	2.0	
Decapoda*	x	x			8.0	38.6	20.2	22.7	
Hippolytidae		x		x	2.2	15.9	8.7	9.1	
Pandalidae		x			.4	.4	3.4	1.4	
Crangonidae		x	x		8.0	1.7	1.0	3.5	
Callianassidae		x			.1			.0	
Paguridae		x					.4	.1	
Majidae	x				.1	.2		.1	
Cancridae	x				.4	.1		.2	
Pinnotheridae	x				1.8	.1	.2	.7	
Insecta	x	x	x		3.0	2.3	6.3	3.7	
Ectoprota			x			1.0		.4	
Entoprota			x			.3		.1	
Ophiuroidea		x	x		2.8	1.0	6.7	3.2	
Holothuroidea		x	x			6.1	4.7	3.6	
Chaetognatha		x			.1			.0	
Urochordata		x				1.1		.4	
Teleostei	x					.9	.2	.3	
Unidentified				x	61.5	534.8	210.8	276.5	
*Unidentified beyond these groups, yet do not necessarily indicate groups other than those listed.					$\bar{x}$ ABUNDANCE	34,644.0	34,340.2	50,187.0	39,359.6

Table 4. Harpacticoid copepods identified from four epibenthic plankton samples. Percent composition in parentheses.

Date	March 17		April 21		April 21		May 19		June 16	
	Brown Pt.	North Carlson Pt.	Devil's Hole Delta	Brown Pt.	Devil's Hole Delta	Brown Pt.	Brown Pt.	Brown Pt.	Brown Pt.	Brown Pt.
Family Harpacticidae										
<i>Harpacticus</i> sp.	15 (36)	3 (5)	1 (2)	35 (69)	11 (24)	18 (37)	57 (92)			
<i>Zaus</i> sp.	1 (2)	4 (7)	1 (2)	8 (16)	4 (9)	9 (18)				
copepodites	4 (10)			1 (2)		1 (2)	3 (5)			
Family Diosaccidae										
<i>Amphiascoides</i> sp.	2 (5)			1 (2)	1 (2)		1 (2)			
<i>A. cinctus</i>		5 (9)	18 (35)							
<i>Amphiascus</i> sp.	2 (5)		2 (4)							
<i>Diosaceus spinatus</i>		3 (5)								
<i>Amonardia</i> sp. (probably <i>pertubata</i> )			1 (2)		8 (17)	3 (6)				
unidentified										
Family Tisbidae										
<i>Tisbe</i> sp.	3 (7)	11 (20)	3 (6)	2 (4)	2 (4)	8 (16)				
copepodites				1 (2)						
Family Thalestridae										
<i>Parathalestris californica</i>	1 (2)					1 (2)				
<i>P.</i> sp.		2 (4)								
<i>Dactylopodia</i> sp.		8 (15)	8 (16)		3 (7)	1 (2)				
<i>Diarthrodes</i> sp.		1 (2)	6 (12)	1 (2)		2 (4)				
Family Ameiridae										
<i>Nitocera</i> sp.	1 (2)						1 (2)			
Family Laophontidae	1 (2)	14 (25)	1 (2)			1 (2)				
Family Ectinosomidae		1 (2)	3 (6)	2 (4)	16 (35)	1 (2)				
Family Canuellidae										
<i>Scottolana canadensis</i>			1 (2)							
Thalestridae										
<i>Microarthridian littorale</i>					1 (2)					
unidentified copepodites	12 (29)	3 (5)	6 (12)			4 (8)				

Table 5. Percent composition of epibenthic gammarid amphipods at Brown Point, Hood Canal, Washington, from 17 March - 22 July, 1977.

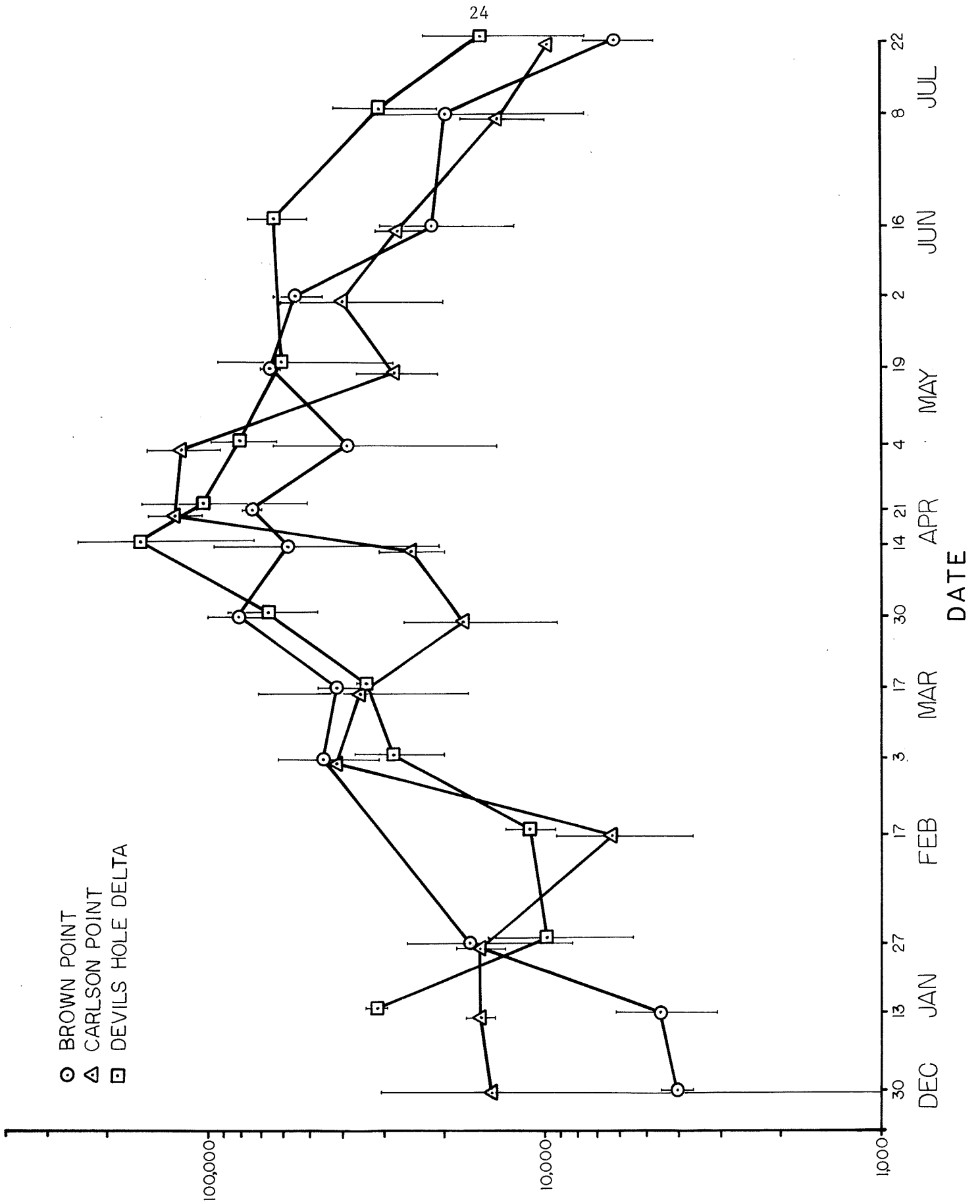
BROWN POINT GAMMARID AMPHIPODS

SPECIES	P.P. #'s	% COMPOSITION												TOTAL NUMBER MAR-JULY	TOTAL %
		6	7	8	9	10	11	12	13	14	15	22	78		
DATE		17	31	14	21	4	19	2	13	8	8	22			
SUBSAMPLE SIZE, N		61	61	54	56	35	56	58	15	60	78				
<u>ALLORCHESIES AUGUSTUS</u>						6						9	15	1	
<u>AMPITHOE SP.</u>									7				7	1	
<u>ACROIDES COLUMBIAE</u>		2					9	9	7				27	3	
<u>ANISOGAMMARUS PUGETTENSIS</u>		16	5	7	46	6	4		13			5	102	10	
<u>PONTOGENEIA SP. (UNDESCRIBED)</u>		67	85	93	36	11	61	74	27	95	31		580	58	
<u>CALLIOPIIDAE</u>															
<u>CALLIOPIELLA PRATTI (?)</u>		5	7		18	57	14	2		5	4		112	11	
<u>CALLIOPIUS SP.</u>		12				20	7		33		51		123	12	
<u>ISAEIDAE</u>							4						4	.4	
<u>PODOCEROPSIS SP.</u>								16	7				23	2	
<u>PARAPHOXUS SPINOSUS</u>							2						2	.2	
<u>PHOTIS BREVIPES</u>									7				7	1	
<u>SYNCHELIDIUM SHOEMAKERI</u>													2	.2	
													<u>2</u>		
													1004		

MEAN TOTAL

NUMBER OF ORGANISMS PER 1000 LITERS

- BROWN POINT
- △ CARLSON POINT
- DEVILS HOLE DELTA



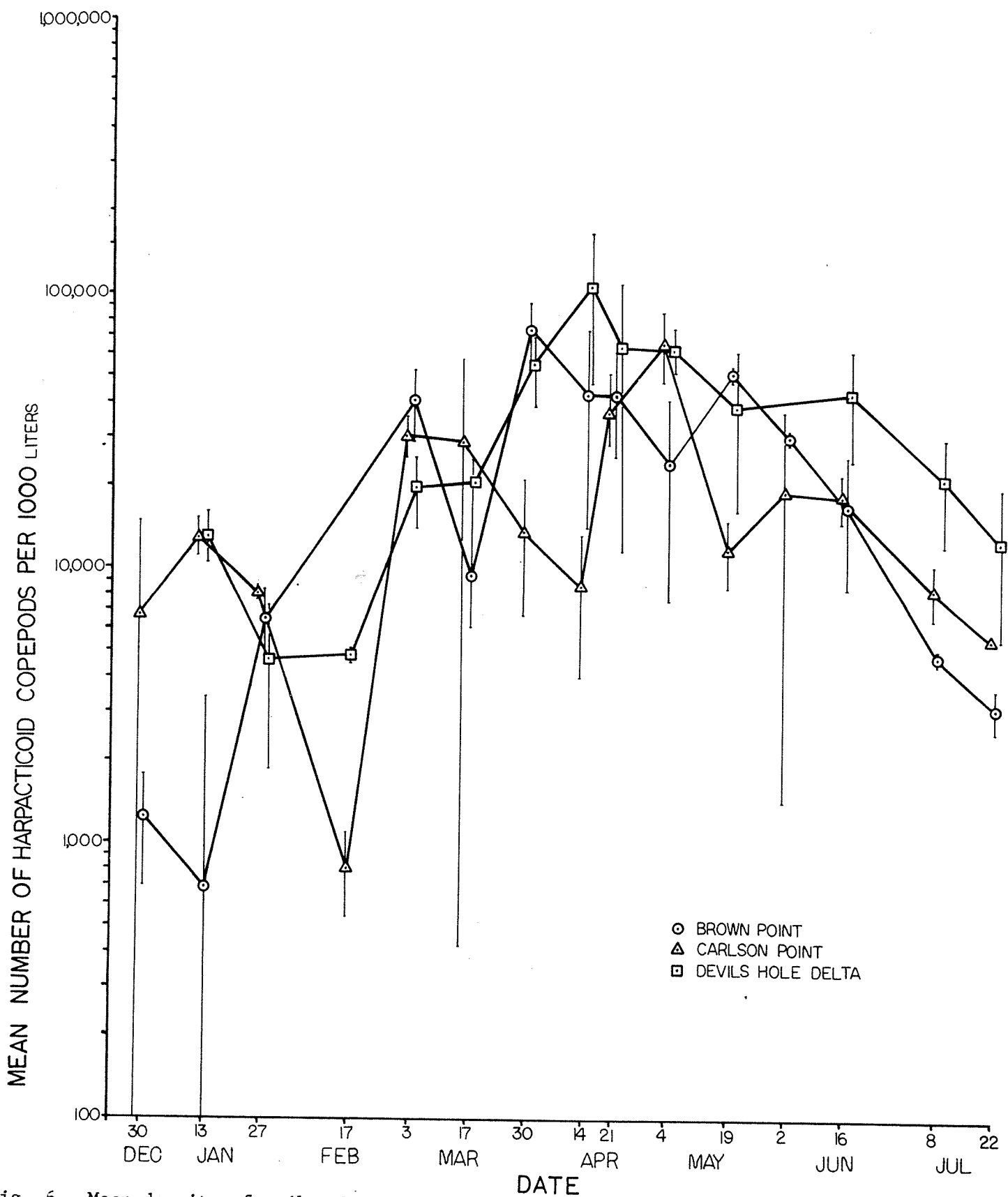


Fig. 6. Mean density of epibenthic harpacticoid copepods at three sites, Hood Canal, Washington, in 1977.

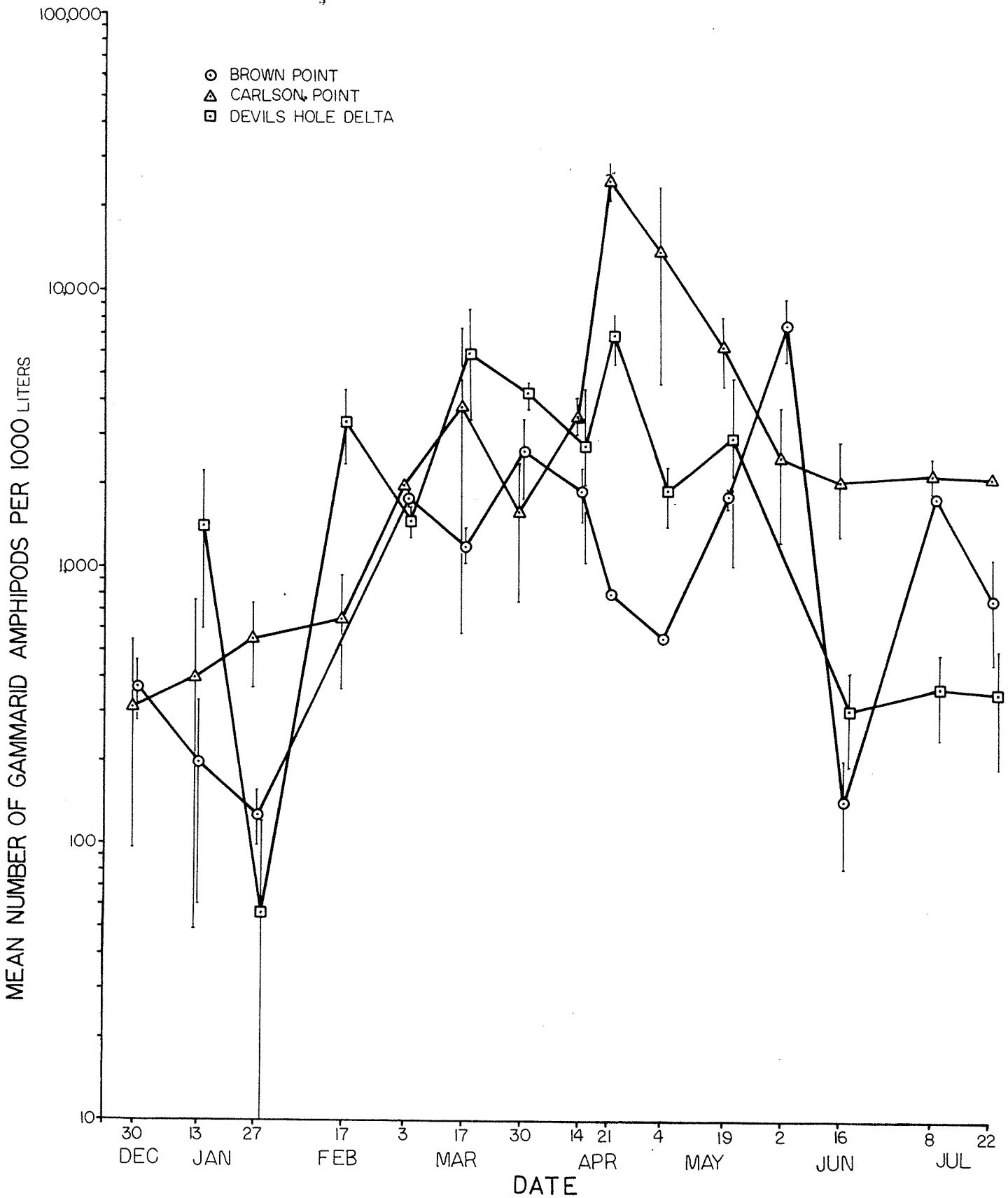


Fig. 7. Mean density of epibenthic gammarid amphipods at three sites, Hood Canal, Washington, in 1977.

The dominant organism taxa also showed some differences between the three sites (Table 4). While Devil's Hole delta's epibenthic community typically had higher densities of most taxa, Brown Point tended to have higher densities of veneroid bivalves, general copepods, mysids and crangonid shrimps, and Carlson Point had significantly more polychaetes (principally polynoids), prosobranch larvae, unidentified crustacean larvae, barnacle larvae, spaeromatid, valviferan and epicaridean isopods, gammarid and caprellid amphipods, hippolytid shrimp, and holothurians.

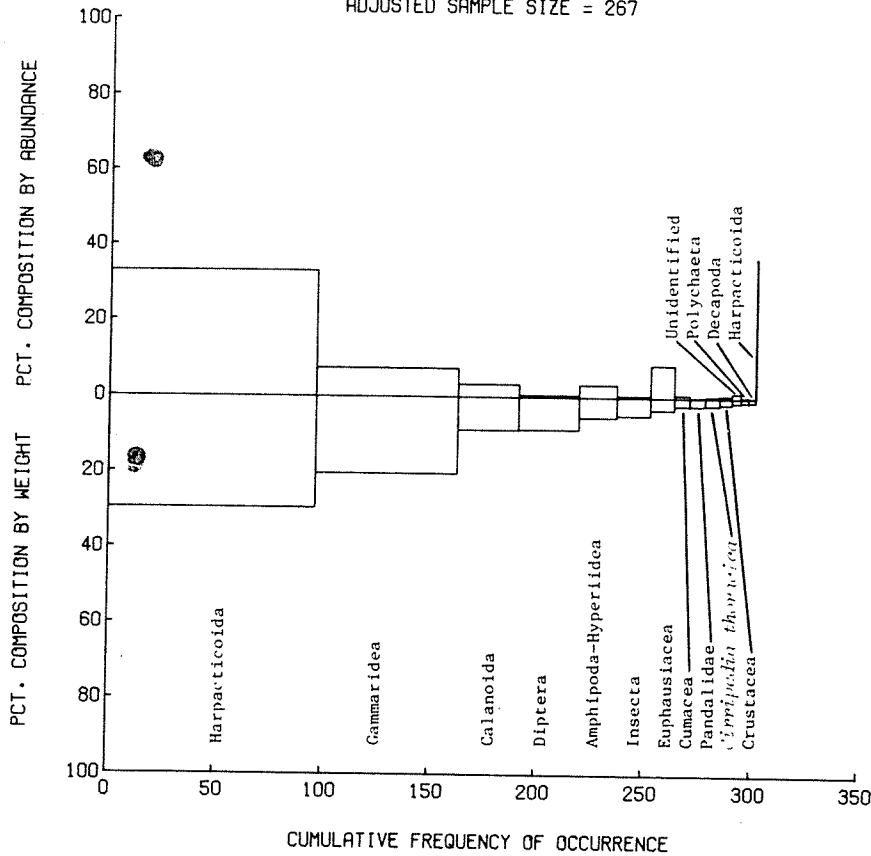
#### Prey Composition of Juvenile Chum Salmon

Chum salmon captured in shallow sublittoral habitats with the beach seine had fed predominantly upon harpacticoid copepods and gammarid amphipods; calanoid copepods, insects, hyperiid amphipods, and euphausiids were of secondary importance (Fig. 8). Harpacticoid copepods and gammarid amphipods predominated throughout the outmigration period except during mid-May when a pulse of euphausiids, calanoid copepods and hyperiids appeared in the prey spectra.

The stomachs of chum fry captured in neritic waters by townet contained both epibenthic and nearshore prey organisms--harpacticoid copepods, gammarid amphipods, crustacean larvae and insects--and pelagic forms--euphausiids, calanoid copepods and hyperiid amphipods (Fig. 9). Even though they were captured offshore, the stomachs of chum fry caught in the townet contained mostly epibenthic organisms until early May, when prey composition shifted dramatically to pelagic organisms; euphausiids predominated in June, eventually tapering off with the appearance of calanoid copepods, and in late June, hyperiid amphipods predominated.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCCHUM, STATION BCHSN

875010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 267



INDEX OF RELATIVE IMPORTANCE (I.R.I.) TABLE  
USING FILEID= HCCHUM, STATION= BCHSN FOR PLOT  
\*\*\*\*\*

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	95.88	33.10	29.53	6004.4	67.18
GAMMARIDEA	66.29	7.50	20.42	1850.5	20.70
CALANOIDA	28.46	3.32	8.77	344.0	3.85
DIPTERA	28.09	.55	8.65	258.4	2.89
AMPHIPODA-HYPERIIDEA	17.60	3.25	5.42	152.6	1.71
INSECTA	15.73	.47	4.84	83.6	.93
EUPHAUSIACEA	10.86	8.47	3.34	128.3	1.44
CUMACEA	7.12	.72	2.19	20.7	.23
PANDALIDAE	7.12	.14	2.19	16.6	.19
CIRRIPEDIA THORACICA	6.74	.39	2.08	16.7	.19
CRUSTACEA	5.62	.67	1.73	13.5	.15
UNIDENTIFIED	4.12	1.28	1.27	10.5	.12
POLYCHAETA	3.37	.30	1.04	4.5	.05
DECAPODA	3.37	.16	1.04	4.0	.05
HARPACTICOIDA	.37	36.77	.12	13.8	.15

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

DIVERSITY INDICES BASED ON FRACTION OF TOTAL IRI --  
PERCENT DOMINANCE INDEX .50  
SHANNON-WEINER DIVERSITY 1.56  
EVENNESS INDEX .30

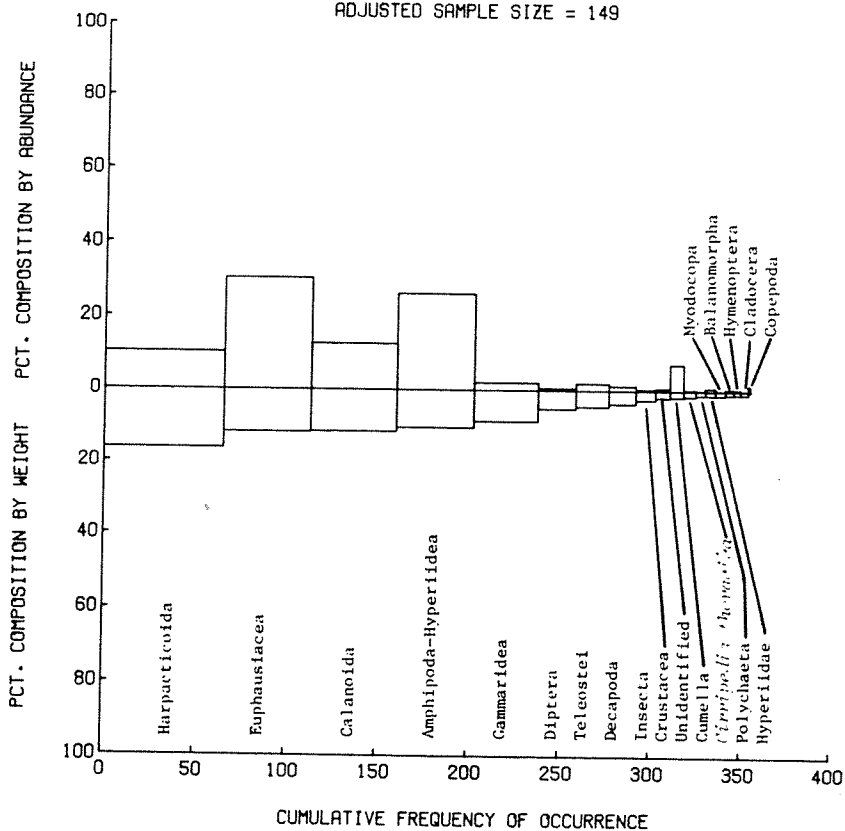
Fig. 8. IRI (Index of Relative Importance) diagram showing prey spectra of chum salmon fry captured by beach seine in shallow sublittoral habitats of Hood Canal, Washington, in 1977.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCCHUM, STATION TOWN

8755010202 - ONCORHYNCHUS KETA

CHUM SALMON

ADJUSTED SAMPLE SIZE = 149



INDEX OF RELATIVE IMPORTANCE (I.R.I.) TABLE  
USING FILEID= HCCHUM, STATION= TOWN FOR PLOT

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	65.10	10.1A	16.30	1724.1	23.52
EUPHAUSIACEA	47.65	30.30	11.93	2012.6	27.46
CALANOIDA	46.98	12.53	11.76	1141.4	15.57
AMPHIPODA-HYPERIIDEA	42.28	26.23	10.59	1556.7	21.24
GAMMARIDEA	34.90	2.04	8.74	376.1	5.13
DIPTERA	20.81	.63	5.21	121.5	1.66
TELEOSTEI	18.12	1.93	4.54	117.3	1.60
DECAPODA	14.77	1.25	3.70	73.0	1.00
INSECTA	10.74	.41	2.69	33.3	.45
CRUSTACEA	8.05	.69	2.02	21.8	.30
UNIDENTIFIED	7.38	7.19	1.85	66.7	.91
CUMELLA	6.71	.29	1.68	13.2	.18
CIRRIPIEDIA THORACICA	5.37	.20	1.34	8.3	.11
POLYCHAETA	5.37	.77	1.34	11.3	.15
HYPERIIDAE	5.37	.09	1.34	7.7	.11
MYODOCOPA	4.70	.47	1.18	7.8	.11
BALANOMORPHA	4.03	.37	1.01	5.6	.08
HYMENOPTERA	4.03	.06	1.01	4.3	.06
CLADOCERA	.67	1.49	.17	1.1	.02
COPEPODA	.67	1.30	.17	1.0	.01

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

DIVERSITY INDICES BASED ON FRACTION OF TOTAL IRI --  
PERCENT DOMINANCE INDEX .20  
SHANNON-WIENER DIVERSITY 2.62  
EVENNESS INDEX .45

Fig. 9. IRI (Index of Relative Importance) diagram showing prey spectra of chum salmon fry captured by townet in neritic habitats of Hood Canal, Washington, in 1977.

Incomplete weight measurements of prey organisms have caused the percent composition by weight in IRI graphs to reflect inaccurate values based on negligible prey weights.

Harpacticoid copepods dominated the IRI prey spectra for beach seine-caught chum fry at all sites (Table 6, Appendix Fig. 12g). Gammarid amphipods usually ranked second in importance except at Devil's Hole delta (Appendix Fig. 1b) where euphausiids ranked higher; at Marginal Wharf (Appendix Fig. 1d), where calanoid copepods and hyperiid amphipods were more important; and at the Explosives Handling Wharf (EHW) site (Appendix Fig. 1e) where dipteran insects were prevalent.

Prey composition of townet caught-chum fry was more variable from site to site (Table 6, Appendix Fig. 2a-d) than for beach seine-captured chums. Harpacticoid copepods, hyperiid amphipods, euphausiids and calanoid copepods were the predominant prey of chum fry in neritic waters adjacent to Carlson Point (Appendix Fig. 2a); the same prey taxa predominated in chum fry at Devil's Hole delta but euphausiids were more important (Appendix Fig. 2b). The prey spectra from Brown Point (Appendix Fig. 2c) were less diverse than from any other site and were dominated by euphausiids (87 percent of total IRI). Harpacticoid and calanoid copepods and hyperiid amphipods were the prevalent organisms composing the prey spectra from Marginal Wharf.

#### Prey Composition of Other Salmonids

Juvenile coho and chinook salmon were often caught in association with the outmigrating chum fry; juvenile pink salmon were not common because of the lack of a significant adult return to Hood Canal in even-numbered years. Searun cutthroat and rainbow (steelhead) trout were

Table 6. Dominant prey organisms, expressed as percent of total IRI, composing prey spectra of juvenile chum salmon at different sites in northern Hood Canal, Washington, in 1977.

<u>Beach seine</u>	Harpacticoid copepods	Gammarid amphipods	Insects	Calanoid copepods	Euphausiids	Hyperiid amphipods	Cumaceans	Shrimp	Barnacle larvae	Decapod larvae
Carlson Point	67.1	23.6	3.8	1.7	0.5	0.5	0.1	0.1		
Devils Hole Delta	57.5	13.5	2.5	9.6	13.1	2.6	0.1	0.2		
Brown Point	58.5	30.3	3.8	1.7	1.3	0.6	1.7	0.6		
Marginal Wharf	67.3	6.2	3.8	11.4	0.7	8.9	0.0	0.0		
EHW	74.4	7.6	10.7	3.1	0.0	2.7	0.2	1.1		
Spit 6	54.2	43.5	0.4	0.8	0.0	0.0	0.0	0.2		
Floral Point	59.1	32.7	5.2	0.6	0.0	0.3	0.3	0.0		
<u>Townet</u>										
Carlson Point	37.6	5.9	3.0	10.6	12.6	21.0	0.4	0.1	2.4	0.4
Devils Hole Delta	11.9	2.7	2.6	19.5	38.2	19.6	0.0	0.0	0.1	1.0
Brown Point	5.7	2.9	0.8	1.2	87.0	1.2	0.1	0.1	0.3	0.0
Marginal Wharf	29.8	7.9	2.9	27.6	5.5	18.5	0.0	0.1	0.4	0.6

also captured during the beach seining and tow-netting collections. In order to determine the significance of their predation upon chum fry, only specimens > 100 mm in length were chosen for stomach content analysis (Appendix Table 1).

Coho juveniles (length  $\bar{x}$  = 122.4 mm) had fed specifically upon brachyuran crab larvae and euphausiids, the latter constituting over 80 percent of the total number of prey in the sample (Fig. 10). Larval fish, gammarid and hyperiid amphipods and calanoid copepods were also common prey items, but were not numerically important.

Juvenile chinook salmon (length  $\bar{x}$  = 267.0 mm), including immature resident blackmouth, fed most frequently upon shrimp larvae, insects and juvenile Pacific herring although brachyuran crab larvae and juvenile Pacific sand lance composed greater percentages of the total number of prey (Fig. 11). Two chum fry were found in the stomach of one of the juvenile chinook, but composed only 0.43 percent of the total number of prey items.

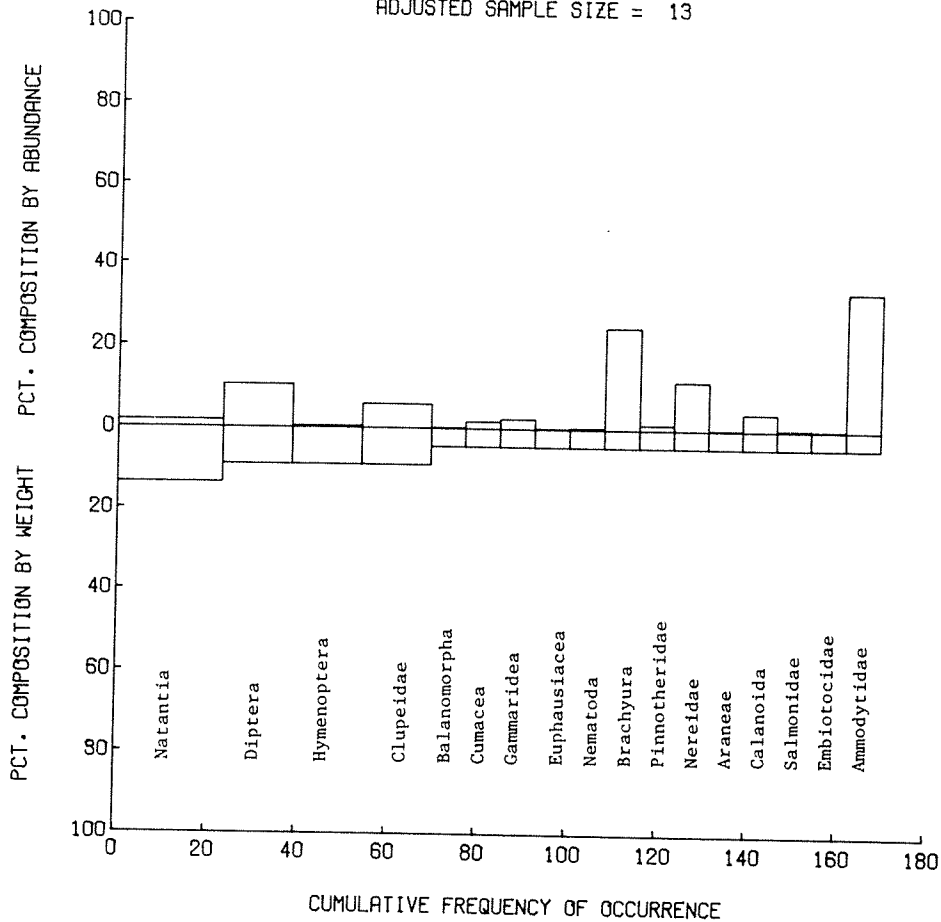
Searun cutthroat trout (length  $\bar{x}$  = 327.5 mm) fed predominantly upon gammarid amphipods, which alone composed over 55 percent of the total number of prey organisms (Fig. 12). Sphaeromatic isopods (*Gnorimosphaeroma oregonensis*, *Exosphaeroma media*), juvenile fish (including several chum and other salmon fry), callianassid shrimp, cumaceans and Pacific sand lance were common but not abundant in the stomach contents examined.

The most common prey organisms of steelhead (rainbow trout) smolts (length  $\bar{x}$  = 166.7 mm) included crab larvae, various insect taxa (Stratiomyidae, Diptera, Coleoptera), gammarid amphipods, euphausiids, and ostracods (Myodocopa); calanoid copepods, crab larvae, ostracods and

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION ALSTA

8755010206 - ONCORHYNCHUS TSHAWYTSCHA  
CHINOOK SALMON

ADJUSTED SAMPLE SIZE = 13



PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
NATANTIA	23.08	1.74	13.64	354.8	16.79
DIPTERA	15.38	10.43	9.09	300.4	14.21
HYMENOPTERA	15.38	.43	9.09	146.5	6.93
CLUPEIDAE	15.38	5.87	9.09	230.2	10.89
BALANOMORPHA	7.69	.22	4.55	36.6	1.73
CUMACEA	7.69	1.74	4.55	48.3	2.29
GAMMARIDEA	7.69	2.39	4.55	53.4	2.52
EUPHAUSIACEA	7.69	.22	4.55	36.6	1.73
NEMATODA	7.69	.43	4.55	38.3	1.81
BRACHYURA	7.69	24.78	4.55	225.6	10.67
PINNOTHERIDAE	7.69	1.30	4.55	45.0	2.13
NEREIDAE	7.69	11.74	4.55	125.3	5.93
ARANEAE	7.69	.22	4.55	36.6	1.73
CALANOIDA	7.69	4.13	4.55	66.7	3.16
SALMONIDAE	7.69	.43	4.55	38.3	1.81
EMBIOTOCIDAE	7.69	.22	4.55	36.6	1.73
ANMODYTIDAE	7.69	33.70	4.55	294.2	13.92

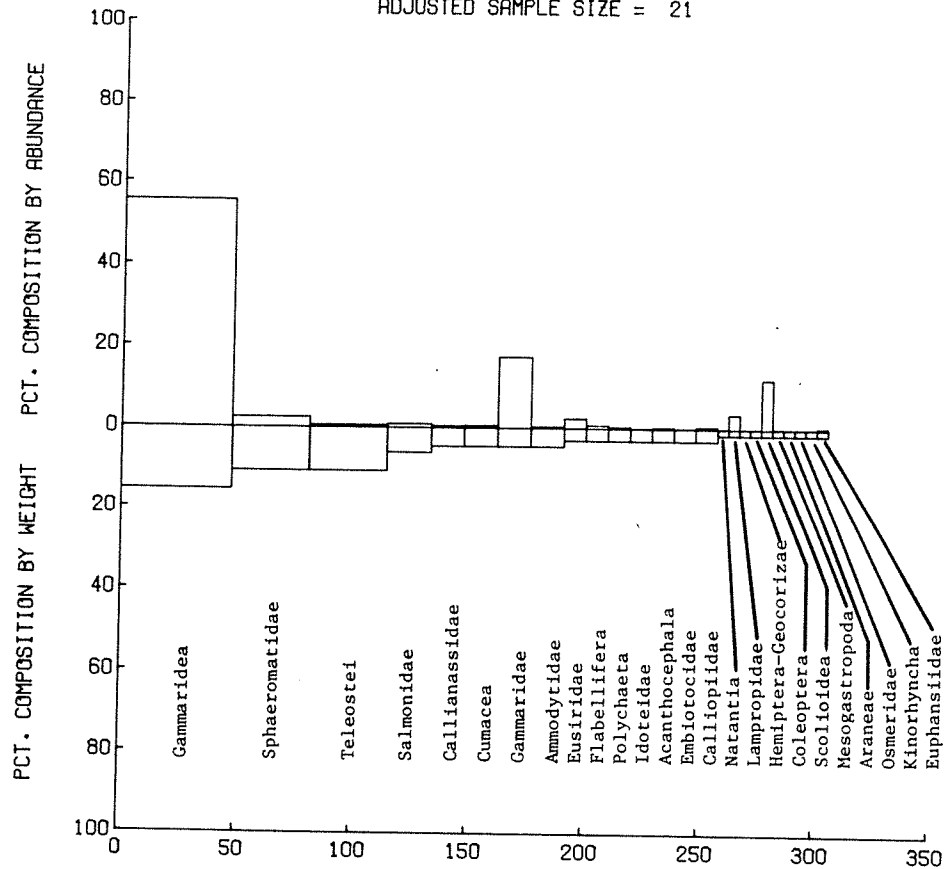
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (DO NOT ENTER INTO CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.21	.07	.10
SHANNON-WIENER DIVERSITY	2.75	3.97	3.58
EVERETT'S INDEX	.67	.97	.88

Fig. 11. IRI (Index of Relative Importance) diagram showing prey spectra of juvenile chinook salmon captured during 1977 salmonid outmigration sampling in Hood Canal, Washington

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION ALSTA

8755010301 - SALMO CLARKI  
CUTTHROAT TROUT  
ADJUSTED SAMPLE SIZE = 21



PREY ITEM	CUMULATIVE FREQUENCY OF OCCURRENCE				
	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
GAMMARIDEA	47.62	55.52	15.63	3387.7	63.90
SPHAEROMATIDAE	33.33	2.39	10.94	444.2	8.38
TELEOSTEI	33.33	.63	10.94	385.7	7.28
SALMONIDAE	19.05	.91	6.25	136.4	2.57
CALLIANASSIDAE	14.29	.49	4.69	74.0	1.40
CUMACEA	14.29	.63	4.69	76.0	1.43
GAMMARIDAE	14.29	17.43	4.69	315.9	5.96
AMMODYTIDAE	14.29	.42	4.69	73.0	1.38
FUSIRIDAE	9.52	2.39	3.13	52.5	.99
FLABELLIFERA	9.52	.77	3.13	37.1	.70
POLYCHAETA	9.52	.42	3.13	33.8	.64
IDOTEIDAE	9.52	.14	3.13	31.1	.59
ACANTHOCEPHALA	9.52	.35	3.13	33.1	.62
EMBIOTOCIDAE	9.52	.14	3.13	31.1	.59
CALLIOPIDAE	9.52	.56	3.13	35.1	.66
NATANTIA	4.76	.07	1.56	7.8	.15
LAMPROLOGIDAE	4.76	3.58	1.56	24.5	.46
HEMIPTERA-GEOCORIZAE	4.76	.07	1.56	7.8	.15
COLEOPTERA	4.76	.07	1.56	7.8	.15
SCOLIOIDEA	4.76	.07	1.56	7.8	.15
MESOGASTROPODA	4.76	12.23	1.56	65.7	1.24
ARANEAE	4.76	.14	1.56	8.1	.15
OSMERIDAE	4.76	.07	1.56	7.8	.15
KINORHYNCHA	4.76	.07	1.56	7.8	.15
EUPHANSIIDAE	4.76	.42	1.56	9.4	.18

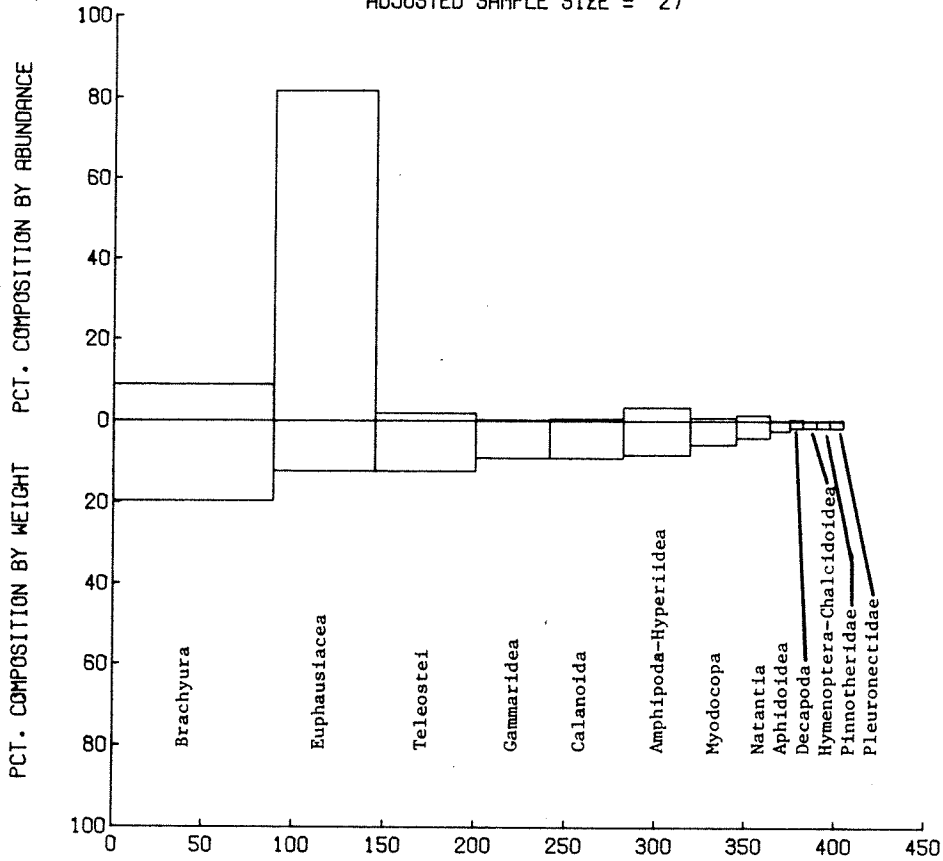
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.36	.07	.43
SHANNON-WEINER DIVERSITY INDEX	2.21	4.23	2.20
SIMPLE DIVERSITY INDEX	.48	.91	.47

Fig. 12. IRI (Index of Relative Importance) diagram showing prey spectra of cutthroat trout captured during 1977 salmonid outmigration sampling in Hood Canal, Washington

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION ALSTA

8755010203 - ONCORHYNCHUS KISUTCH  
COHO SALMON  
ADJUSTED SAMPLE SIZE = 27



PREY ITEM	CUMULATIVE FREQUENCY OF OCCURRENCE				
	FREQ. OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
BRACHYURA	84.89	8.96	19.67	2544.8	25.11
EUPHAUSIACEA	55.56	81.53	12.30	5212.4	51.42
TELEOSTEI	55.56	1.86	12.30	786.1	7.76
GAMMARIDEA	40.74	.26	9.02	378.0	3.73
CALANOIDA	40.74	.51	9.02	388.2	3.83
AMPHIPODA-HYPERIDEA	37.04	3.43	8.20	430.5	4.25
MYDOCOPA	25.93	.83	5.74	170.3	1.68
NATANTIA	18.52	1.44	4.10	102.5	1.01
APHIDOIDEA	11.11	.11	2.46	28.5	.28
DECAPODA	7.41	.34	1.64	14.7	.15
HYMENOPTERA-CHALCIDOIDEA	7.41	.08	1.64	12.8	.13
PINNOTHERIDAE	7.41	.14	1.64	13.2	.13
PLEURONECTIDAE	7.41	.19	1.64	13.6	.13

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.67	.10	.34
SHANNON-WEIFER DIVERSITY	1.15	3.81	2.12
EVENNESS INDEX	.24	.81	.45

Fig.10. IRI (Index of Relative Importance) diagram showing prey spectra of juvenile coho salmon captured during 1977 salmonid outmigration sampling in Hood Canal, Washington.

dipteran insects were numerically predominant (Fig. 13). The stomach of one steelhead smolt contained fish remains--15 unidentified fish larvae.

#### Prey Composition of Other Nearshore Fish as Potential Predators

A number of nonsalmonid marine fish commonly caught along the nearshore region of northern Hood Canal in conjunction with the salmonid outmigration sampling were also considered potential predators upon juvenile chum salmon. Thirteen species--spiny dogfish, Pacific herring, Pacific hake, Pacific tomcod, Pacific cod, whitespotted greenling, buffalo sculpin, great sculpin, cabezon, staghorn sculpin, striped seaperch, shiner perch and starry flounder--were specifically examined to detect stomachs containing juvenile salmonids (Appendix Table 1).

None of the pelagic or epibenthic plankton-feeding species showed any indication of predation upon juvenile salmonids (Table 7). Pacific herring preyed predominantly upon calanoid copepods and the euphausiid *Euphausia pacifica*. Facultative plankton feeders, such as spiny dogfish (Fig. 14), Pacific hake and Pacific tomcod, utilized both pelagic and epibenthic plankton--euphausiids, mysids and gammarid amphipods. Neither did the true benthic feeding fishes indicate any piscivorous food habits; starry flounder preyed upon bivalves and polychaetes, and while cabezon and buffalo sculpins ate a variety of benthic crab species.

Facultative benthivores, however, were quite omnivorous in their food habits and several had fishes in their stomach contents. Pacific cod preyed principally upon gammarid amphipods but one chum fry was found in one of the two cod stomachs examined. Three whitespotted greenling stomachs contained mostly gammarid and caprellid amphipods and crangonid shrimp. Of the several sculpins (family Cottidae) included in

Table 7. Feeding categories of common marine species captured during 1977 salmonid outmigration sampling in Hood Canal, Washington.

Feeding type	Species	Feeding realm	Principal Food organisms
Planktivores (obligative)	Pacific herring	Pelagic	Calanoid copepods Hyperiid amphipods Euphausiids <sup>1</sup>
	Spiny dogfish	Epibenthic	Euphausiids <sup>1</sup>
	Pacific hake Pacific tomcod	Pelagic	Mysids <sup>2</sup> Gammarid amphipods <sup>3</sup> Nereid worms <sup>4</sup> Fish larvae <sup>5</sup>
Benthivores (obligative)	Starry flounder	Benthic	Bivalves <sup>6</sup> Crabs <sup>7</sup> Shrimp <sup>8</sup> Nereid worms <sup>4</sup> Isopods <sup>9</sup>
	Cabezon		
	Buffalo sculpin		
(facultative)	Pacific cod	Epibenthic	Gammarid amphipods <sup>3</sup> Caprellid amphipods Isopods <sup>9</sup> Shrimp <sup>8</sup> Crabs <sup>7</sup> Fish Gastropods <sup>10</sup>
	Whitespotted greenling	Benthic	
	Great sculpin		
	Staghorn sculpin		
	Striped seaperch		
	Shiner perch		

<sup>1</sup>*Euphausia pacifica*

<sup>2</sup>*Acanthomysis* sp., *Mysis oculata*

<sup>3</sup>*Pontogeneia* sp., *Anisogammarus confervicolus*, *Calliopins* sp.

<sup>4</sup>*Platynereis bicanaliculata*, *Lumbrineris* sp.

<sup>5</sup>*Clupea harengus pallasi*, *Ammodytes hexapterus*

<sup>6</sup>*Lucinidae*, *Tellinidae*, *Clinocardium nuttalli*, *Tresus* sp., *Mopalia* sp., *Mytilus edulis*

<sup>7</sup>*Hemigrapsus oregonensis*, *Pugettia gracilis*, *Telmessus cheiragonus*, *Cancer productus*, *Pinnixa* sp.

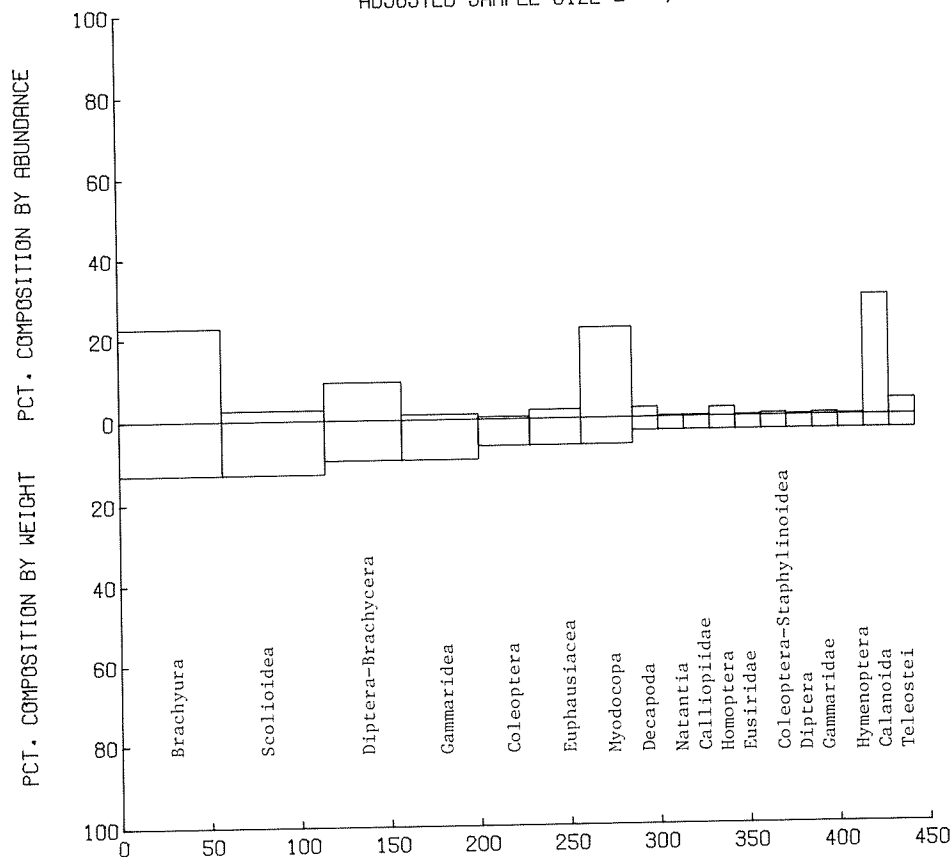
<sup>8</sup>*Callinassidae*, *Crangon* sp., *Hippolytie clarki*

<sup>9</sup>*Gnорimosphaeroma oregonensis*, *Idotea ressecata*, *Erosphaeroma media*

<sup>10</sup>*Lacuna* sp., *Lihorina scutulata*, *Tonicella lineata*, *Collisella pelta*, *Margarites* sp.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION ALSTA

8755010302 - SALMO GAIRDNERI  
RAINBOW TROUT  
ADJUSTED SAMPLE SIZE = 7



PREY ITEM	CUMULATIVE FREQUENCY OF OCCURRENCE				
	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PPEY I.R.I.	PERCENT TOTAL IRI
BRACHYURA	57.14	22.70	12.90	2034.7	31.19
SCOLIOIDEA	57.14	2.55	12.90	883.1	13.54
DIPTERA-BRACHYCERA	42.86	9.18	9.68	808.3	12.39
GAMMARIDEA	42.86	1.28	9.68	469.4	7.20
COLEOPTERA	28.57	.51	6.45	198.9	3.05
EUPHAUSIACEA	28.57	2.04	6.45	242.6	3.72
MYDOCOPA	28.57	21.94	6.45	811.2	12.43
DECAPODA	14.29	2.30	3.23	78.9	1.21
NATANTIA	14.29	.26	3.23	49.7	.76
CALLIOPIDAE	14.29	.26	3.23	49.7	.76
HOMOPTERA	14.29	2.04	3.23	75.2	1.15
EUSIRIDAE	14.29	.26	3.23	49.7	.76
COLEOPTERA-STAPHYLINOIDEA	14.29	.51	3.23	53.4	.82
DIPTERA	14.29	.26	3.23	49.7	.76
GAMMARIDAE	14.29	.51	3.23	53.4	.82
HYMENOPTERA	14.29	.26	3.23	49.7	.76
CALANOIDA	14.29	29.34	3.23	465.2	7.13
TELEOSTEI	14.29	3.83	3.23	100.7	1.54

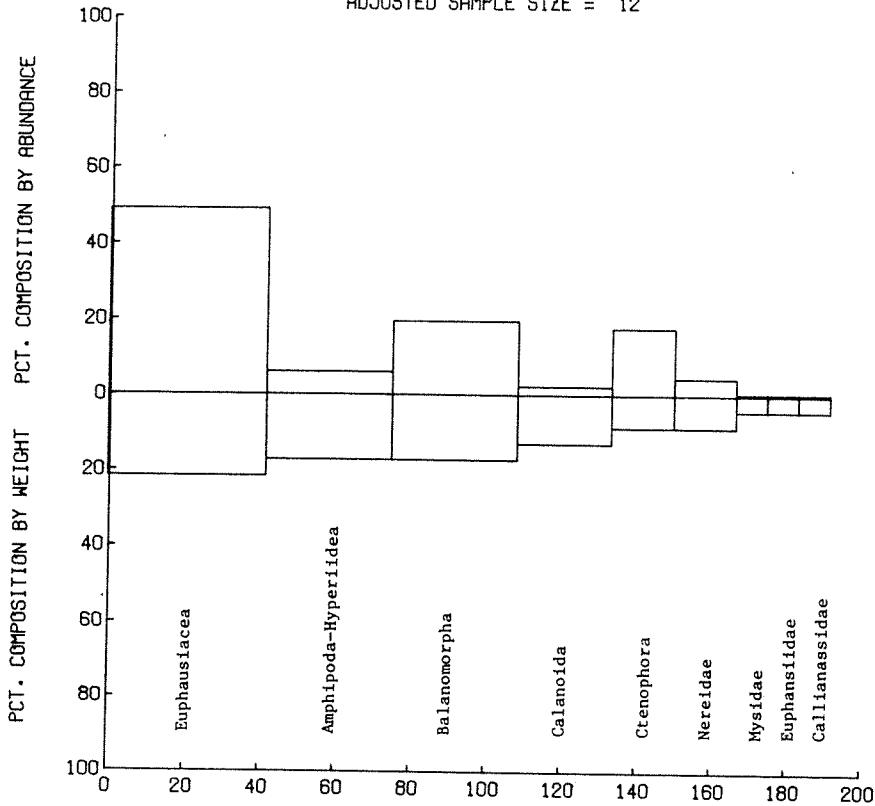
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.20	.08	.16
SHANNON-WIENER DIVERSITY	2.78	3.94	3.16
EVENNESS INDEX	.67	.94	.76

Fig. 13. IRI (Index of Relative Importance) diagram showing prey spectra of anadromous rainbow (steelhead) trout captured during 1977 salmonid outmigration sampling in Hood Canal, Washington.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION COMBD

8710010201 - SQUALUS ACANTHIAS  
SPINY DOGFISH  
ADJUSTED SAMPLE SIZE = 12



PREY ITEM	CUMULATIVE FREQUENCY OF OCCURRENCE				
	FREQ. OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
EUPHAUSIACEA	41.67	49.10	21.74	2951.6	48.29
AMPHIPODA-HYPERIIDFA	33.33	5.86	17.39	774.9	12.68
BALANOMORPHA	33.33	19.37	17.39	1225.4	20.05
CALANOIDA	25.00	2.25	13.04	382.4	6.26
CTENOPHORA	16.67	17.57	8.70	437.7	7.16
NEPEIDAF	16.67	4.50	8.70	220.0	3.60
MYSIDAE	8.33	.45	4.35	40.0	.65
EUPHANSIIDAE	8.33	.45	4.35	40.0	.65
CALLIANASSIDAE	8.33	.45	4.35	40.0	.65

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.32	.15	.30
SHANNON-WFINER DIVERSITY	2.07	2.94	2.19
EVENNESS INDEX	.65	.93	.69

Fig. 14. IRI (Index of Relative Importance) diagram showing prey spectra of spiny dogfish captured during 1977 salmonid outmigration sampling in Hood Canal, Washington.

the analysis, only the staghorn sculpin had fed upon chum salmon fry (Fig. 15), two of the 12 stomachs containing eight chum fry (4 percent of prey items); however gammarid amphipods (*Anisogammarus pugettensis*), euphausiids (*E. pacifica*), unidentified crabs and fish eggs were predominate food items. Great sculpins had fed upon calinoid copepods and gammarid amphipods (*A. confervicolus*). One striped seaperch stomach contained 1,120 gammarid amphipods while the other embiotocid, shiner perch, had fed on a diverse array of isopods (*Exosphaeroma media*), bivalves (*Mytilus edulis*), gastropods (*Littorina scutulata*) and gammarid amphipods.

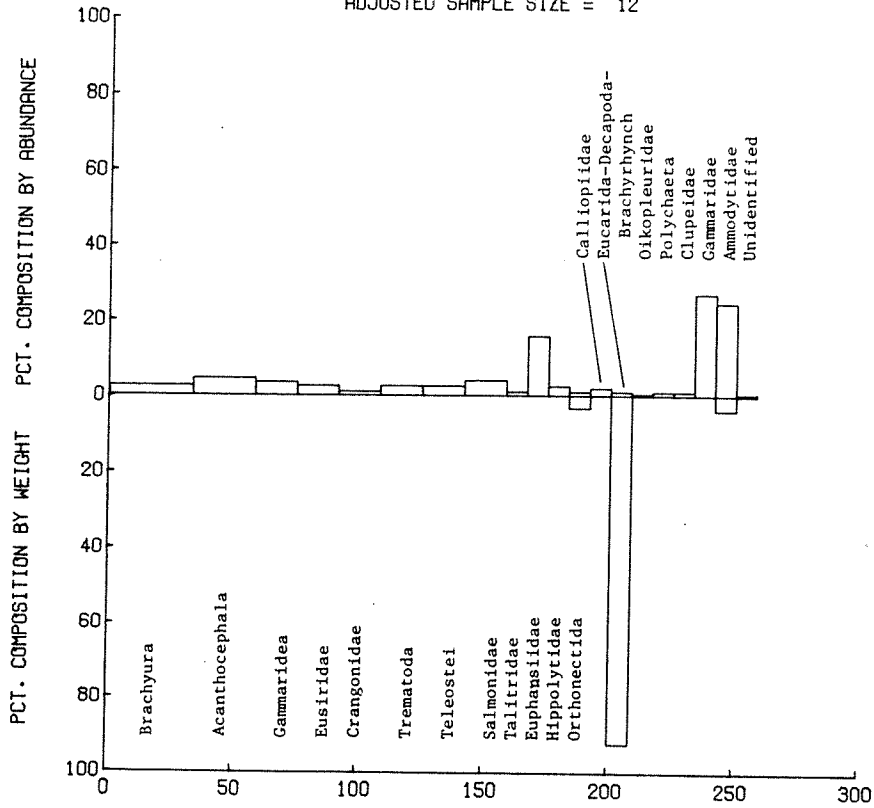
#### Overlap Between Epibenthic Plankton Community and Chum Prey

Positive electivity of epibenthic organisms by chum fry occurring in shallow sublittoral habitats, as measured by Ivlev's coefficient, E (Fig. 16), appears to shift from crustacean larvae, juvenile shrimp and calanoid copepods early in the outmigration period to gammarid amphipods, harpacticoid copepods, euphausiids, crustacean eggs and hyperiid amphipods during the peak outmigration period and to calanoid copepods and hyperiid amphipods as the migration ends. Insects always had positive values of E, primarily because they were not well sampled by the plankton pump.

Size selection of harpacticoid copepods and gammarid amphipods was quite apparent. For example, the sizes (metasome lengths) of harpacticoid copepods characterizing the Brown Point epibenthic plankton community were  $0.817 \pm 0.174$  mm, through the period of the 1977 outmigration period (Fig. 17), whereas the sizes of harpacticoids found in the stomach contents of juvenile chums caught in the nearshore region adjacent to the plankton pumping site ranged from  $1.499 \pm 0.132$  mm to  $0.781 \pm$

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCPRED, STATION COMBD

8831021801 - LEPTOCOTTUS ARMATUS  
PAC. STAGHORN SCULPIN  
ADJUSTED SAMPLE SIZE = 12



PREY ITEM	CUMULATIVE FREQUENCY OF OCCURRENCE				
	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
BRACHYURA	33.33	2.45	.00	81.8	4.24
ACANTHOCEPHALA	25.00	4.41	.00	110.4	5.71
GAMMARIDEA	16.67	3.43	.00	57.2	2.96
EUSIRIDAE	16.67	2.45	.00	40.9	2.12
CRANGONIDAE	16.67	.98	.00	16.4	.85
TREMATODA	16.67	2.45	.00	40.9	2.12
TELEOSTEI	16.67	2.45	.00	40.9	2.12
SALMONIDAE	16.67	3.92	.00	65.4	3.38
TALITRIDAE	8.33	.98	.00	8.2	.42
EUPHANSIIDAE	8.33	15.69	.00	130.7	6.76
HIPPOLYTIDAE	8.33	2.45	.00	20.4	1.06
ORTHONECTIDA	8.33	.98	3.43	36.8	1.90
CALLIOPIDAE	8.33	1.96	.00	16.3	.85
EUCARIDA-DECAPODA-BRACHYRYHNCH	8.33	.98	92.50	779.0	40.31
OIKOPLEURIDAE	8.33	.49	.00	4.1	.21
POLYCHAETA	8.33	.98	.00	8.2	.42
CLUPEIDAE	8.33	.98	.00	8.2	.42
GAMMARIDAE	8.33	26.96	.00	224.7	11.63
AMMODYTIDAE	8.33	24.51	4.03	237.9	12.31
UNIDENTIFIED	8.33	.49	.00	4.1	.21

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.17	.86	.20
SHANNON-WFINER DIVERSITY	3.21	.46	3.05
EVENNESS INDEX	.74	.11	.71

Fig. 15. IRI (Index of Relative Importance) diagram showing prey spectra of staghorn sculpins captured during 1977 salmonid outmigration sampling in Hood Canal, Washington.

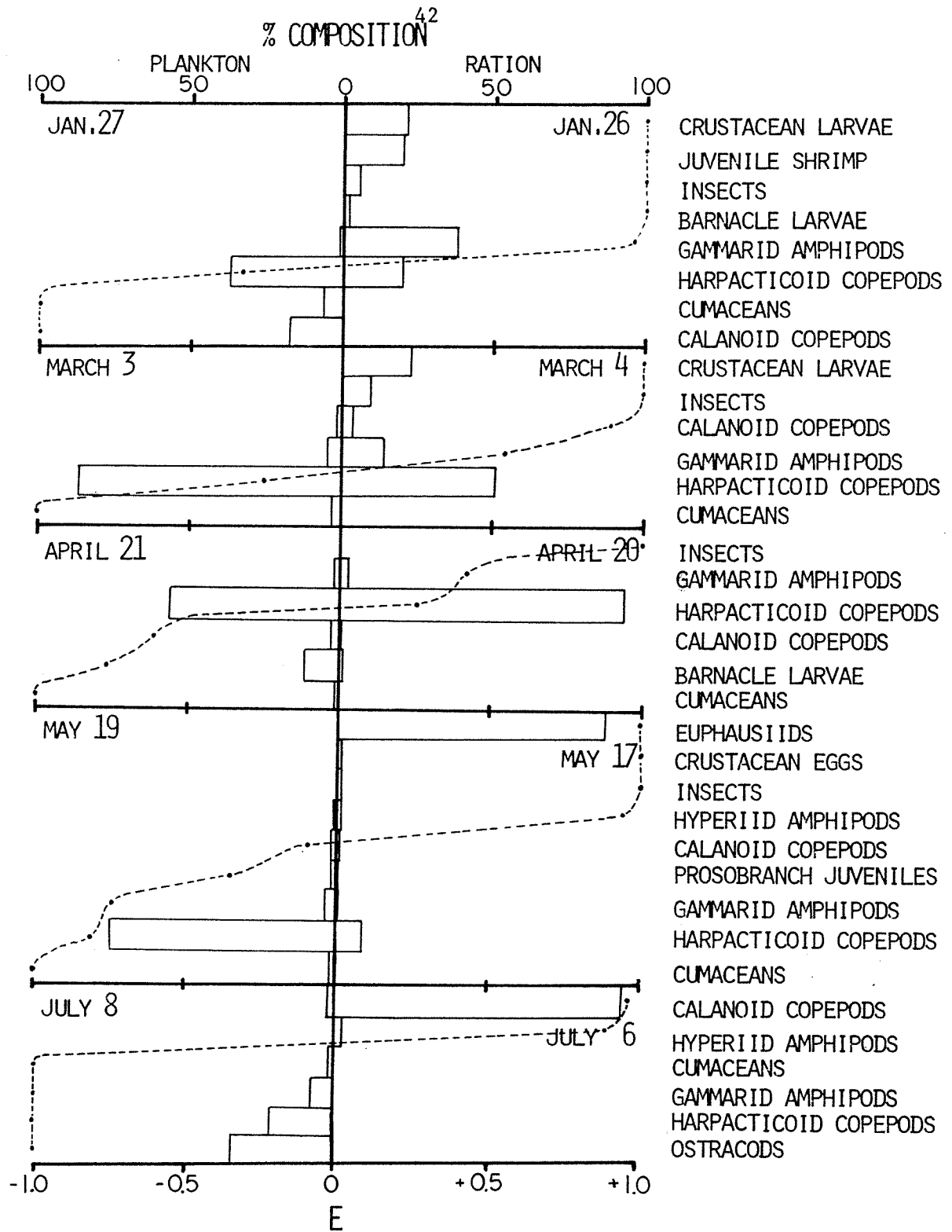


Fig. 16. Electivity curves for epibenthic plankton sample composition and ration composition of juvenile chum salmon, Hood Canal, Washington, in 1977.

## 1977 HARPACTICOID COPEPODS

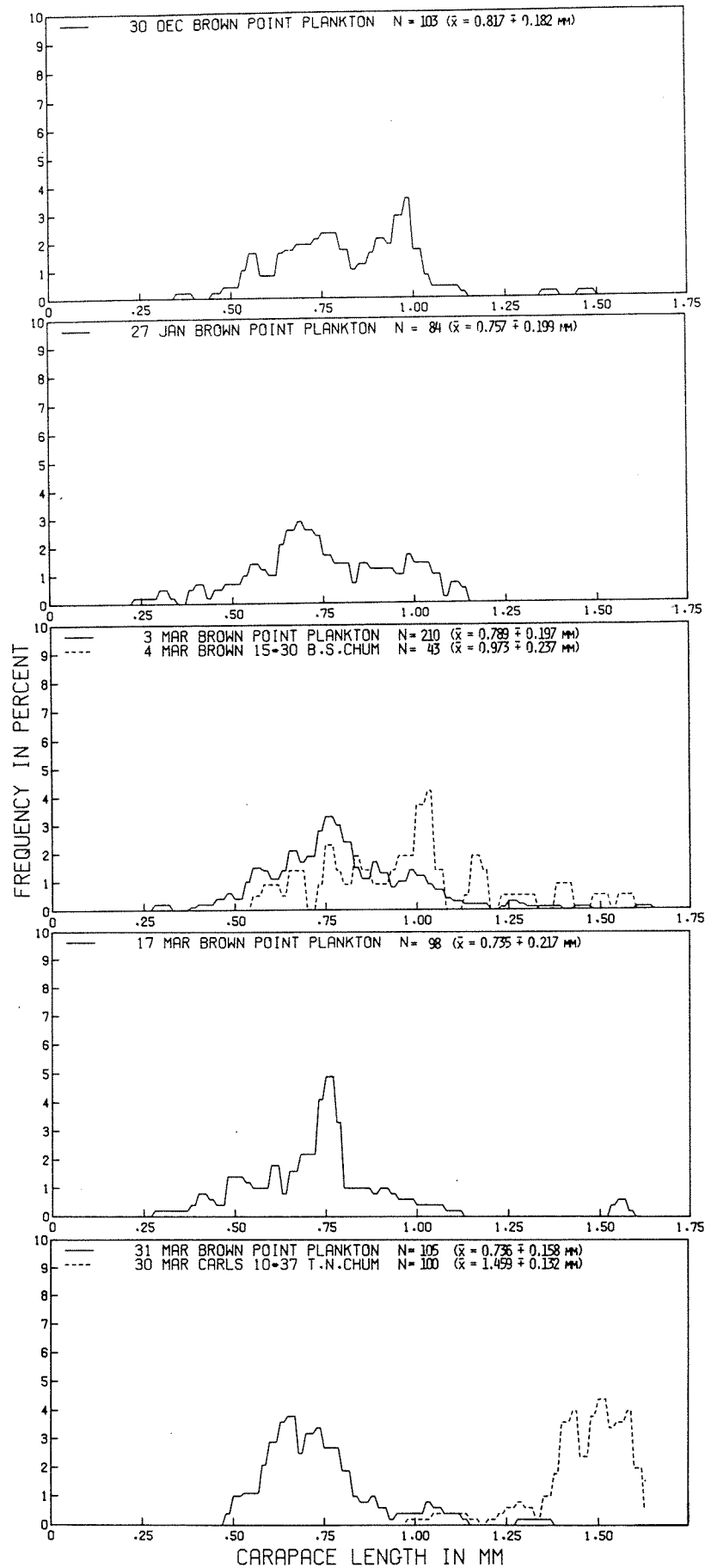


Fig.17. Harpacticoid copepod size (metasome length) distributions from epibenthic plankton community (solid line) and in stomach contents of juvenile chum salmon (dashed line) during 1977 outmigration period in Hood Canal, Washington.

44  
1977 HARPACTICOID COPEPODS

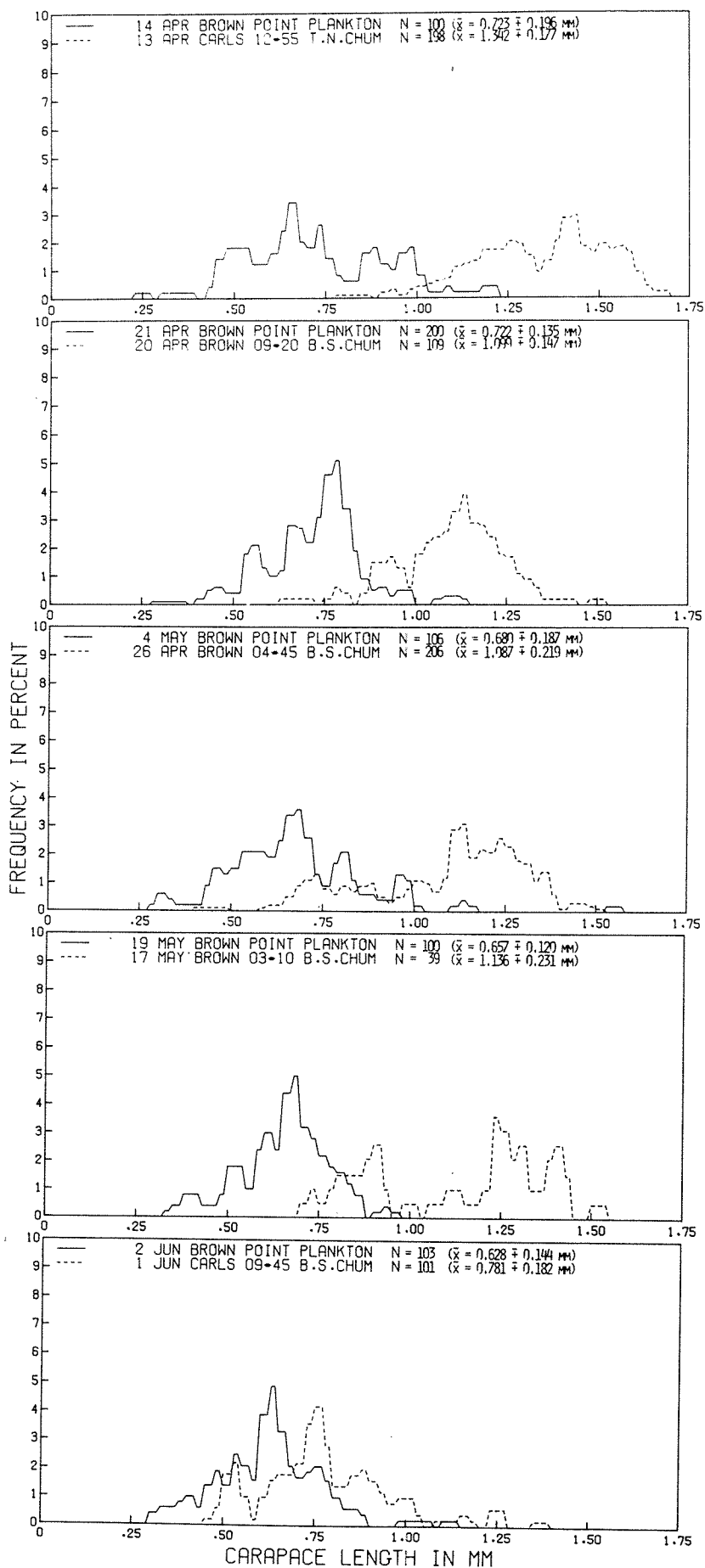


Fig. 17. (continued).

## 1977 HARPACTICOID COPEPODS

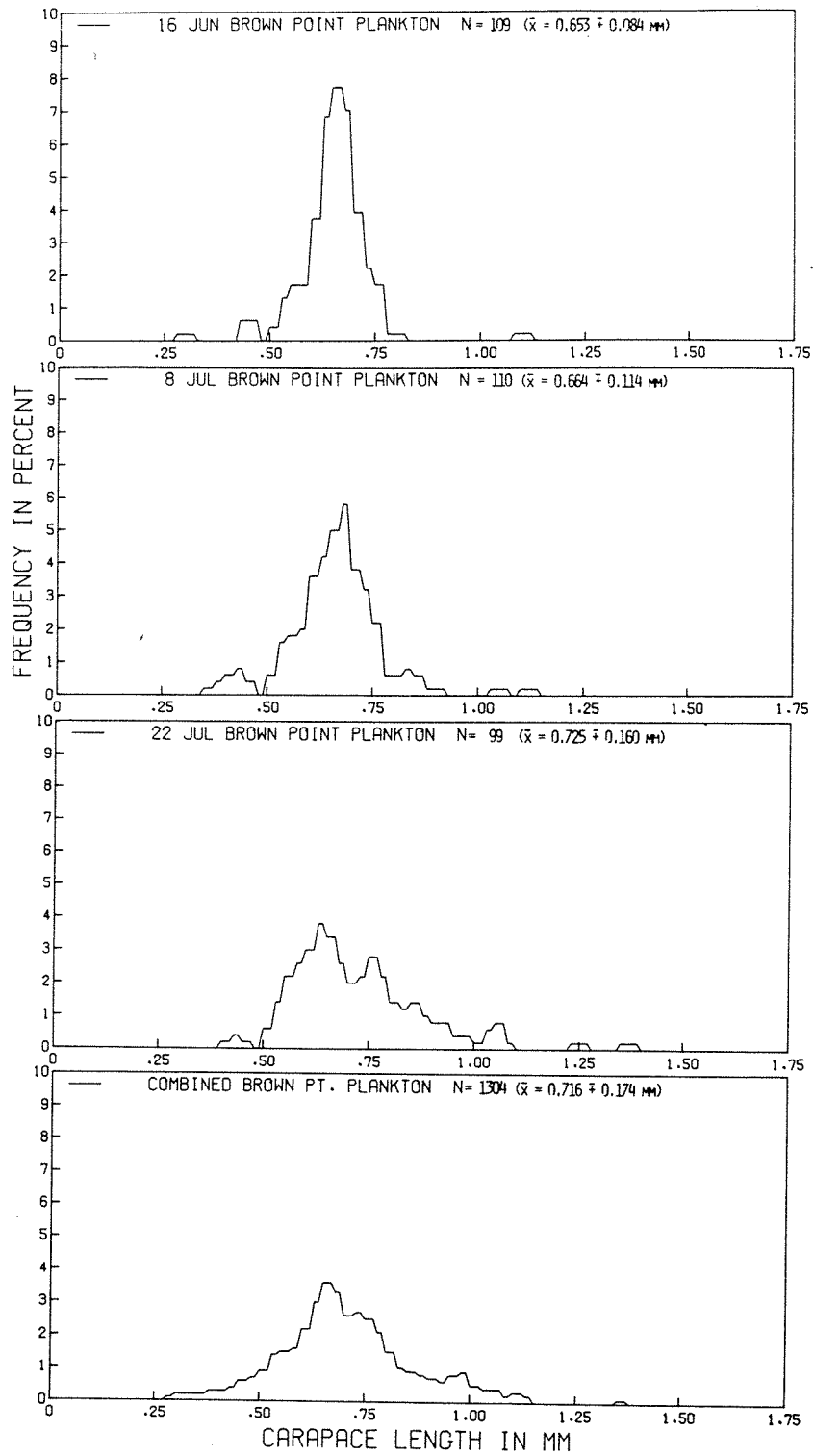


Fig. 17. (continued).

0.182 mm. In many instances the upper distributions of the harpacticoids consumed by the chum fry were completely out of range of those sampled by the plankton pump. In addition, the mean harpacticoid sizes were typically larger in the stomach contents of chum fry caught with the townet in neritic waters than those from fry caught by beach seine in shallow sublittoral habitats (Fig. 18); this may also reflect size selective predation as a function of predator size since townet-caught chums are also generally larger than those caught in the beach seine.

There was some evidence, though far from conclusive, that intense size-specific predation was depressing the mean size distributions of epibenthic harpacticoids during the peak outmigration period (Fig. 19), suggesting overexploitation of the prey source.

There was also some suggestion of size-selective predation upon gammarid amphipods (Fig. 20), although the sample sizes for measurable organisms from the contents of chum fry stomachs were not sufficient to compare with individual epibenthic plankton samples except in one instance, May 18, when the chum-consumed amphipods' size distribution was distinctly larger. Unlike the harpacticoids, however, there was not any indication of declining size distributions during the peak outmigration period.

#### DISCUSSION

Preferential feeding by chum fry upon harpacticoid copepods has been well documented for Puget Sound (Feller 1945, Feller and Kaczynski 1975, Kaczynski et al. 1973, Gerke and Kaczynski 1972, Miller et al. 1977, Simenstad 1977*a* and *b*, Schreiner et al. 1977), as well as for the Strait of Georgia (Healey et al. 1976, Mason 1974, Sibert et al. 1977), Alaska (Harris and Hartt 1977), and the White and Barrents seas (Bakshtansky

## 1977 HARPACTICOID COPEPODS

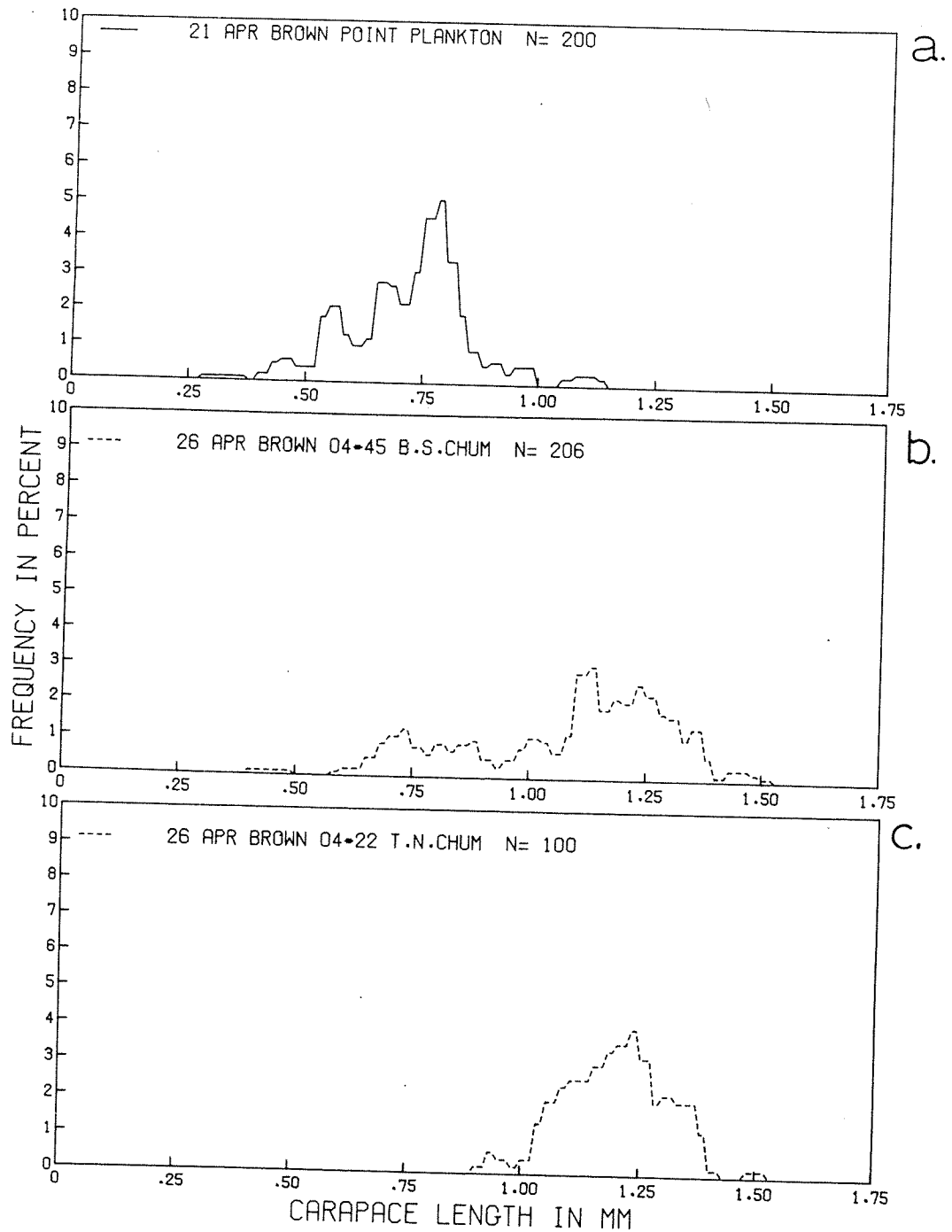


Fig. 18. Harpacticoid copepod size (metasome length) distributions from epibenthic plankton community (a), and from stomach contents of juvenile chum salmon caught in shallow sublittoral (b) and neritic (c) environments in Hood Canal, Washington, late April, 1977.

## 1977 HARPACTICOID COPEPODS

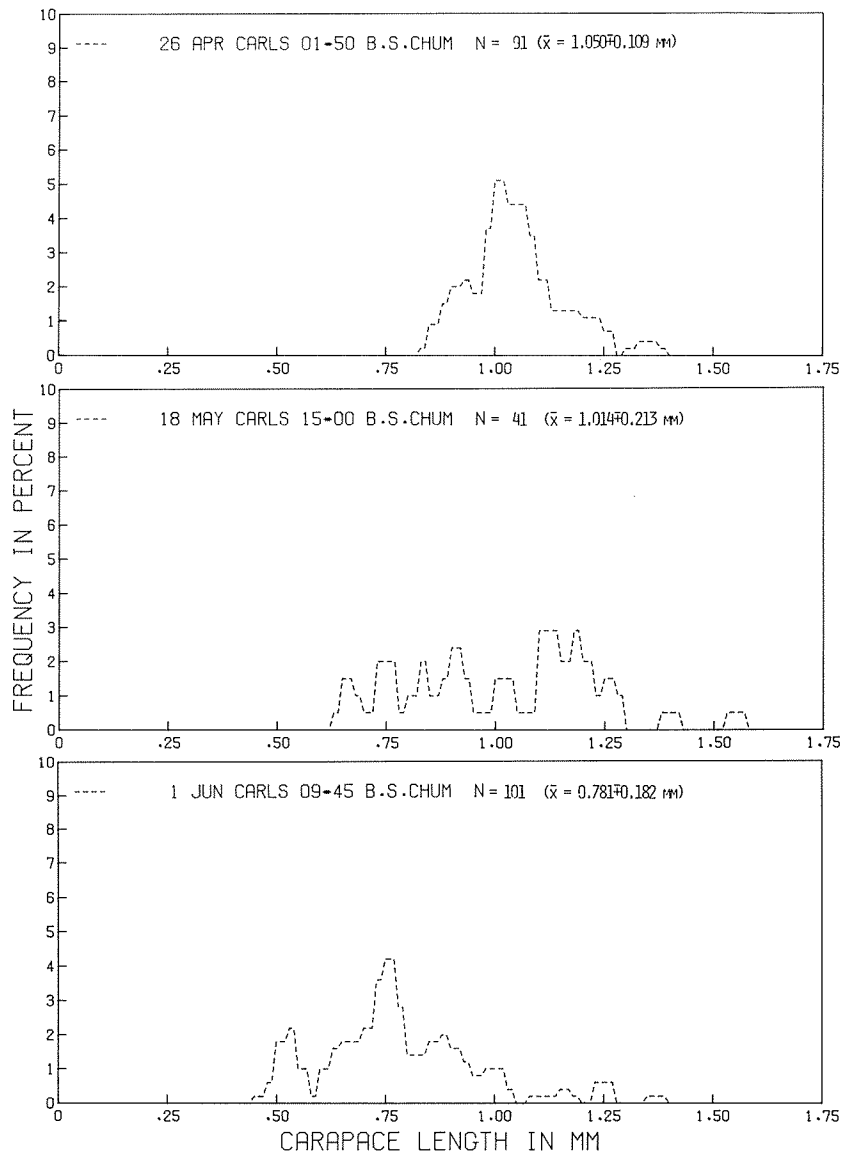


Fig. 19. Harpacticoid copepod size (metasome lengths) distribution from stomach contents of juvenile chum salmon caught in shallow sublittoral environments during peak outmigration period, Hood Canal, Washington, 1977.

## 1977 GAMMARID AMPHIPODS

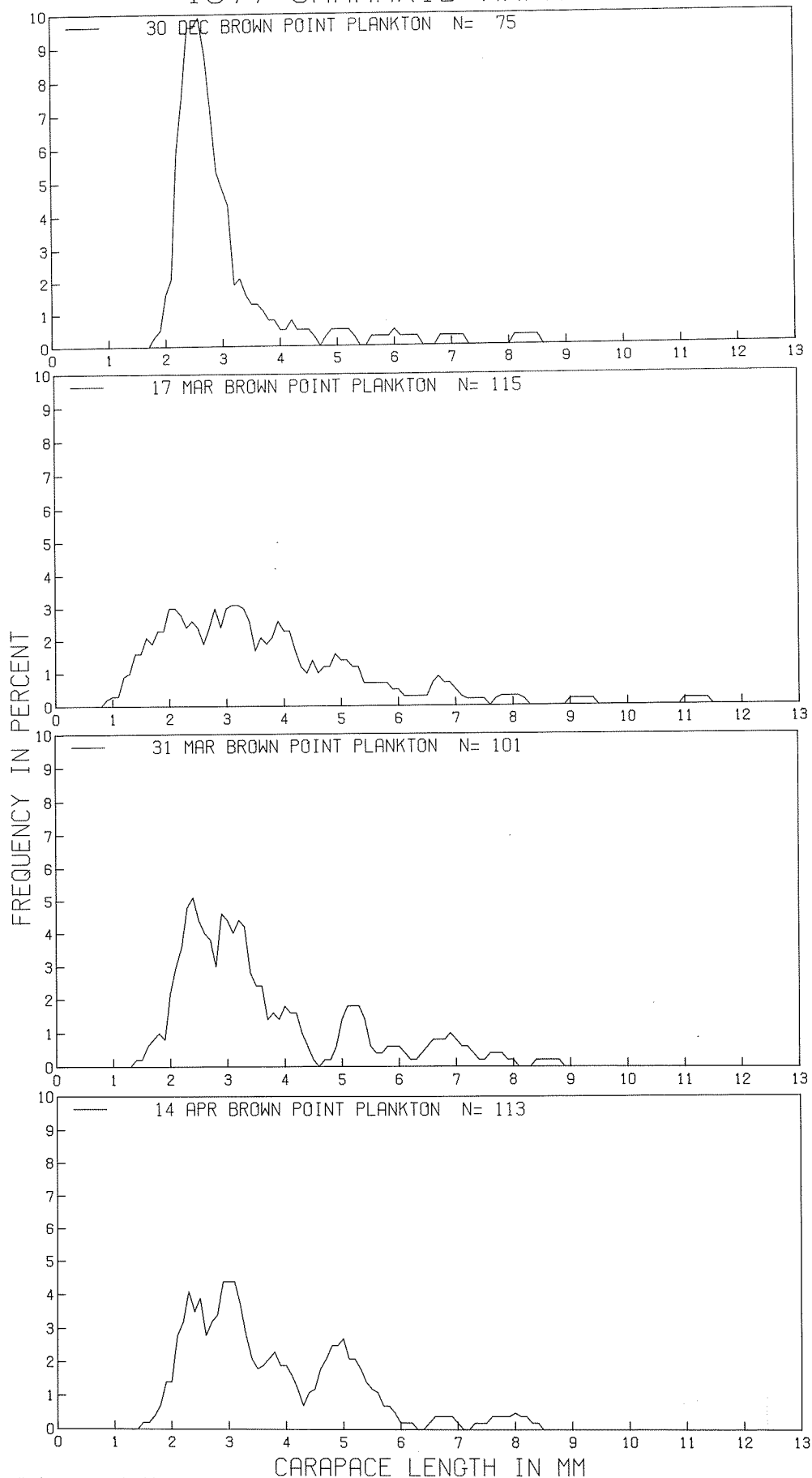


Fig 20. Gammarid amphipod size (carapace length) distributions from epibenthic plankton community (solid line) and in stomach contents of juvenile chum salmon (dashed line) during 1977 outmigration period in Hood Canal, Washington.

## 1977 GAMMARID AMPHIPODS

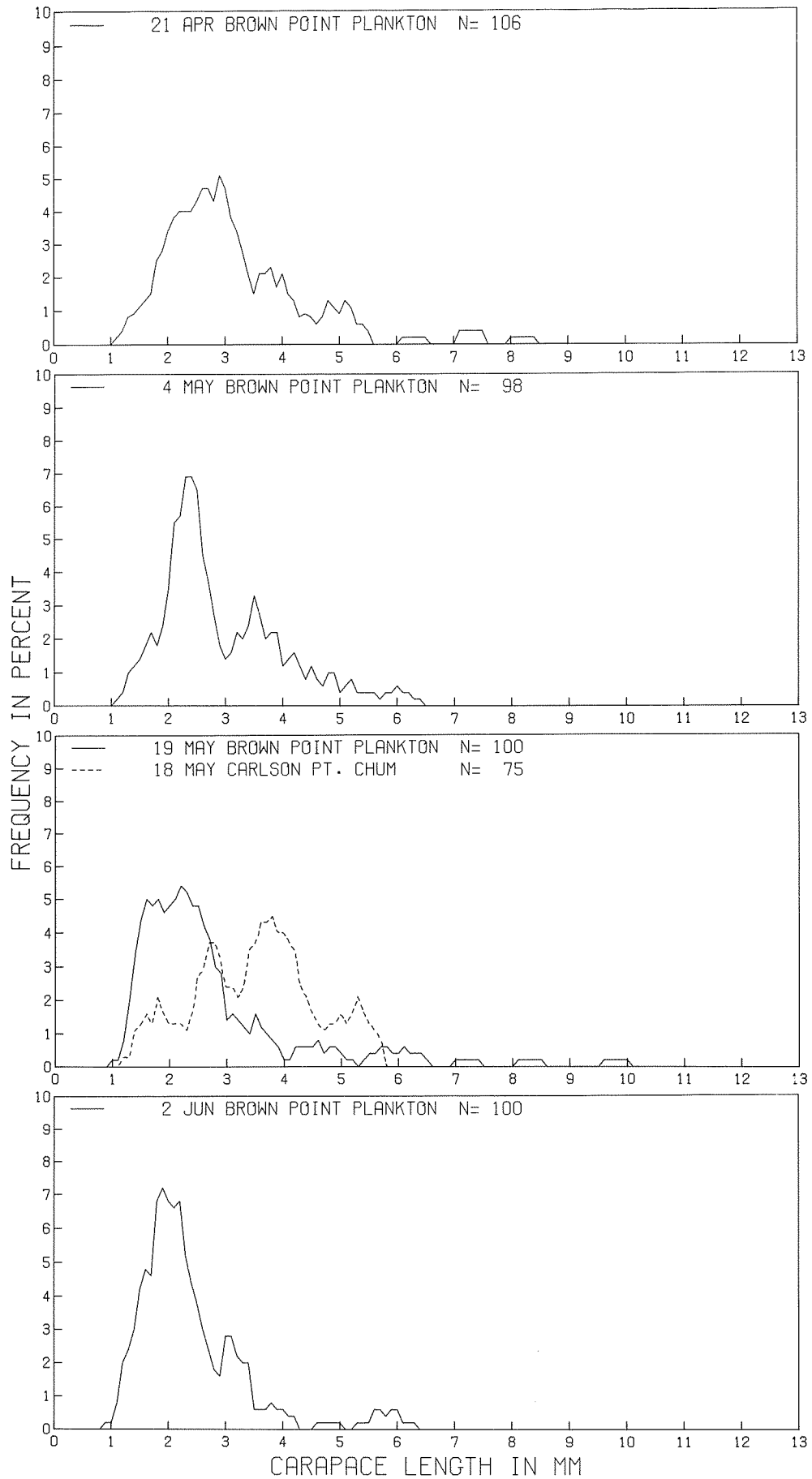


Fig. 20. (continued)

## 1977 GAMMARID AMPHIPODS

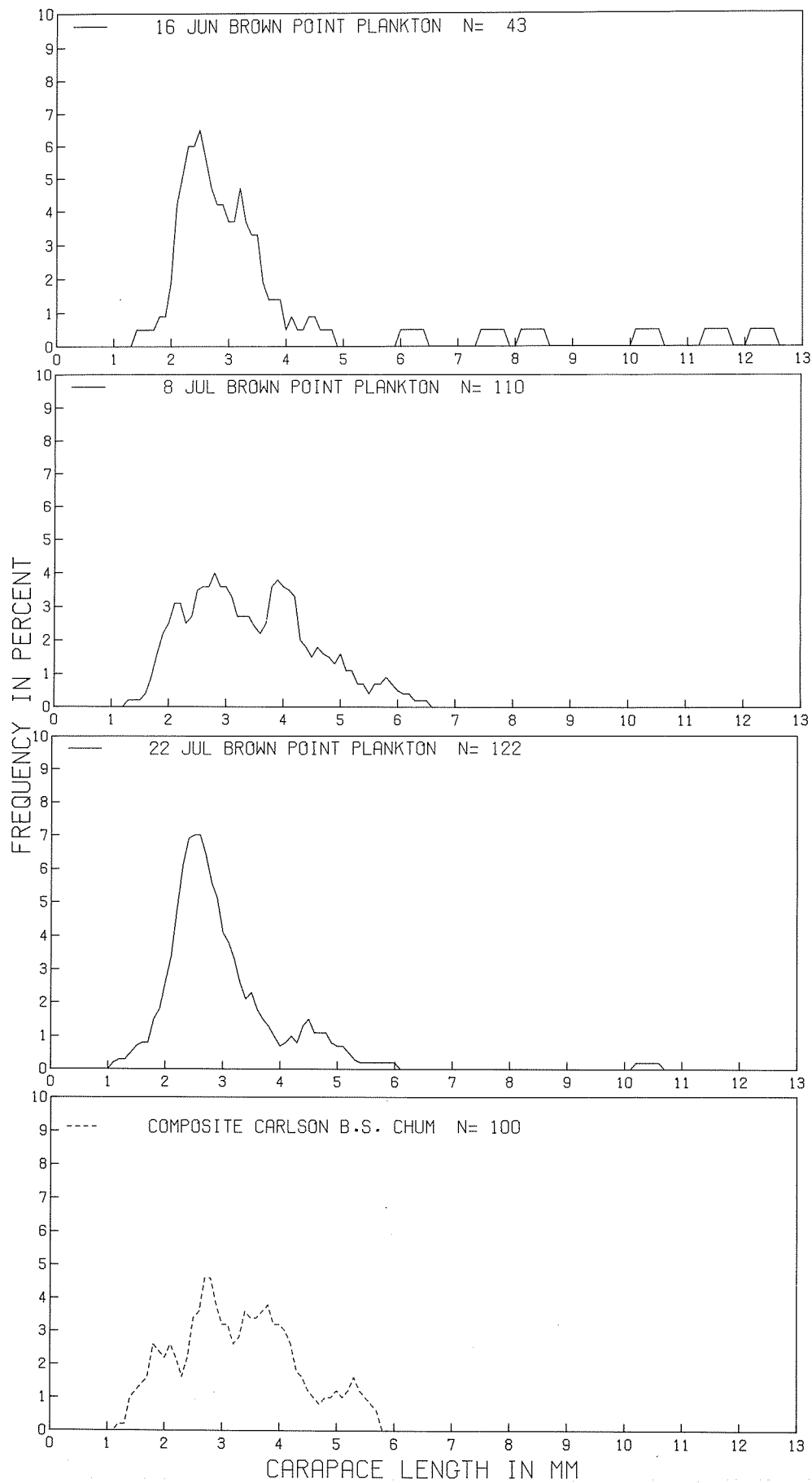


Fig. 20. (continued).

1964). The change from epibenthic to neritic or pelagic prey organisms, however, is still not well documented nor has the mechanism been established. The principal candidate is prey size as a function of the ontogeny of the chum fry during their migration (Foskett 1951, Okada and Taniguchi 1971, LeBrasseur 1969). Our data indicate that the Hood Canal chum fry between 35 and 50 mm in length select the larger size fraction of harpacticoid copepods available to them. This is consistent with much of the recent literature for other planktivorous fish species (Brooks and Dodson 1965, Confer and Blades 1975, Werner and Hall 1974, Galbraith 1967), but is contrary to the findings of Feller and Kaczynski (1975) who documented selection for the smaller fraction of the available size distribution. The chum fry they examined were smaller (averaging  $\leq 40$  mm in length) than the size range we utilized, which may explain the difference. Another possibility is that the two epibenthic pump systems had opposite biases in their sampling of representative harpacticoid size distribution; comparison of the two size distribution series, however, shows no significant differences.

A possible interpretation of both data sets is that, as the chum fry grow during outmigration, they exploit a changing size continuum of epibenthic harpacticoids, showing selection for smaller organisms when first in the estuary (30-40 mm chum fry length), later (when 40-55 mm in length) for larger size fractions and eventually (when  $\geq 55$ ) switching to large planktonic prey. There are several mechanisms that account for the changing selection, namely: (1) the changing morphology (i.e., mouth gape size, Wong and Ward 1972) of the predator; (2) increasing ability to visually perceive its prey (e.g., increasing reactive distance,

Confer and Blades 1975); (3) increasing ability to catch prey (i.e., increasing potential swimming speed, Kislalioglu and Gibson 1975); and (4) changing energetic demands which drive a continually changing feeding strategy integrating energy expended in feeding with biomass gained per prey ingested and the prey density or encounter rate (*see* Pyke et al. 1977, for review). More field measurements and experimentation are required, however, before we will be able to explain the changing prey selection and shift to pelagic organisms.

An interesting aspect of harpacticoid size distribution curves is that a large proportion of the harpacticoids consumed by the chum fry were not included in the epibenthic pump samples. This would suggest the inability of the sampler to capture large harpacticoids, which is questionable since it effectively sampled other larger, more "evasive" organisms such as gammarid amphipods, isopods and euphausiids. The alternative explanation is that large (> 1.25 mm) harpacticoids occur so infrequently as to be generally unavailable to our sampling effort. It is not surprising that chum fry, migrating along miles of shoreline in a day's time, have a higher frequency of encounter, but the selection of these over the more abundant, smaller harpacticoids is astounding.

Despite the taxonomic and size selection evidenced by the data, depression of the resource may be occurring, at least in the case of Hood Canal's early chum run at a time when the density of epibenthic organisms was low to begin with. This calls into question the ability or need of the fry to functionally change their food habits in response to changing food resources. There are obviously great numbers of alternative organisms available, though perhaps not as many as we originally

thought. One suggestion is that there is an energetic cost in survival and growth to switching to "suboptimal" food organisms for a given size of the juvenile chum. This may not be so wild an idea if we consider the apparent responses to food availability as measured by residence times between the early and late chum runs in Hood Canal. We have preliminary data on the time several different lots of chum fry spent in the northern reaches of Hood Canal after they were released from Big Beef Creek (Bruce Snyder, personal communication). Small (38-40 mm) fry released in February or early March (before the spring increase in epibenthic plankton) spent as little as 19 hours in the sampling area, having moved rapidly through the canal along the shoreline. Later groups of similar sized fry released in April and May typically spent several weeks in the northern canal, growing and dispersing into neritic waters to feed on pelagic organisms. Such variable residence times certainly could be due to myriad environmental variables besides or in addition to food availability, but this relationship bears testing.

There were few differences in prey composition for chum fry migrating through the shallow sublittoral zones of different habitats in northern Hood Canal. Harpacticoid copepods appear to be the preferred food organism in all cases, accounting for 53-74 percent of the total IRI prey spectra. The highest contributions by harpacticoids originated from chum fry collected north of Devil's Hole delta. This suggests, and is supported by the epibenthic pump data, that the shallow delta region, with sandy substrate and abundant eelgrass, may provide the maximum abundances of this prey resource. Conversely, gammarid amphipods appear to be most common in the diets of chum fry collected from exposed spits

which typically have clean gravel, coarse sand substrates in the shallow sublittoral zone (Brown Point, Floral Point and Spit 6).

The role of predation as a principal component of mortality of juvenile pink and chum salmon in estuarine habitats has been supported by many researchers (*see* Iwamoto and Salo 1977, for review). Other salmonids--juvenile and immature coho and chinook and cutthroat and Dolly Varden trout--have particularly been implicated. Allen (1974), Heiser and Finn (1970), Parker (1971), Sano (1966), and Walker (1974) have suggested, on the basis of observational data, that coho smolts are potentially significant predators upon chum fry. Stober et al. (1973), suggested stomach analysis evidence of coho smolt predation upon chum and pink fry but no data were provided. Thus, there are no concrete data in the available literature which document the actual incidence of chum fry in the stomachs of coho smolts, although few studies have specifically been designed around the predation hypothesis. Extensive stomach contents analyses of coho smolts during FRI's Hood Canal studies, as well as those in northern Puget Sound (Miller et al. 1977), the Strait of Juan de Fuca (Simenstad et al. 1977) and Nisqually Reach (Fresh et al., in preparation), do not substantiate any indication of such predation upon juvenile salmonids.

Similarly, evidence of predation by juvenile and immature chinook in the literature is confined to the incomplete evidence in Stober et al. (1973). Our Hood Canal data show only minimal evidence (1.8 percent total IRI) of chinook predation on other juvenile salmonids; samples from Nisqually Reach (Fresh et al., in preparation) and northern Puget Sound (Miller et al. 1977) also provide little or no evidence. Resident

chinook (blackmouth) were not effectively sampled during most of these studies, however, and they may represent a significant mortality factor (especially considering the WDF delayed release programs designed to expand these stocks). Studies specifically designed to sample these larger, deeper occurring salmonids and other neritic predators must be implemented before their trophic role can be adequately assessed. New sampling techniques, such as purse seining and midwater trawling, will be required if they are to be effectively sampled.

Searun cutthroat trout have also been implicated as potential predators upon chum fry (Heiser and Finn 1970). This potential has been illustrated by the results of our Hood Canal collections, where salmon fry were fourth in frequency of occurrence of all prey taxa; fish overall constituted only 11.4 percent of the total IRI prey spectra, however.

Other marine fish which have been suggested as potential predators include numerous cottid (sculpin) species (Beall 1972, Heiser and Finn 1970, Simenstad 1976) and walleye pollock (Armstrong and Winslow 1968). Chum fry occurred in only two species--Pacific cod and Pacific staghorn sculpin--included in the Hood Canal collections. The sample size of Pacific cod stomachs was too small to draw any conclusions concerning the significance of predation by this species. Juvenile salmonids occurred in 17 percent of the Pacific staghorn sculpin stomachs examined but made up only 3.4 percent of the total IRI prey spectrum. Stomach analysis of Pacific staghorn sculpins from Nisqually Reach (Fresh et al., in preparation), northern Puget Sound (Miller et al. 1977) and the Strait of Juan de Fuca (Simenstad et al. 1977) provided no indication of predation upon juvenile salmonids.

Within the limits of the nearshore fish collections conducted by FRI in Puget Sound and the Strait of Juan de Fuca, we can find no empirical data illustrating concentrated, large-scale predation upon chum fry during the early period of marine residence. Either the few potential predators--searun cutthroat, Pacific cod and Pacific staghorn sculpins--do not appear in high density coincident with the chum fry, or juvenile salmonids do not constitute a high proportion of the predators' diet. Alternative predators such as nearshore-feeding birds (Allen 1974) should be examined in detail if predation is to continue as a major explanation of estuarine mortality of juvenile chum and pink salmon.

When the results of our Hood Canal studies are appended to the existing information on trophic dynamics of juvenile chum salmon, we are still left with a major uncertainty, that is, the estuarine component of the total marine survival from fry to returning adult. The corollary data gap is the relationship between early marine survival rates and the variability in food rations gained during the various feeding stages--epibenthic, neritic and pelagic. Presumably, growth is the mechanism by which variable feeding conditions affect survival; it already appears that there are some differences in opinion about the influence of growth and size upon survival rates. There is a need to quantify variability in growth as a function of ration size and composition in order to test the bioenergetic advantage of the food selection we are observing; conversely, the cost in growth and survival of overexploiting the preferred prey organisms should also be established.

The bottom line of this discussion obviously relates to enhancement. If the concepts of limited carrying capacity and density-dependent

estuarine growth as applied to juvenile chum salmon are rooted in real phenomena, artificial enhancement strategies must include criteria to optimize estuarine survival around maximum prey availability. This would involve manipulating release times, densities, size of released fry and other species' releases around some measure of the prey community composition and size distribution such that the maximum amount of preferred ration would be predictably available.

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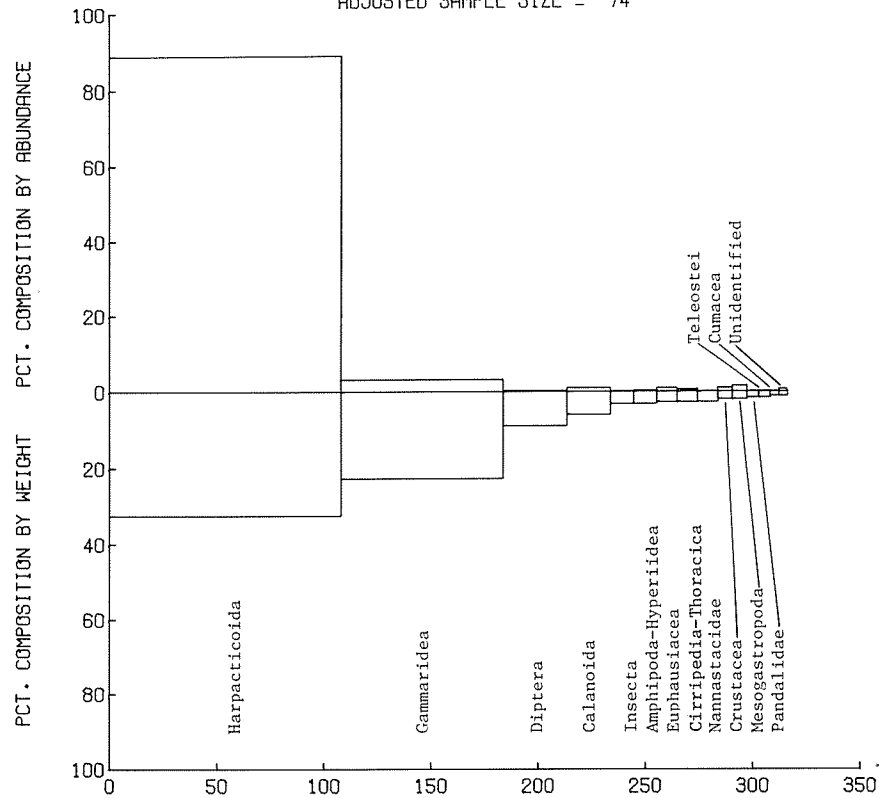
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APPENDICES

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION CARLS

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 74



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	105.11	18.83	31.39	5537.5	67.07
GAMMARIDEA	79.68	3.12	22.67	1951.6	23.64
DIPTERA	29.73	.29	6.91	275.5	3.31
CALANOIDA	25.27	.99	6.07	145.2	1.74
INSECTA	18.81	.09	3.24	35.9	.44
AMPHIPODA-HYPERIIDEA	18.81	.36	3.24	36.3	.46
EUPHAUSIACEA	9.46	.93	2.65	35.6	.43
CIRRIPIEDIA-THORACICA	9.46	.94	2.85	31.9	.39
NANNASTACIDAE	9.46	.09	2.65	27.7	.34
CRUSTACEA	6.76	.95	2.02	26.1	.24
MESOGASTROPODA	6.76	1.50	2.02	25.8	.29
PANDALIDAE	5.41	.04	1.62	9.0	.11
TELEOSTEI	5.41	.05	1.62	9.1	.11
CUMACEA	4.05	.02	1.21	5.0	.06
UNIDENTIFIED	4.05	.64	1.21	7.5	.09

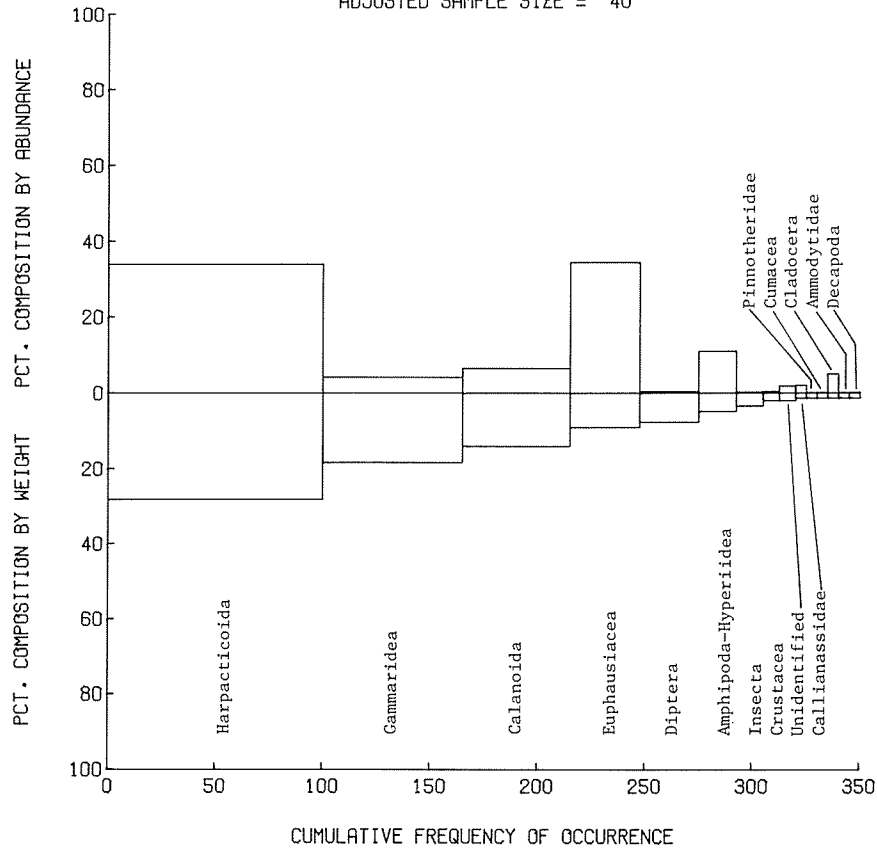
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.55	.17	.51
SHANNON-WEINER DIVERSITY	1.43	3.30	1.48
EVENNESS INDEX	.30	.70	.31

Appendix Fig. 1. IRI (Index of Relative Importance) diagram showing prey spectra of chum salmon fry captured by beach seine in shallow sublittoral habitat at a) Carlson Pt., Hood Canal, Washington in 1977.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSM, STATION DEVIL

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 40



PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL I.R.I.
HARPACTICOIDA	100.00	33.94	26.17	6210.6	57.53
GAMMARIDEA	65.00	4.15	16.31	1439.7	13.52
CALANOIDA	50.00	6.93	14.06	1036.5	9.55
EUPHAUSIACEA	32.50	34.40	9.15	1415.5	13.11
DIPTERA	27.50	.40	7.75	224.0	2.08
AMPHIPODA-HYPERIDEA	17.50	10.95	4.95	277.8	2.57
INSECTA	12.50	.25	3.52	47.2	.44
CRUSTACEA	7.50	.36	2.11	16.7	.17
UNIDENTIFIED	7.50	1.85	2.11	29.7	.28
CALLINANASSIDAE	5.00	2.00	1.41	17.0	.16
PINNOTHERIDAE	5.00	.06	1.41	7.4	.07
CUMACEA	5.00	.04	1.41	7.3	.07
CLADOCERA	5.00	4.93	1.41	31.7	.29
AMMODYTIDAE	5.00	.04	1.41	7.3	.07
DECAPODA	5.00	.04	1.41	7.3	.07

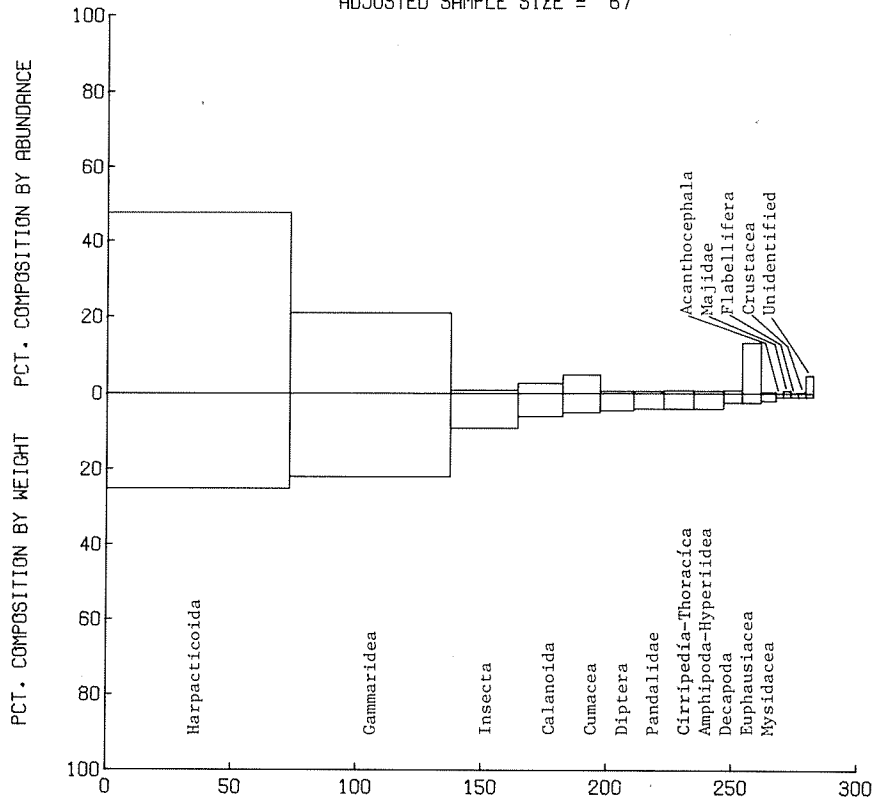
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PERCENT DOMINANCE INDEX	.25	.15	.36
SHANNON-WEINER DIVERSITY	2.40	3.20	1.95
EVENNESS INDEX	.59	.76	.48

Appendix Fig. 1. (cont) b) Devils Hole delta.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION BROWN

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 67



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	75.13	47.64	25.13	5321.5	58.52
GAMMARIDEA	64.18	20.91	22.05	2757.3	30.32
INSECTA	25.37	.85	9.23	271.7	2.99
CALANOIDA	17.91	2.65	6.13	157.7	1.73
CUMACEA	14.93	4.90	5.13	149.7	1.65
DIPTERA	13.43	.57	4.62	69.7	.77
PANDALIDAE	11.94	.63	4.10	58.5	.64
CIRRIPEIDIA THORACICA	11.94	.63	4.10	58.5	.64
AMPHIPODA-HYPERIDEA	11.94	.63	4.10	57.2	.63
DECAPODA	7.46	.83	2.56	25.3	.28
EUPHAUSIACEA	7.46	13.02	2.56	110.3	1.28
MYSIDACEA	5.97	.34	2.05	14.3	.16
ACANTHOCEPHALA	2.99	.06	1.03	3.2	.04
MAJIDAE	2.99	.06	1.03	3.1	.06
FLABELLIFERA	2.99	.11	1.03	3.4	.04
CRUSTACEA	2.99	.26	1.03	3.9	.04
UNIDENTIFIED	2.99	4.70	1.03	17.1	.19

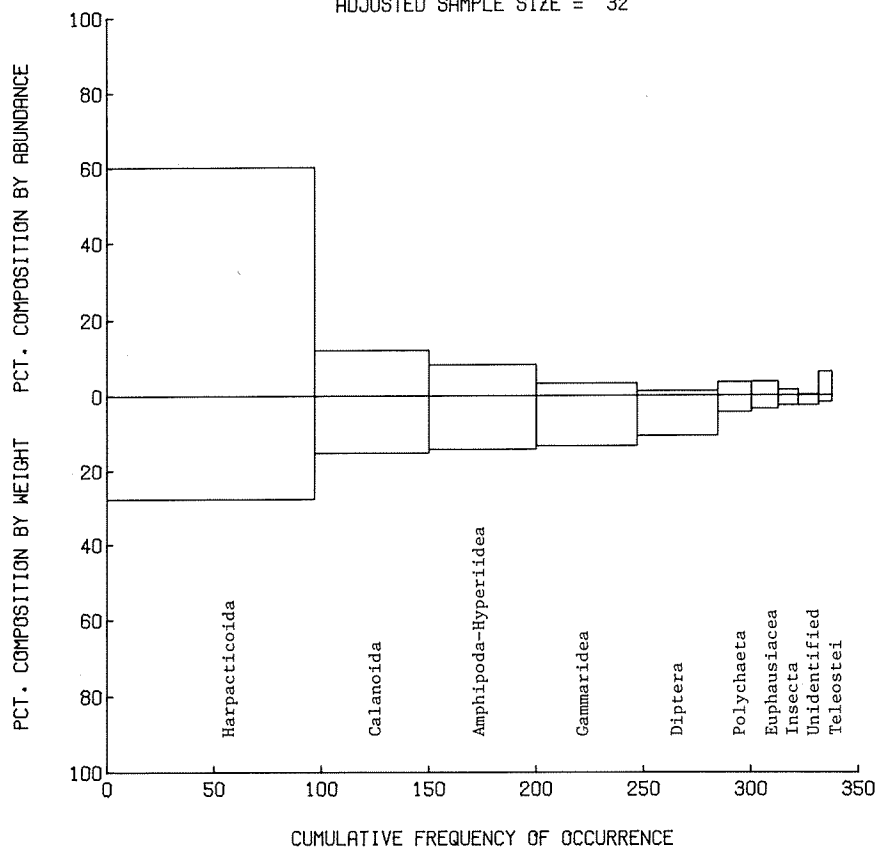
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PERCENT DOMINANCE INDEX	.29	.14	.44
SHANNON-WEINER DIVERSITY	2.39	3.50	1.68
EVENNESS INDEX	.53	.77	.37

Appendix Fig. 1. (cont) c) Brown Pt.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION MARGL

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 32



PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	98.88	50.13	27.68	8506.0	67.30
CALANOIDA	53.13	11.99	15.18	1443.3	11.42
AMPHIPODA-HYPERIDEA	50.00	8.22	14.29	1125.2	8.90
GAMMARIDEA	48.88	3.19	13.39	777.2	6.15
DIPTERA	37.50	1.17	10.71	445.6	3.53
POLYCHAETA	15.83	3.46	4.46	123.8	.98
EUPHAUSIACEA	12.50	3.59	3.57	89.5	.71
INSECTA	9.38	1.48	2.68	39.0	.31
UNIDENTIFIED	9.38	.18	2.68	26.8	.21
TELEOSTEI	6.25	6.15	1.79	49.6	.39

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.39	.15	.48
SHANNON-WEINER DIVERSITY	2.07	3.06	1.67
EVENNESS INDEX	.54	.80	.44

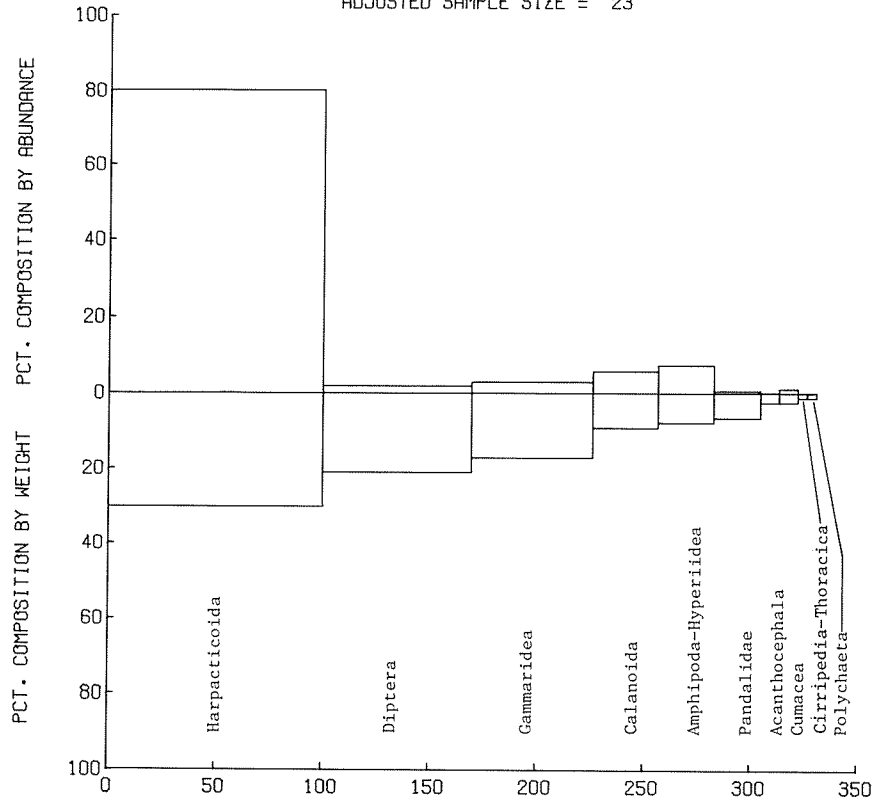
Appendix Fig. 1. (cont) d) Marginal Wharf.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION EHW

8755010202 - ONCORHYNCHUS KETA

CHUM SALMON

ADJUSTED SAMPLE SIZE = 23



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	100.00	80.11	30.26	11037.4	74.37
DIPTERA	69.57	1.87	21.05	1594.7	10.74
GAMMARIDEA	56.52	2.91	17.11	1131.3	7.62
CALANOIDA	30.43	5.75	9.21	455.4	3.07
AMPHIPODA-HYPERIDEA	26.09	7.35	7.89	397.6	2.68
PANDALIDAE	21.74	.62	6.58	156.6	1.06
ACANTHOCEPHALA	8.70	.14	2.63	24.1	.16
CUMACEA	8.70	1.11	2.63	32.5	.22
CIRRIPIEDIA THORACICA	4.35	.07	1.32	6.0	.04
POLYCHAETA	4.35	.07	1.32	6.0	.04

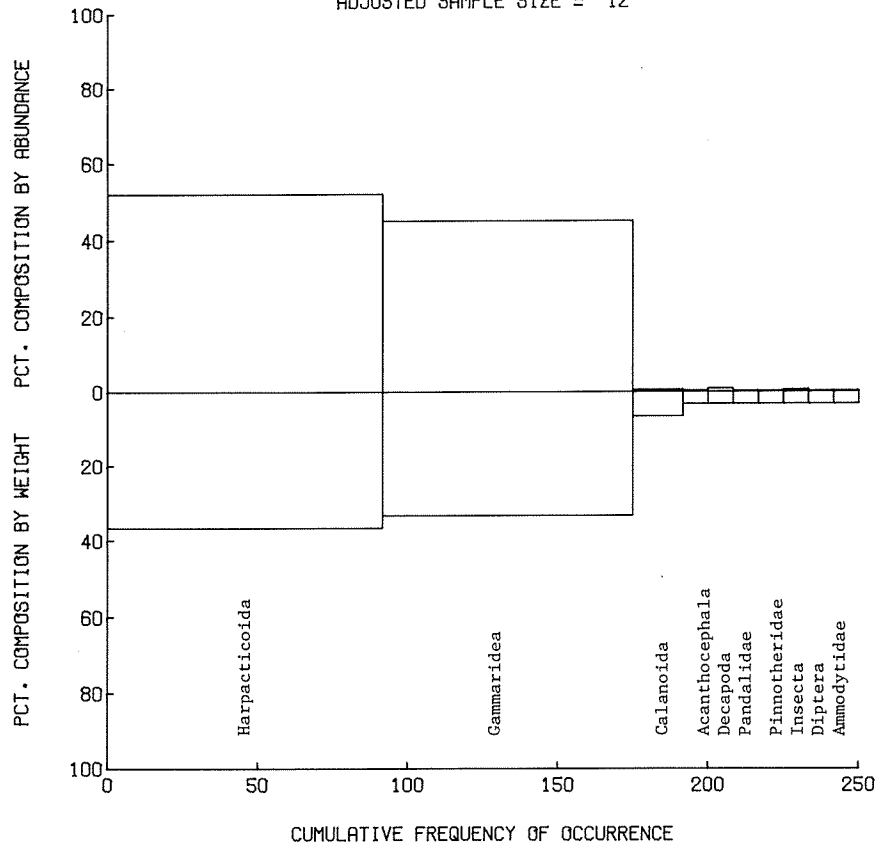
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.65	.19	.57
SHANNON-WEINER DIVERSITY	1.17	2.74	1.35
EVENNESS INDEX	.35	.82	.41

Appendix Fig. 1. (cont) e) EHW (Explosive Handling Wharf), Bangor Annex.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION SPIT6

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 12



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	91.67	52.07	36.67	8134.1	54.24
GAMMARIDEA	83.33	45.00	33.33	8527.8	43.53
CALANOIDA	16.67	.52	6.67	119.7	.80
ACANTHOCEPHALA	8.33	.34	3.33	30.7	.20
DECAPODA	8.33	.86	3.33	35.0	.23
PANDALIDAE	8.33	.17	3.33	29.2	.19
PINNOOTHERIDAE	8.33	.17	3.33	29.2	.19
INSECTA	8.33	.52	3.33	32.1	.21
DIPTERA	8.33	.17	3.33	29.2	.19
AMMODYTIDAE	8.33	.17	3.33	29.2	.19

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

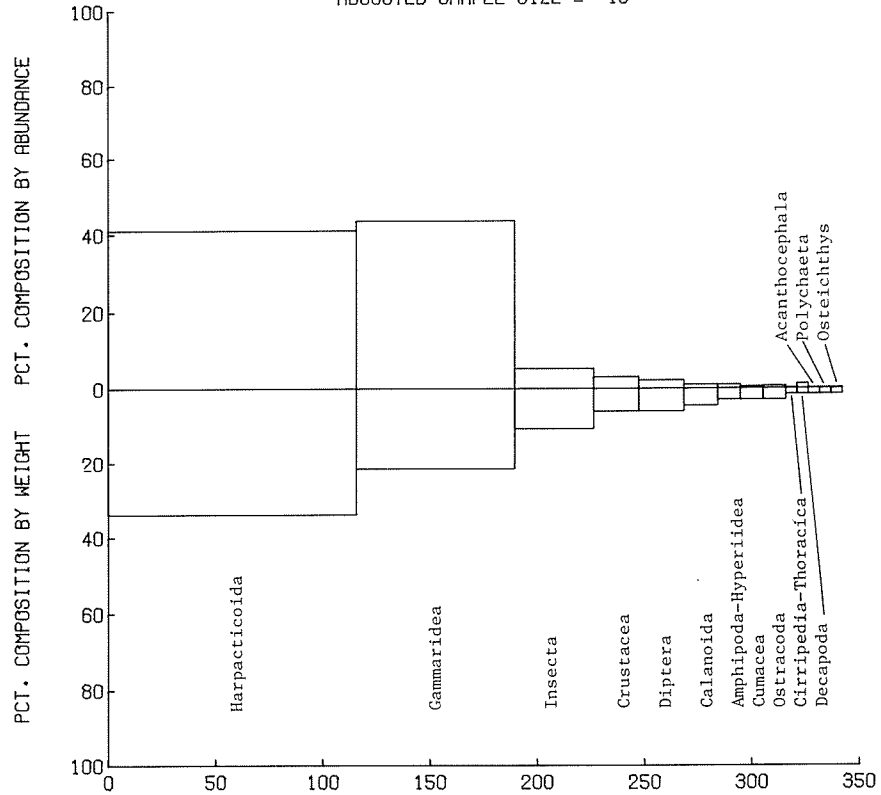
PERCENT DOMINANCE INDEX	.47	.26	.48
SHANNON-WEINER DIVERSITY	1.24	2.40	1.18
EVENNESS INDEX	.37	.74	.36

Appendix Fig. 1. (cont) f) Spit 6.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCBSCM, STATION FLORL

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON

ADJUSTED SAMPLE SIZE = 19



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ. OCCUR.	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	119.79	41.06	35.85	3872.0	59.05
GAMMARIDEA	73.68	43.59	21.24	4795.9	32.65
INSECTA	36.84	2.28	10.77	291.2	4.03
CRUSTACEA	21.05	3.98	6.15	194.4	1.32
DIPTERA	21.05	2.20	6.15	175.9	1.20
CALANOIDA	15.79	1.03	4.62	69.1	.61
AMPHIPODA-HYPERIDEA	10.53	1.03	3.06	43.2	.29
CUMACEA	10.53	.44	3.06	37.0	.25
OSTRACODA	10.53	.59	3.06	36.6	.26
CIRRIPIEDIA THORACICA	5.26	.15	1.54	6.9	.06
DECAPODA	5.26	1.17	1.54	14.3	.10
ACANTHOCEPHALA	5.26	.15	1.54	6.9	.06
POLYCHAETA	5.26	.15	1.54	6.9	.06
OSTEICHTHYS	5.26	.15	1.54	6.9	.06

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.36	.19	.46
SHANNON-WEINER DIVERSITY	1.89	2.96	1.47
EVENNESS INDEX	.56	.76	.39

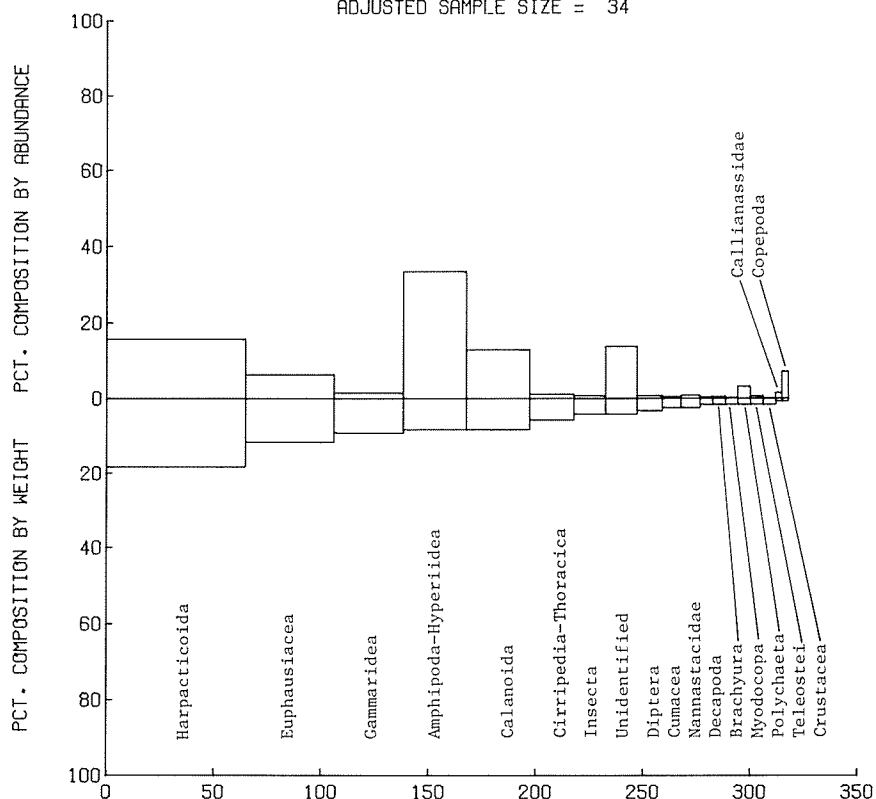
Appendix Fig. 1. (cont) g) Floral Pt.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCTNCM, STATION CARLS

8755010202 - ONCORHYNCHUS KETA

CHUM SALMON

ADJUSTED SAMPLE SIZE = 34



PREY ITEM	FREQ. OCCUR	NUM. COMP.	GRAV. COMP.	PPEY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	64.71	15.62	18.33	2197.1	37.62
EUPHAUSIACEA	41.18	6.13	11.67	732.8	12.55
GAMMARIDEA	32.35	1.39	9.17	341.4	5.85
AMPHIPODA-HYPERIIDEA	29.41	33.36	8.33	1226.2	20.99
CALANOIDA	29.41	12.74	8.33	621.0	10.63
CIRRIPIEDIA THORACICA	20.59	1.04	5.83	141.5	2.42
INSECTA	14.71	.66	4.17	71.0	1.21
UNIDENTIFIED	14.71	13.61	4.17	261.5	4.48
DIPTERA	11.76	.66	3.33	47.0	.80
CUMACEA	8.82	.42	2.50	25.7	.44
NANNASTACIDAE	8.82	.76	2.50	28.8	.49
DECAPODA	5.88	.35	1.67	11.8	.20
BRACHYURA	5.88	.38	1.67	12.0	.21
MYODOCOPA	5.88	.17	1.67	10.8	.19
POLYCHAETA	5.88	3.08	1.67	27.9	.48
TELEOSTEI	5.88	.52	1.67	12.9	.22
CRUSTACEA	5.88	.10	1.67	10.4	.18
CALLIANASSIDAE	2.94	1.39	.83	6.5	.11
COPEPODA	2.94	6.96	.83	22.9	.39

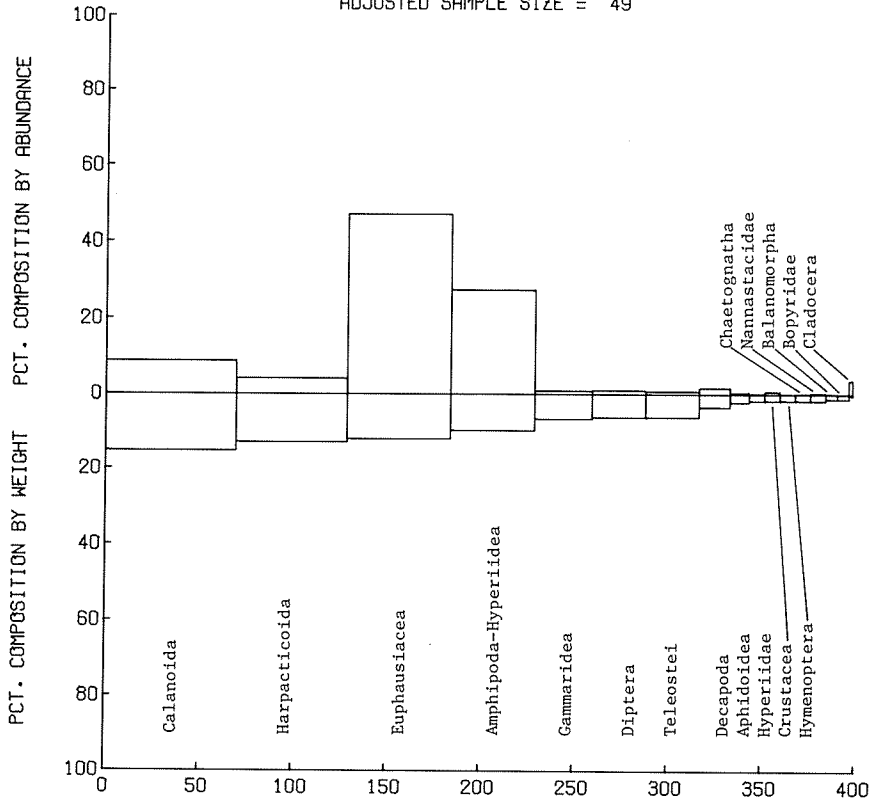
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.18	.08	.22
SHANNON-WEINER DIVERSITY	3.00	4.17	2.73
EVENNESS INDEX	.61	.84	.55

Appendix Fig. 2. IRI (Index of Relative Importance) diagram showing prey spectra of chum salmon fry captured by tow net in neritic habitat at a) Carlson Pt., Hood Canal, Washington, in 1977.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCTNCM, STATION DEVIL

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 49



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
CALANOIDA	69.39	8.72	15.25	1662.7	19.50
HARPACTICOIDA	59.18	4.07	13.00	1010.4	11.85
EUPHAUSIACEA	55.10	47.05	12.11	3259.6	38.24
AMPHIPODA-HYPERIIDEA	44.90	27.42	9.87	1674.0	19.64
GAMMARIDEA	30.61	.88	6.73	232.8	2.73
DIPTERA	28.57	1.02	6.28	208.5	2.45
TELEOSTEI	28.57	.72	6.28	200.0	2.35
DECAPODA	16.33	1.68	3.59	86.0	1.01
APHIDOIDEA	10.20	.41	2.24	27.0	.32
HYPERIIDAE	8.16	.14	1.79	15.8	.19
CRUSTACEA	8.16	.64	1.79	19.9	.23
HYMENOPTERA	8.16	.09	1.79	15.4	.18
CHAETOGNATHA	8.16	.13	1.79	15.7	.18
NANNASTACIDAE	8.16	.24	1.79	16.6	.19
BALANOMORPHA	6.12	.11	1.35	8.9	.10
BOPYRIDAE	6.12	.05	1.35	8.5	.10
CLADOCERA	2.04	3.61	.45	8.3	.10

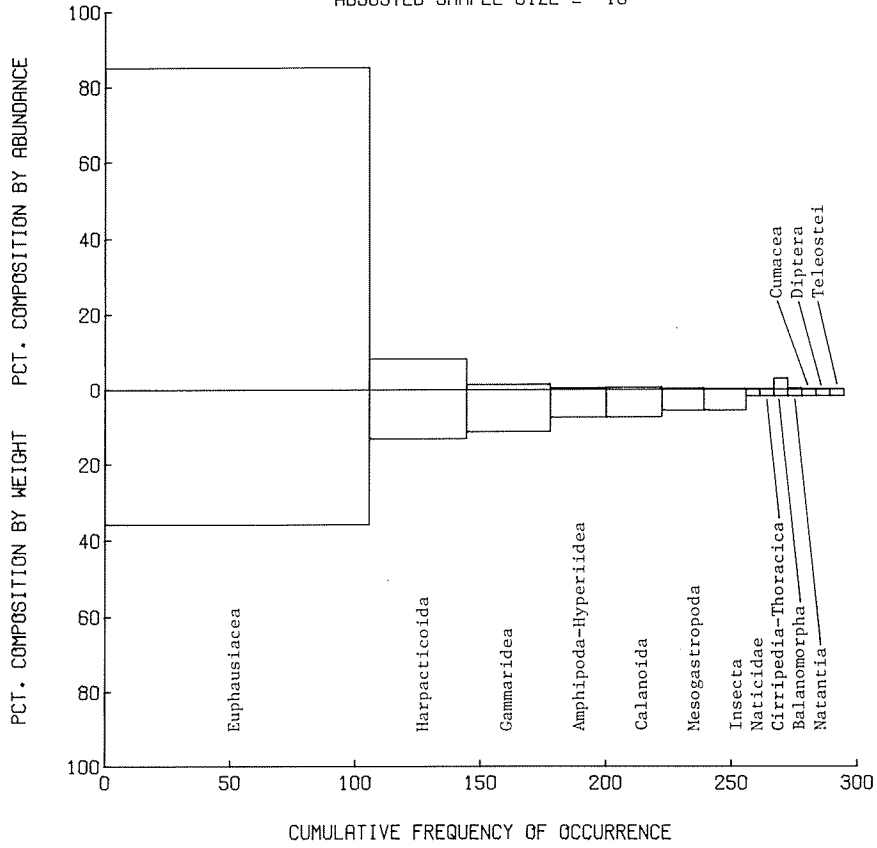
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.31	.08	.24
SHANNON-WEINER DIVERSITY	2.36	4.17	2.50
EVENNESS INDEX	.46	.81	.49

Appendix Fig. 2. (cont) b) Devils Hold delta.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCTNCM, STATION BROWN

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 18



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
EUPHAUSIACEA	105.56	85.16	35.85	12772.9	86.99
HARPACTICOIDA	38.89	8.30	13.21	836.5	5.70
GAMMARIDEA	33.33	1.38	11.32	423.5	2.88
AMPHIPODA-HYPERIDEA	22.22	.50	7.55	178.9	1.22
CALANOIDA	22.22	.57	7.55	180.3	1.23
MESOGASTROPODA	16.67	.31	5.66	99.6	.68
INSECTA	16.67	.19	5.66	97.5	.66
NATICIDAE	5.56	.13	1.89	11.2	.08
CIRRIPEIDIA THORACICA	5.56	.06	1.89	10.8	.07
BALANOMORPHA	5.56	2.96	1.89	26.9	.18
NATANTIA	5.56	.25	1.89	11.0	.08
CUMACEA	5.56	.06	1.89	10.8	.07
DIPTERA	5.56	.06	1.89	10.8	.07
TELEOSTEI	5.56	.06	1.89	10.8	.07

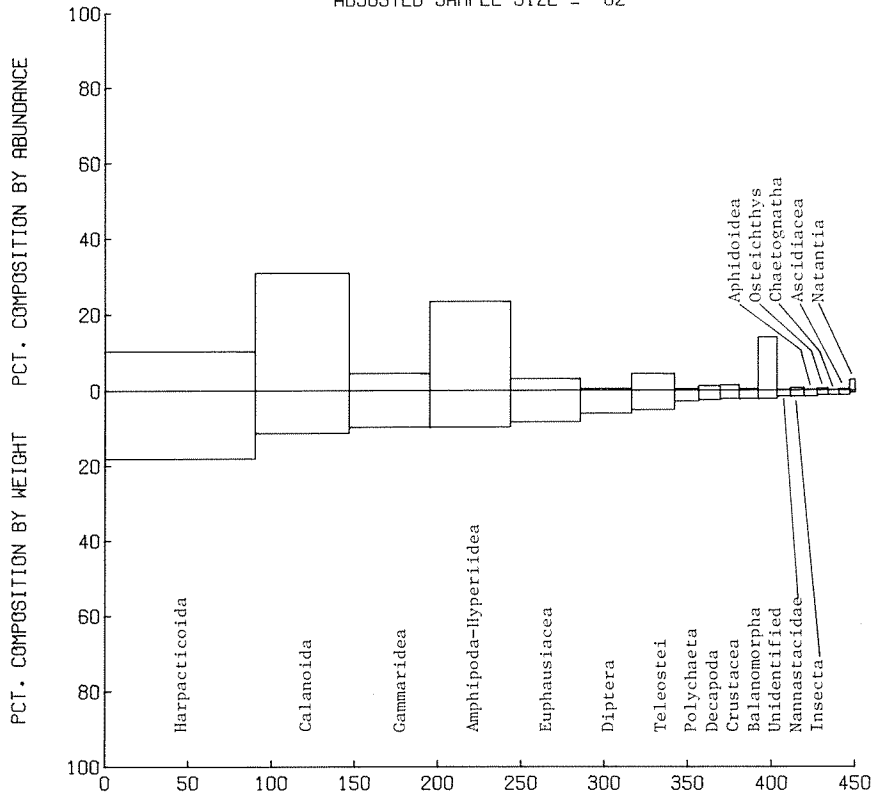
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.73	.18	.76
SHANNON-WINER DIVERSITY	.92	3.06	.97
EVENNESS INDEX	.24	.80	.23

Appendix Fig. 2. (cont) c) Brown Pt.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM  
FROM FILE IDENT. HCTNCM, STATION MARGL

8755010202 - ONCORHYNCHUS KETA  
CHUM SALMON  
ADJUSTED SAMPLE SIZE = 62



CUMULATIVE FREQUENCY OF OCCURRENCE

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	90.32	10.33	18.12	2569.6	29.78
CALANOIDA	56.45	30.66	11.33	2381.2	27.60
GAMMARIDEA	46.39	4.33	9.71	681.6	7.90
AMPHIPODA-HYPERIIDEA	46.39	23.34	9.71	1599.0	18.53
EUPHAUSIACEA	41.94	2.97	8.41	477.2	5.53
DIPTERA	30.65	.48	6.15	203.0	2.35
TELEOSTEI	25.81	4.27	5.18	243.9	2.83
POLYCHAETA	14.52	.39	2.91	47.9	.56
DECAPODA	12.90	1.15	2.59	48.2	.56
CRUSTACEA	11.29	1.36	2.27	40.9	.47
BALANOMORPHA	11.29	.41	2.27	30.2	.35
UNIDENTIFIED	11.29	13.87	2.27	182.2	2.11
NANNASTACIDAE	8.06	.21	1.62	14.8	.17
INSECTA	8.06	.58	1.62	17.7	.21
APHIDOIDEA	8.06	.21	1.62	14.8	.17
OSTEICHTHYS	6.45	.44	1.29	11.2	.13
CHAETOGNATHA	6.45	.11	1.29	9.0	.10
ASCIDIACEA	6.45	.35	1.29	10.6	.12
NATANTIA	3.23	2.72	.65	10.9	.13

PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

PERCENT DOMINANCE INDEX	.19	.08	.21
SHANNON-WEINER DIVERSITY	3.00	4.19	2.60
EVENNESS INDEX	.57	.79	.51

Appendix Fig. 2. (cont) d) Marginal Wharf.