FRI-UW-8026
December 1980

PREY COMMUNITY STRUCTURE AND TROPHIC ECOLOGY OF OUTMIGRATING JUVENILE CHUM AND PINK SALMON IN HOOD CANAL, WASHINGTON

A Synthesis of Three Years' Studies, 1977-1979[1]

by

Charles A. Simenstad, William J. Kinney, Steven S. Parker,
Ernest O. Salo, Jeffery R. Cordell and Hannele Buechner

Fisheries Research Institute
College of Fisheries
University of Washington
Seattle, Washington 98195

---

[1] This project supported jointly by the Washington State Department of Fisheries and the National Marine Fisheries Service.

Submitted December 31, 1980

Approved:
Roy E. Nakatani
Acting for the Director

CONTENTS

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

ACKNOWLEDGMENTS

Support for the collection of juvenile salmon and epibenthic zooplankton was derived principally from U.S. Navy funding as a part of their OICC-Trident environmental studies. Support for laboratory processing, data analysis, interpretation of the stomach and zooplankton samples, and later epibenthic and neritic zooplankton sampling was provided by the State of Washington's Department of Fisheries (WDF). We are especially indebted to Dr. Rick Cardwell and Mr. Kurt Fresh of WDF's Research and Development Division for their continuous support and encouragement.

Bruce Snyder and the other staff members of FRI's Big Beef Research Station contributed immeasurable assistance and cooperation in providing chum and pink salmon samples as well as other valuable support services for our studies on Hood Canal. Andy Palmer was instrumental in keeping our noble research vessel, the <u>Monty Python</u>, operating.

The critical reviews of this report, which were important to the final synthesis of this research and its clear presentation, were provided by Dr. Rick Cardwell and Mr. Kurt Fresh of WDF, Drs. Robert Burgner and Douglas Eggers of FRI.

ABSTRACT

Results from detailed studies of the prey organisms and prey community structure of juvenile chum (Oncorhynchus keta) and pink salmon (O. gorbuscha) in Hood Canal during the 1977-1979 outmigrations suggested that the migration rate of and habitat selection by the juvenile salmon related directly to availability of preferred prey organisms. Both epibenthic (harpacticoid copepods, gammarid amphipods) and neritic (calanoid copepods, hyperiid amphipods, larvaceans) zooplankton were important prey taxa, depending upon the size of the fish and the stage in the outmigration. Juvenile chum salmon entering Hood Canal early in the outmigration (February-March), especially naturally-spawned chums less than 40 mm FL, encountered relatively meager prey resources in shallow sublittoral and neritic habitats. Rapid migraton rates during this period suggested a behavioral response to low prey availability might have included immediate migration into habitats or regions with higher densities of preferred prey. In spring, as prey resources increased, migration rates decreased as the juvenile salmon spent more time foraging in nearshore habitats. During spring, small fish (<~50 mm) initially fed upon epibenthic zooplankton; upon growing to 45-55 mm FL (or being released at or larger than that size from hatcheries) they moved into neritic habitats and fed upon pelagic and nektonic zooplankton. Both depletion of epibenthic zooplankton and growth of the fish to the point that they could feed upon larger neritic prey and avoid predators may have been responsible for this habitat transition.

Selectivity for large prey was quite apparent in both epibenthic and neritic feeding modes, and could be attributed to a number of mechanisms, including 1) visual perception and active selection, 2) differential prey escape abilities, 3) functional morphology of the juvenile salmon, and 4) optimization of bioenergetic cost of foraging with nutritional value or prey. Comparison of biweekly estimates of surplus carrying capacity of Hood Canal for juvenile chum salmon and the abundance of almost 16×10^6 juvenile chums entering the canal in 1978 indicate that the existing densities of fish depleted the resources of utilizable epibenthic prey until early May, when the size of fish and increases in neritic zooplankton enabled the outmigrating chums to move into neritic habitats to feed. A number of recommendations were proferred relative to further research and development of hatchery release strategies based upon the estimated surplus carrying capacity of such estuarine and nearshore rearing habitats.

x 11

Blank

1.0 INTRODUCTION

1.1 Previous Investigations and the Argument for Limited Carrying Capacity of Chum and Pink Salmon in Hood Canal

Until recently the principal factors assumed to limit the production of juvenile salmonids in the northeast Pacific have usually included only those associated with the freshwater phase of their life history, e.g., spawning habitat, rearing habitat, and freshwater predator populations (McDonald 1960). Of the estuarine and nearshore marine[1] influences, predation has been most often implicated as the more significant factor affecting the survival of juvenile salmon (Parker 1968; Wickett 1958; Gilhousen 1962). Such early marine influences are especially important to chum (Oncorhynchus keta) and pink salmon (O. gorbuscha) which, because of their emigration from freshwater at a small size, appear to require nearshore habitats and environmental conditions conducive to rapid growth in order to avoid high mortalities due to predation (Parker 1971; Healey 1979).

The role of food limitation in estuarine and nearshore marine environs may be critical to the production of salmon (Healey 1979, 1980; Gallagher 1980; Gunsolus 1978). While freshwater feeding by chum and pink salmon prior to outmigration has been reported to be significant in British Columbia (Sparrow 1968; Mason 1974) and the eastern Soviet Union (Levanidov and Levanidova 1957), in Puget Sound and many regions of Alaska and Japan the prevalent migration behavior involves rapid migration from freshwater into estuarine and shallow nearshore marine habitats (Neave 1955; Bakkala 1970). Epibenthic and neritic food resources are utilized extensively during the initial period of marine residence (Kaczynski et al. 1973; Feller and Kaczynski 1975; Mason 1974; Healey 1979). Thus, in Puget Sound the first few weeks of residence in the marine environment may actually constitute a "critical" life history stage for juvenile chum and pink salmon in terms of feeding, growth, and escape from natural mortality forces such as predators and disease (Wickett 1958; Mason 1974; Healey et al. 1976; Healey 1979).

While there are few quantitative data on marine mortality rates of outmigrating juveniles salmon in Puget Sound. Koski's (1975) and Schroder's (1977) analyses of the survival of chum salmon stocks from the Big Beef Creek Research Station in northern Hood Canal, a fjord of Puget Sound, illustrated that the total marine survival rate of adults

---

[1] See the glossary, Appendix A, for definitions.

from early (March) chum salmon stocks tends to be lower and more variable than that of the late (April) outmigrating chum. This suggested to us that juvenile chum salmon entering northern Hood Canal early in the outmigration period may experience low growth, and higher mortality as a consequence, possibly because they migrated too early to take advantage of the spring increase in epibenthic and neritic zooplankton. Just what the mechanisms of mortality are, and how the rates are distributed among the estuarine, nearshore marine and oceanic phases of the chum salmon's life history are still not known. Taylor (1980) documented similarly differential mortality rates for early run and late run pink salmon from Auke Creek, Alaska; early run fish had an average ocean life of 515 days and a marine survival rate of 0.17% while late run fish had an average ocean life of 513 days and a marine survival rate eight foled (1.46%) that of the early run. Taylor attributed the differential mortality rates to the effect of low water temperatures slowing the growth of early run juveniles, thus making them more vulnerable to size-selective predators.

The hypothesis that limited prey resources and inadequate foraging success are responsible for higher mortality rates of outmigrating, early stock juvenile chum in Hood Canal also suggested that even the expanded populations of zooplankton present later in the outmigration could be overexploited given high enough densities of juvenile chum salmon. Hood Canal is receiving high priority by the Washington Department of Fisheries as a principal chum salmon production and harvest region and in fact is being managed almost exclusively for the production and harvest of chum salmon. By 1979 hatchery releases of chum salmon for Hood Canal, combined with other hatchery releases by the U.S. Fish and Wildlife Service and several Indian tribes approached 50 X 10^6 (Fig. 1). This total is exclusive of juveniles produced by naturally spawning chum salmon, the magnitude of which is inadequately known, although they are presumed to be generally depleted from historic levels. Enhancement of pink salmon is significantly lower, on the order of 2.5 X 10^6 juveniles released annually and is not expected to undergo the increase projected for chum salmon (J. Ames, Washington State Department of Fisheries, personal communication).

Optimal management of these and other chum salmon enhancement programs would seemingly require a basic knowledge of the functional relationships between the state of estuarine and nearshore marine prey resources and the migration behavior, foraging success, growth, residence time, and mortality rates of outmigrating juvenile chum. Such research information is certainly required in order to estimate the potential carrying capacity of Hood Canal at various stages in the juvenile salmon outmigration. Subsequent research and experimentation toward salmon hatchery release strategies to minimize the potential effects of competition and food limitation and increase the total survival to adult return.

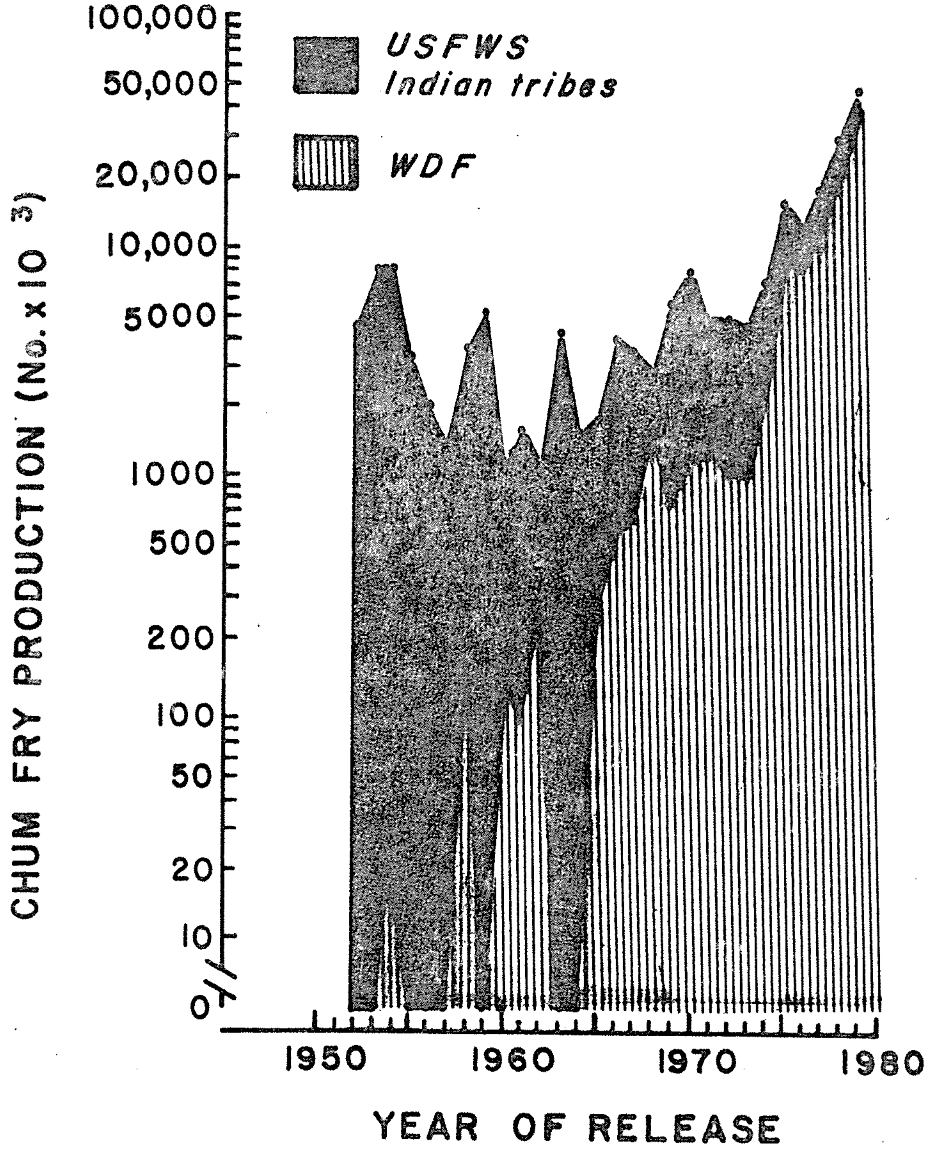


Fig. 1. Numbers of chum salmon fry released annually into Hood Canal, Washington (1952-1980) from state, federal, and Indian hatcheries (from Cardwell 1978).

The purpose of this report is to describe the functional trophic relationships between juvenile chum and pink salmon and their food resources as interpreted from the results of three and one half years of studies of the chum and pink salmon outmigrations in northern Hood Canal by the Fisheries Research Institute (FRI), University of Washington. We present evidence for a direct relationship between salmon outmigration behavior and the abundance of critical epibenthic and neritic prey populations and suggest that under some conditions the juvenile chum salmon production may be constrained by the carrying capacity of the Hood Canal ecosystem.

1.2 Development of Studies

Interactions between the zooplanktivorous juvenile salmon and their prey resources were examined as a part of FRI′s 1975-1979 investigations of the chum and pink salmon outmigration in northern Hood Canal that evaluated the potential impacts of U.S. Navy construction activities along the east shoreline (Fig. 2). Since it was suggested that the outmigration behavior of the juvenile salmon might reflect the composition and availability of prey organisms, these influences were also considered in evaluating the influence of the shoreline construction. In addition, it was considered important to compare different shoreline habitats relative to their support of preferred food organisms of chum and pink fry. Preliminary results of these studies in Hood Canal were reported in Simenstad (1977), Schreiner et al. (1977), Simenstad and Kinney (1978, 1979), Bax et al. (1978), and Salo et al. (1980).

1.3 Objectives

The central objective of the trophic studies was to document predator-prey interactions between juvenile chum and pink salmon and their prey resources.

Component objectives were to:

1) Describe the temporal and spatial prey composition and consumption by juvenile chum and pink;

2) Describe the temporal and spatial composition of epibenthic and neritic zooplankton communities;

3) Evaluate the characteristic selective predation by juvenile chum and pink salmon upon "available" zooplankton;

4) Evaluate the trophic importance of representative nearshore habitats;

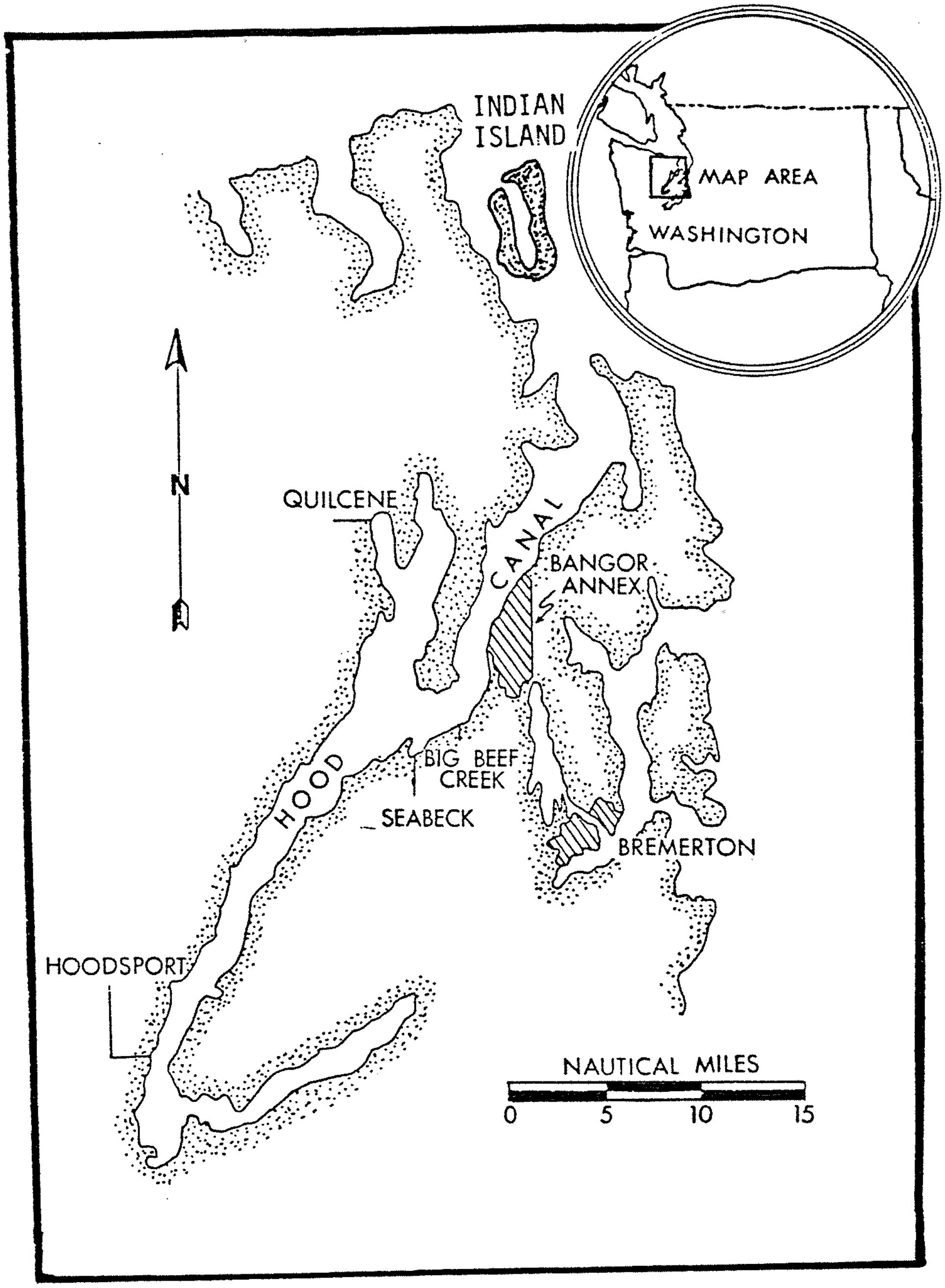


Fig. 2. Location of Bangor Annex, Indian Island Annex, and fish hatcheries at Big Beef Creek, Quilcene, and Hoodsport.

5) Relate the observed outmigration behavior of juvenile chum and pink salmon with their food habits and distribution and composition of prey resources;

6) Evaluate the potential for a limited "carrying capacity"--i.e., trophic relationships which bioenergetically or behaviorally set a threshold on the biomass or number of juvenile chum and pink salmon which can be supported by the Hood Canal ecosystem at any time.

2.0 MATERIALS AND METHODS

2.1 Capture of Juvenile Salmon

Earlier studies (Stober and Salo 1973; Tyler 1964, 1972) of outmigrating salmonids indicated that migrating juvenile chum and pink occur mainly in the surface waters of littoral, shallow sublittoral and neritic habitats. Accordingly, floating beach seines and surface trawls were utilized as the primary sampling gear in FRI's salmonid outmigration studies in northern Hood Canal (Salo et al. 1980).

2.1.1 Beach Seine Collections

A 10-m hand-held beach seine was used in the early stages of the outmigration until salmonids were captured frequently; thereafter a 37-m floating beach seine was used, deployed from an outboard skiff parallel to and 30 m from the shoreline. Both daytime and nighttime samplings were made at eleven locations over the five years' study (Fig. 3). A detailed description of the 37-m beach seine is included in Miller et al. (1977) and the associated operating procedure in Schreiner et al. (1977).

2.1.2 Townet Collections

The surface trawl utilized in Hood Canal was a 3 x 6-m opening townet that was towed spread between two vessels at a water speed of 1.5 to 2.0 knots. Except for 1976, when tow durations varied considerably, tow durations were standardized at 10 min. Both daytime and nighttime collections were made. A detailed description of the townetting procedure is available in Schreiner (1977) and Salo et al. (1980).

Twenty-eight townet transects, including shoreline, cross-canal and parallel offshore tow patterns, were sampled during the five years' study (Fig. 3).

2.1.3 Handling of Fish Samples

Subsamples of up to 100 juvenile chum and pink salmon were retained from each collection for length-weight measurements and selection for stomach analyses. In 1976, co-occurring juvenile coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*) and other potential predators (i.e., cutthroat trout, *Salmo clarki*, Pacific staghorn sculpin, *Leptocottus armatus*, Pacific tomcod, *Microgadus proximus*, buffalo sculpin, *Enophrys bison*) were also retained for indication of their predation upon juvenile chum and pink salmon.

All juvenile salmon were preserved in 10% buffered seawater formalin for at least 7 days before measuring and weighing, after which variations in length and weight were assumed to have been minimal.

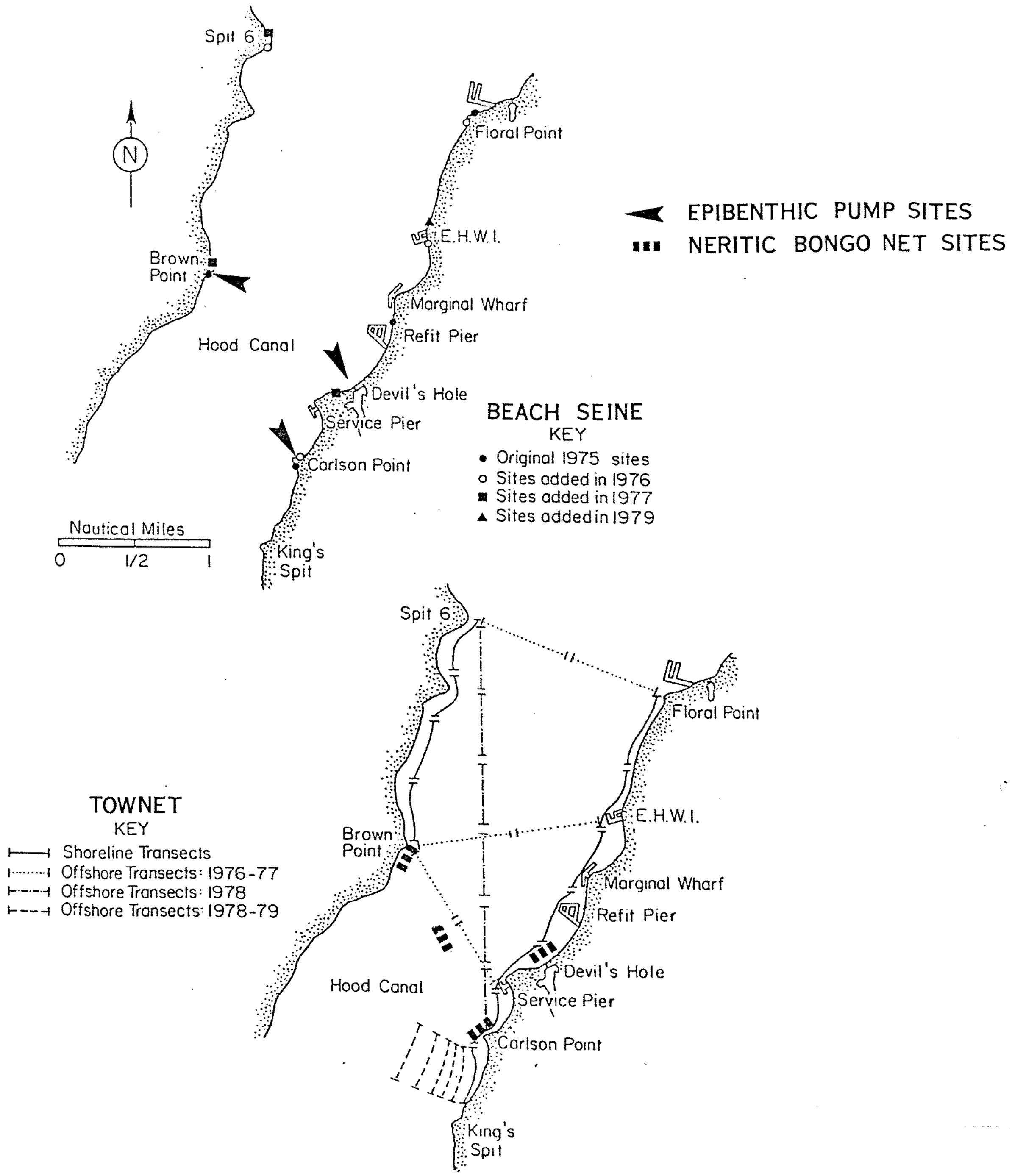


Fig. 3. Beach seine sites, townet transects, and epibenthic and neritic zooplankton sampling sites in northern Hood Canal, Washington, from 1975 to 1979.

2.2 Epibenthic Zooplankton Sampling

Epibenthic zooplankton was collected from three shallow sublittoral habitats in the study area, South Brown Point, North Carlson Point and Devil′s Hole Delta (Fig. 3). While the two points have similar bottom characteristics (sand substrate with eelgrass), Brown Point is more affected by current and wave energy and has a steeper slope than Carlson Point. Devil′s Hole Delta, the most protected habitat, is characterized by extensive eelgrass beds and is the only site with any freshwater dilution (from the small Devil′s Hole marsh). Seasonal production of benthic algae between April and October is considerable at Devil′s Hole and Carlson Point, but minimal at Brown Point.

Sampling was conducted from an anchored boat at approximately the -0.3 m tide level, using a diver-operated suction pump. The pump system (Fig. 4) drew water and associated plankters through a sealed-register, totalizing flowmeter and through two nested, conical nets of 0.505-mm and 0.209-mm mesh sizes with area/aspect ratios of 1:2.5 and 1:5.2, respectively. The epibenthic organisms were retained in standard net buckets with window screen of appropriate mesh size.

The 1-m^2 area sampling cylinder used in 1977 was reduced in 1978 to 0.25-m^2 and modified to exclude extra-area organisms by attachment of 0.209-mm mesh netting over the top of the cylinder and on ports cuts along the lower margin. SCUBA-equipped divers randomly placed the sampling cylinder on substrate bordering eelgrass (typically 50% inside-outside of eelgrass bed), then proceeded to "vacuum" the epibenthic area within the cylinder. After pumping 56.8 liters the two nested nets were then placed within the sampling tank and removed after 372.5 liters had been filtered in 1977 and after 200 liters were filtered in 1978 and 1979. Samples were fixed with 10% buffered seawater formalin to assure a solution of at least 5% formalin. Replicate samples were obtained by moving the sampling cylinder to nearby, similar substrate; duplicate samples were collected in 1977 and triplicate samples were collected in 1978 and 1979.

Epibenthic plankton samplings totaled 84 (each in two size fractions) in 1977, biweekly between December 30, 1976, and July 22, 1977. In 1978, 138 plankton pump samples were collected biweekly between February and December at these sites, including a diel series of 19 samples at Carlson Point on May 15. Forty-five epibenthic plankton samples were collected monthly between January and June in 1979, but only the fifteen samples from Carlson Point were examined.

2.3 Neritic Zooplankton Sampling

Surface neritic zooplankton was collected just offshore of the three principal epibenthic sites; oblique tows were made farther offshore of these areas as well as in mid-canal along a transect between

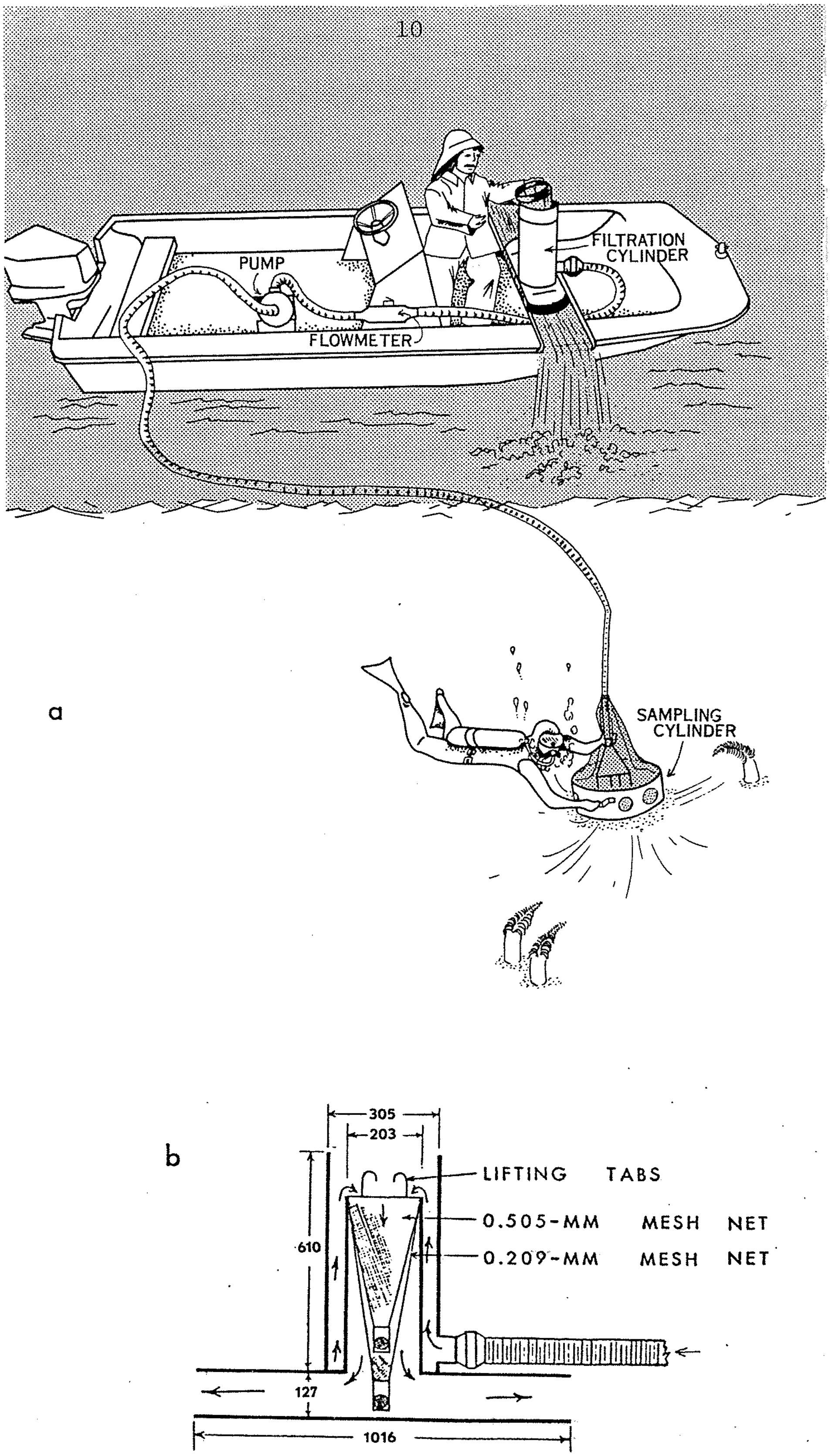


Fig. 4. Components of epibenthic suction-pump sampling system as in use (a) and cross-sectional detail of filtration cylinder (b). All measurements in mm.

Brown and Carlson points. A standard 60-cm fiberglass bongo net frame was equipped with Nitex nets of 0.333-mm mesh having an open area/aspect ratio of 8:1. Sample volume was determined using a General Oceanics propeller flowmeter centered in one frame. A recording depth meter was periodically used to determine the depth path of the gear during oblique hauls. Engine speed was set to 1000 rpm (1.8-2.7 knots) for both tow types.

Surface tows of 3 to 6 min duration were made with the net positioned 35° to port off the stern of the vessel. The gear was lowered one meter below the surface as the vessel approached the epibenthic sites, causing the vessel to heel into a spiral transect around the pivot of the bongo nets.

Oblique tows were made at a constant speed, parallel to shore (except for the mid-canal transect) with the boom positioned straight off the stern of the vessel. The gear was released from the boat, 22 m of cable were rapidly paid out from the winch before being stopped at a depth of 15 m, and then recovered at a constant speed of 0.25 m/sec).

As with epibenthic samples, neritic zooplankton samples were preserved in a 5% solution of buffered seawater formalin.

2.4 Stomach Analysis Procedure

Samples of five preserved fish per species per sample (when available) were measured for length (fork length) in millimeters and damp weight to the nearest 0.1 g. The stomach from the esophagus to just posterior of the pylorus was dissected from each fish, blotted on paper toweling, and then weighed to the nearest 0.01 g. The contents were then removed to a petri dish and the stomach lining immediately blotted on toweling and reweighed to derive the total contents weight by subtraction. Stomach fullness was qualitatively evaluated and coded from 1 (empty) to 7 (distended) and the stage of digestion determined and coded from 1 (all unidentifiable) to 6 (no digestion evident). Prey items were sorted under an illuminated dissecting microscope, enumerated and identified as specifically as the state of digestion allowed, and the history stage of the prey and the blotted wet weight of each taxon recorded to the nearest 0.001 g.

The mouth gape of juvenile chums was determined from selected subsamples of 1978 and 1979 chum, using a series of three graduated metal cones as described by Eggers (in review). A calibrated ocular micrometer was used to measure a pooled subsample (up to 100) of gammarid amphipods from tip of rostrum to end of telson, and copepods from anterior-most margin of hear to end of caudal furca. Amphipods and calanoid copepods were measured to the nearest 0.1 mm (minus antennae and setae), and harpacticoid and cyclopoid copepods to the nearest 0.025 mm.

2.5 Zooplankton Sorting and Identification

After being fixed at least 7 days in 5% formalin, plankton samples were transferred to 45% isopropanol with 5% propylene glycol. Rose bengal dye was added to the 0.209-mm epibenthic pump fractions at this time. Prior to sorting, the 0.209-mm fraction usually required panning to float the organisms away from fine sand and subsampling because of large numbers of organisms. A 10-ml glass syringe with a 2-mm orifice attached to a 250-ml flask was utilized in subsampling. The preserved sample was brought to 200 ml, the syringe was slowly filled with fluid, then forcibly expelled back into the flask, agitating the sample before each of five 2-ml subsamples was withdrawn. Neritic zoopankton samples were split using a Cooney plankton splitter.

The entire 0.505-mm fractions and the 0.209-mm subsamples of each epibenthic pump replicate and the subsamples of each neritic zooplankton replicate were completely identified and enumerated. In 1978 gammarid amphipods were separated from the other organisms, rinsed with isopropanol and water to remove glycerol, dried at 70°C for 24 hr, then weighed separately to the nearest 0.001 g. The two weights were combined and recorded as total fraction dry weight.

The lengths of up to 100 specimens of harpacticoid, calanoid, and cyclopoid copepods, and gammarid amphipods from selected samples were measured as previously described for the prey organisms.

2.6 Feeding Chronology Experiment

On May 15, during the peak of the 1978 outmigration season, a series of concurrent epibenthic pump and 10-m beach seine collections were made at Carlson Point. Seven samples were collected every three hours between 0200 and 2000, Pacific Standard Time (Table 1). Up to 10 juvenile chum and 10 pink salmon were collected with the 10-m beach seine and triplicate epibenthic zooplankton pump samples were collected immediately thereafter.

2.7 Otolith Daily Ring Determinations

Marshall and Parker (1979) have recently shown that sockeye salmon otoliths (sagittae) grow in diurnal cycles which result in the formation of a concentric, daily ring pattern as long as allometric growth is occurring. To investigate the feasibility of using daily otolith growth patterns to estimate early marine growth and residence time, otoliths were removed from a preserved (47% isopropanol) sample of juvenile chum marked during the 1979 outmigration studies (Salo et al. 1980). The otoliths were ground to the maximum diameter of the sagittal plane on 600 grit sandpaper, etched for 5-10 seconds with 10% HCl, thoroughly

Table 1. Samples of juvenile chum and pink salmon and epibenthic zooplankton collected during diel feeding chronology study, Carlson Point, 15 May 1972.

#	Time (PST)	Beach Seine Size (m)	Number of Fish Chum	Number of Fish Pink	Plankton Pump Time (PST)	Number of Replicates
1	0200	10	10	6	0340	1
2	0450	10	10	4	0525	3
3	0800	10	12	8	0840	3
4	1100	10	10	10	1130	3
5	1400	37	10	10	1430	3
6	1700	10	10	10	1755	3
7	1945	10	10	5	2010	3

rinsed with water, and set aside to dry. A gummed notebook paper reinforcer was affixed to the slide around each otolith pair, flooded with Euparal, and covered with a glass cover slip.

Visual examination and measurements of the otoliths were made microscopically at a 200X magnification. Two counts of the concentric rings, usually made in the posterior-dorsal quadrant, were obtained from the more readable of the two otoliths and the mean value determined. Special attention was given to the detection of ring patterns which could consistently be identified. Those patterns which are consistent throughout a sample may mark some transitional event in the growth history of salmon fry (Marshall and Parker 1979). When the chronology of this event is known, for example hatching or first feeding, the corresponding ring pattern formed on the otolith becomes a useful marker for initializing or correcting ring counts. Thus, these classifiable patterns are essential for aging juvenile (sub-yearling) salmonids precisely and reliably.

2.8 Data Manipulation

All data were recorded directly onto National Oceanic Data Center (NODC) type computer coding forms, which utilize the NODC taxonomic code. Raw data were verified and checked for accuracy, keypunched, and stored on magnetic tape for computer processing. Tabulation and basic statistical analyses of the data were performed using computer program packages specifically developed for FRI's stomach content and zooplankton data.

2.9 Data Presentation and Statistical Analysis

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 (usually >10). The three-axis IRI graphs illustrate frequency of occurrence (the proportion of stomachs containing a specific prey organism) plotted cumulatively on the abscissa and the percentages of total prey abundance and biomass plotted above and below the abscissa, respectively. Prey taxa with differing stages of digestion (e.g., partly digested shrimp, as opposed to the family Pandalidae or the species, *Pandalus borealis*) are graphed separately. All prey groups, including those assigned to a broad taxonomic level (family, order, or class) because of advanced digestion, have been arranged from left to right by decreasing frequency of occurrence.

The IRI value was computed as follows:

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

and is equivalent to the area encompassed by the bar for each prey category. In order to compare the IRI values between prey spectra with different sample sizes, the overall importance of general prey taxa has been discussed as a percentage of the sum of the IRI values of all prey taxa.

Three indices were used to describe numerical and gravimetric trophic diversity of the diet (Pielou 1977):

1) Percent dominance index:

$$\%\ \text{dominance} = \Sigma(p_i)^2$$

where p_i's are ratios of the number or biomass of prey i to the total prey abundance or biomass.

2) Shannon-Wiener diversity index:

$$H' = -\ \Sigma(p_i \log_2 p_i)$$

where p_i's are the same as above.

3) Evenness index:

$$e = \bar{H}/\ln S$$

where $\bar{H} = H$ and S = number of species and lnS is equivalent to H_{max}.

Diet overlap has been measured using a modified index of affinity (Sanders 1960), also called percent similarity index or PSI (Cailliet and Barry 1979):

$$\% S = \Sigma \min p_i$$

where p_i's are the ratios of the IRI prey i to the total sum of all prey IRI's.

2.10 Determination of Daily Ration

Estimates of daily ration were derived from the results of the May 15-16, 1978, feeding chronology experiment using the adjusted Bajkov (1935) method as proposed by Eggers (1977, 1979):

$$24\ \bar{S}\alpha = C_{t'} - (S_{24} - S_o)$$

where $\bar{S}$ is the mean level of food in the gut during the diel cycle, α is the instantaneous rate of gastric evacuation, $C_{t'}$ is the food consumed during the interval 0 to t′ and is the daily ration, S_{24} and S_o are the levels of food in the stomach at the end and beginning of the diel period, respectively.

The instantaneous rate of gastric evacuation, α, was estimated using Eggers' (1975) exponential decay function fitted for data for sockeye salmon smolts (40 - 130 mm) in Lake Washington and comparable data reported in the literature (e.g., Brett and Higgs 1970):

$$\alpha_{(T,W)} = (1 + K1\ e^{-(K_2 W)})K_3 T$$

where T = water temperature (°C), W = body weight (grams), K_1 = the constant 4.70988, K_2 = the constant 0.18703, and K_3 = the constant 0.006705.

2.11 Limitations of the Sampling Design

The sampling design from which fish stomachs were obtained was oriented toward other objectives (Salo et al. 1980) which required optimizing the number of sites and transects sampled in control and experimental areas along the Bangor shoreline and not necessarily toward collection of feeding juvenile salmon. As a consequence of limited sampling time, the collection of juvenile chum and pink salmon and their potential predators for stomach contents analysis was compromised in many instances, especially at either end of the outmigration period, when sample sizes sufficient for stomach analysis were not obtained during the standard sampling regime. Sampling locations for epibenthic and neritic zooplankton were chosen, however, to correspond to the best fish sampling sites in terms of frequency and intensity of effort.

3.0 RESULTS

3.1 Prey Composition of Outmigrating Juvenile Chum and Pink Salmon

3.1.1 Juvenile Chum Salmon

Juvenile chum salmon migrating out of Hood Canal fed upon epibenthic and neritic zooplankton. A composite IRI prey spectrum from 587 stomach samples[1] examined over the three years′ studies indicates that epibenthic harpacticoid copepods and gammarid amphipods and neritic calanoid copepods, hyperid amphipods, euphausiids and larvaceans comprised the most important prey taxa (Fig. 5). The size (fork length, FL) range of the juvenile chum salmon included in this summary was between 32 mm and 121 mm. A complete, detailed breakdown of IRI prey spectra, by date, sampling location and species, can be found in a separate volume (Simenstad and Kinney, in press).

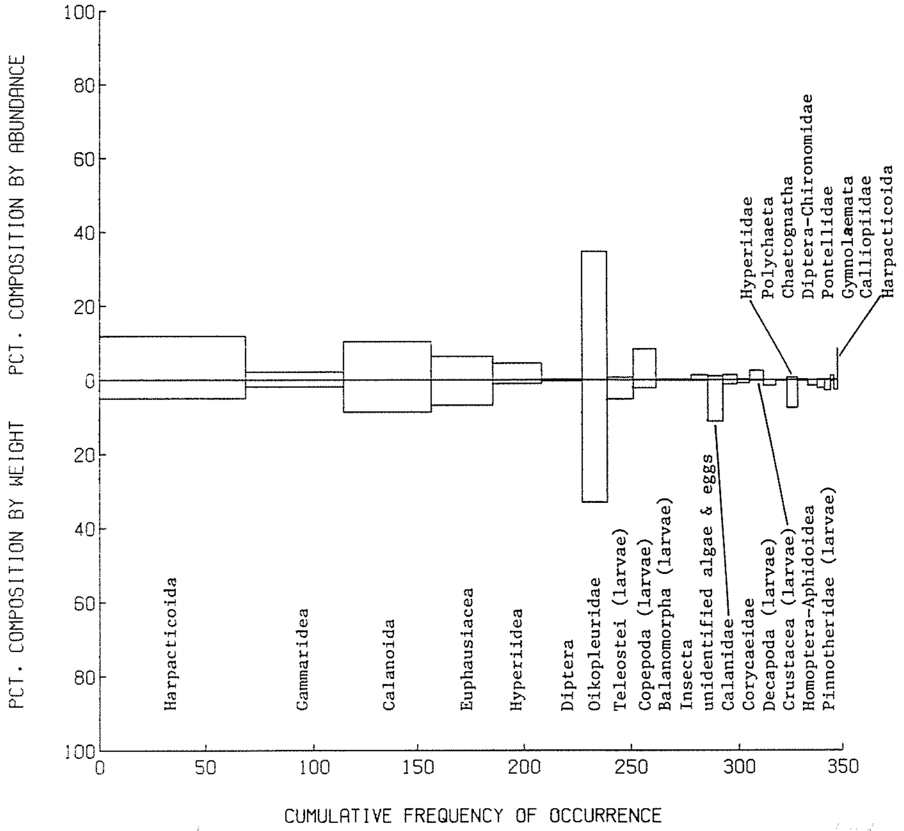
The harpacticoid copepods were usually not identified to species due to their difficult taxonomy, but examination of subsamples from 1977 and 1979 collections indicated that _Harpacticus_ sp. were the prominent prey. The prevalent gammarid amphipod species were _Paracalliopiella pratti_ and _Ischyrocerus_ sp.; the common calanoids were _Calanus_, (_pacificus_ x _marshallae complex_), _Pseudocalanus_ spp., and _Epilabidocera amphitrites_; hyperiid amphipods were primarily _Parathemisto pacifica_; and the euphausiids were unidentifiable larvae and juveniles. The larvacean was _Oikopleura_ sp. Most fish larvae were unidentifiable but larvae of Pacific herring, _Clupea harengus pallasi_, and Pacific sand lance, _Ammodytes hexapterus_, were identified on several occasions.

Whether the migrating salmon forage upon epibenthic organisms of shallow sublittoral habitats or upon neritic organisms in open water appears to depend upon the size of the fish and stage in the outmigration period. Immediately upon entry into Hood Canal small (30-40 mm FL) juvenile chum (typically orginating from naturally-producing populations or from the spawning channel at Big Beef Creek) fed predominantly upon the epibenthos, including harpacticoid copepods, gammarid amphipods, polychaete annelids and crustacean eggs (Table 2). After the fish grew larger than 45-55 mm FL or entered the Canal at such a size from hatchery facilities they fed more upon neritic organisms such as euphausiids,

---

[1] Only 4 (0.7%) of the total sample of 591 had no prey organisms in their stomachs; sample sizes from beach seine collections included 270 in 1977, 81 in 1978 and 64 in 1979 and those from townet collections included 167 in 1977, 6 in 1978, and 3 in 1973.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. 77-79 , STATION ALCHM
PREDATOR 8755010202 - ONCORHYNCHUS KETA
(CHUM SALMON) ADJUSTED SAMPLE SIZE = 587



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	68.48	11.78	4.91	1143.0	29.46
GAMMARIDEA	45.83	2.16	1.71	177.4	4.57
CALANOIDA	42.42	10.33	8.59	802.4	20.68
EUPHAUSIACEA	29.13	6.40	6.88	387.0	9.97
AMPHIPODA-HYPERIIDEA	22.66	4.57	.98	125.9	3.24
DIPTERA	18.57	.24	.31	10.2	.26
OIKOPLEURIDAE	12.10	34.64	32.90	816.9	21.05
TELEOSTEI	11.75	.70	5.16	68.9	1.77
COPEPODA	10.56	8.36	2.04	109.8	2.83
BALANOMORPHA	8.69	.15	.11	2.2	.06
INSECTA	7.84	.16	.15	2.5	.06
UNIDENTIFIED ALGAE AND EGGS	7.67	1.40	.15	11.9	.31
CALANIDAE	6.98	.98	11.10	84.3	2.17
CORYCAEIDAE	6.64	1.35	1.16	16.6	.43
DECAPODA	6.13	.25	.76	6.2	.16
CRUSTACEA	6.13	2.57	.08	16.2	.42
HOMOPTERA-APHIDOIDEA	5.96	.06	1.56	9.7	.25
PINNOTHERIDAE	5.62	.08	.09	.9	.02
HYPERIIDAE	5.11	.72	7.54	42.2	1.09
POLYCHAETA	5.11	.19	.14	1.7	.04
CHAETOGNATHA	4.43	.04	1.37	6.3	.16
DIPTERA-CHIRONOMIDAE	3.75	.23	2.12	8.8	.23
PONTELLIDAE	2.73	.13	2.86	8.2	.21
GYMNOLAEMATA	1.87	1.18	.36	2.9	.07
CALLIOPIIDAE	1.70	.29	2.61	4.9	.13
HARPACTICOIDA	.17	8.53	.00	1.5	.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)

	NUM. COMP.	GRAV. COMP.	PERCENT TOTAL IRI
PERCENT DOMINANCE INDEX	.17	.15	.19
SHANNON-WEINER DIVERSITY	3.37	3.67	2.89
EVENNESS INDEX	.49	.54	.42

Fig. 5. IRI prey spectrum of juvenile chum salmon in Hood Canal, Washington, 1977-1979. Prey taxa have been pooled to the phylogenetic level of family or above.

Table 2. Prey taxa composition, based on percent of total index of relative importance, of beach seine-caught chum fry in northern Hood Canal according to fish size interval, 1977.

Sample	Fish length interval (mm)							
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
April 20-May 19, 1977								
(n)	(12)	(29)	(24)	(2)				
Harpacticoid copepods	34.85	10.65	13.89	22.78				
Polychaete annelids	22.20	0.46	0.57					
Unidentified eggs	24.37	2.55	0.19					
Calanoid copepods	6.23	4.97	8.35	5.64				
Gammarid amphipods	4.58	5.42	5.33					
Euphausiids	4.26	73.89	65.88	66.87				
Barnacle larvae	2.28	0.24	0.92					
Fish larvae	0.28	0.60	0.91					
Insects	0.24	0.33	1.30	4.71				
Tunicate larvae	0.24	0.04	0.17					
Cumaceans	0.24	0.15						
Hyperiid amphipods		0.59	0.32					
Decapod larvae		0.08						
Mesogastropods		0.04	0.14					
Cladocerans			1.69					
May 20-June 19, 1977								
(n)	(1)	(2)	(9)	(2)				
Harpacticoid copepods	55.43	4.91	52.84					
Calanoid copepods	17.43	26.55	13.67	29.46				
Gammarid amphipods	13.91		11.69	3.80				
Decapod larvae	13.20			3.80				
Hyperiid amphipods		60.32	7.55	51.40				
Euphausiids		4.11	2.14					
Insects		4.11	0.23	3.80				
Mesogastropods			6.59					
Unidentified eggs			2.97	7.73				
Fish larvae			1.88					
Bopyrid isopods			0.23					
Cumaceans			0.23					

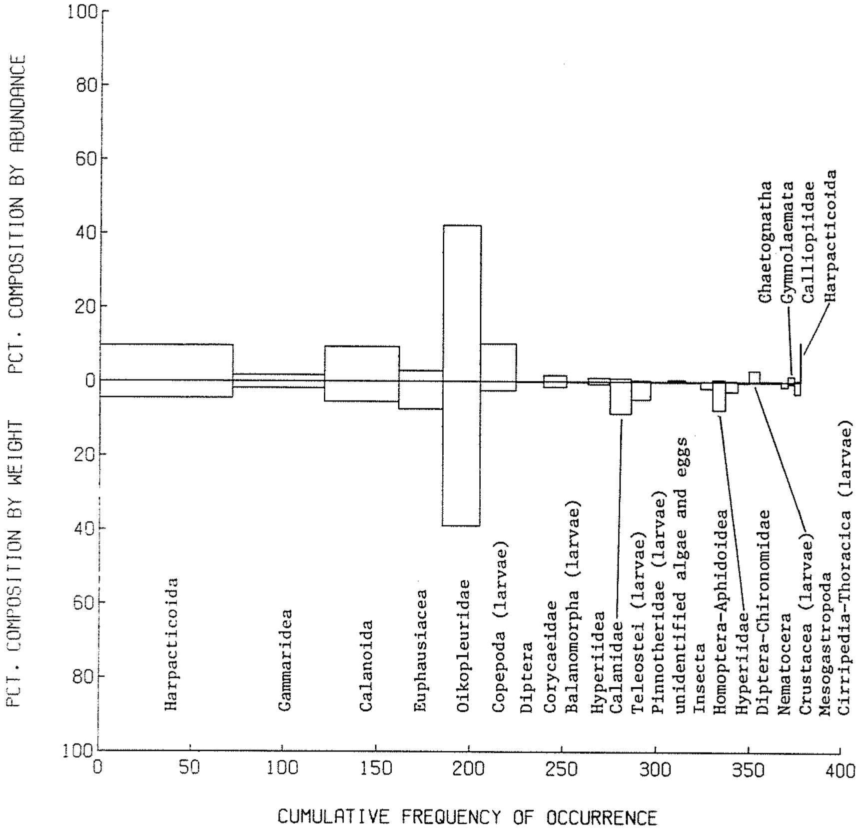
Table 2. Prey taxa composition, based on percent of total index of relative importance, of beach seine-caught chum fry in northern Hood Canal according to fish size interval, 1977 - continued.

Sample	Fish length interval (mm)							
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
June 20-July 21, 1977								
(n)			(6)	(13)		(8)	(5)	(1)
Calanoid copepods			22.28	22.34		41.33	31.50	
Hyperiid amphipods			16.19	29.58		42.15	55.84	58.93
Insects			14.86	18.39		1.14		
Harpacticoid copepods			12.57	7.59		4.19	2.50	
Gammarid amphipods			12.33	4.41		0.94		
Copepod larvae			7.65					
Cumaceans			7.38	1.64		0.22		
Decapod larvae			2.07	2.31		4.67	3.05	41.07
Sphaeromatid isopods			1.22					
Polychaete annelids			0.66					
Caligoid copepods			0.56					
Ostracods			0.56	3.01				
Caprellid amphipods			0.56					
Fish larvae			0.56	0.57		0.22	0.58	
Unidentified eggs			0.56			0.89		
Euphausiids				6.42		3.58	5.36	
Chaetognaths				0.57		0.22	0.59	
Cladocerans				1.84				
Barnacle larvae						0.22		
Bopyrid isopods						0.22		
Mysids							0.59	

calanoid copepods, and hyperiid amphipods. This effect of fish size upon selection of foraging habitat can also be illustrated by comparing the prey spectra of fish captured in shallow sublittoral habitats by beach seining to those captured in neritic habitats by townetting because there is a general increase in size of chum with increasing distance from shore (Salo et al. 1980). Larvaceans and harpacticoid copepods comprised over 60% of the total IRI prey spectrum of beach seine-caught chums (Fig. 6), whereas over 85% of the prey spectrum of townet-caught chums was euphausiids, calanoid copepods, and hyperiid amphipods (Fig. 7). Larvaceans Oikopleura sp. were prominent in the diet of beach seine-caught chums in the diet of large ($\bar{x}$ = 53 mm FL) chums in the June 1979 collections. In the three years sampled this neritic organism appeared most frequently in townet-caught chums and was rarely found in the 1977 pump samples.

Temporal shifts in the prey composition of juvenile chums captured in shallow sublittoral habitats (Fig. 8) and those captured in neritic habitats (Fig. 9) in 1977 (the sampling year with the highest, most consistent sample size distribution) illustrated that neritic fish were eating predominantly neritic prey organisms by early May. Although there were several prominent pulses of nonepibenthic prey consumed by fish captured in shallow sublittoral habitats, their diet generally consisted of epibenthic prey throughout the outmigration period until early July when calanoid copepods became prominent. Variability in diet composition of juvenile chums captured at the three principal shallow sublittoral sampling sites--Carlson Point, Devil's Hole Delta, and Brown Point--was less than among sampling years (Table 3; Appendix B, Table 1). Although there was considerable variability in overlap of prey spectra, even within a month, the mean overlap between sites, within years, was considerably higher (PSI $\bar{x}$ = 60.72) than between years, within site (PSI $\bar{x}$ = 25.78). Diet overlap also appeared to be consistently higher for larger, neritic-feeding chums captured late in the outmigration period (Appendix B, Table 1).

Although the sample sizes were often too low to provide good comparisons, differences in prey composition were evident between juvenile chum marked and released from the Big Beef Creek Research Station and unmarked conspecifics captured concomitantly in northern Hood Canal early in the 1979 outmigration (Table 4; Appendix B, Table 2). Much of the variation is probably due to differences in size between the marked and unmarked fry because diet overlap values between marked cohorts were generally higher (despite size differences) than the overlap between marked and unmarked chum fry, especially between adjacent size groups. Diet overlap, however, increased with the progression of the outmigration. After the transition to neritic feeding the marked fry often illustrated similar prey composition across different size intervals. By June, however, larvaceans (Oikopleura sp.) constituted the principal prey component for all chum fry; only the 50-59 mm-long unmarked chum fry had less than 80% of the total prey IRI contributed by these pelagic tunicates.



INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. 77-79 . STATION BSBCD
PREDATOR 8755010202 - ONCORHYNCHUS KETA
(CHUM SALMON) ADJUSTED SAMPLE SIZE = 321

PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	72.59	9.75	4.43	1029.4	23.97
GAMMARIDEA	48.60	1.72	1.77	169.4	3.94
CALANOIDA	39.88	9.43	5.48	594.4	13.84
EUPHAUSIACEA	24.30	2.89	7.56	253.7	5.91
OIKOPLEURIDAE	19.94	42.26	38.97	1619.6	37.71
COPEPODA	19.00	10.27	2.48	242.4	5.64
DIPTERA	14.95	.10	.22	4.8	.11
CORYCAEIDAE	12.15	1.69	1.41	37.6	.88
BALANOMORPHA	11.84	.10	.10	2.3	.05
AMPHIPODA-HYPERIIDEA	11.53	1.03	.68	19.7	.46
CALANIDAE	11.21	.91	8.68	107.6	2.51
TELEOSTEI	10.28	.35	4.78	52.8	1.23
PINNOTHERIDAE	9.66	.09	.10	1.9	.04
UNIDENTIFIED ALGAE AND EGGS	9.03	.45	.15	5.4	.13
INSECTA	8.72	.07	.14	1.9	.04
HOMOPTERA-APHIDOIDEA	6.54	.03	1.81	12.1	.28
HYPERIIDAE	6.54	.60	7.67	54.1	1.26
DIPTERA-CHIRONOMIDAE	6.54	.29	2.57	18.7	.44
NEMATOCERA	5.92	.04	.24	1.6	.04
CRUSTACEA	5.61	3.07	.05	17.5	.41
MESOGASTROPODA	5.61	.25	.05	1.7	.04
CIRRIPEDIA THORACICA	5.30	.11	.04	.8	.02
CHAETOGNATHA	3.43	.02	1.29	4.5	.10
GYMNOLAEMATA	3.43	1.48	.44	6.6	.15
CALLIOPIIDAE	3.12	.37	3.17	11.0	.26
HARPACTICOIDA	.31	10.71	.00	3.3	.08

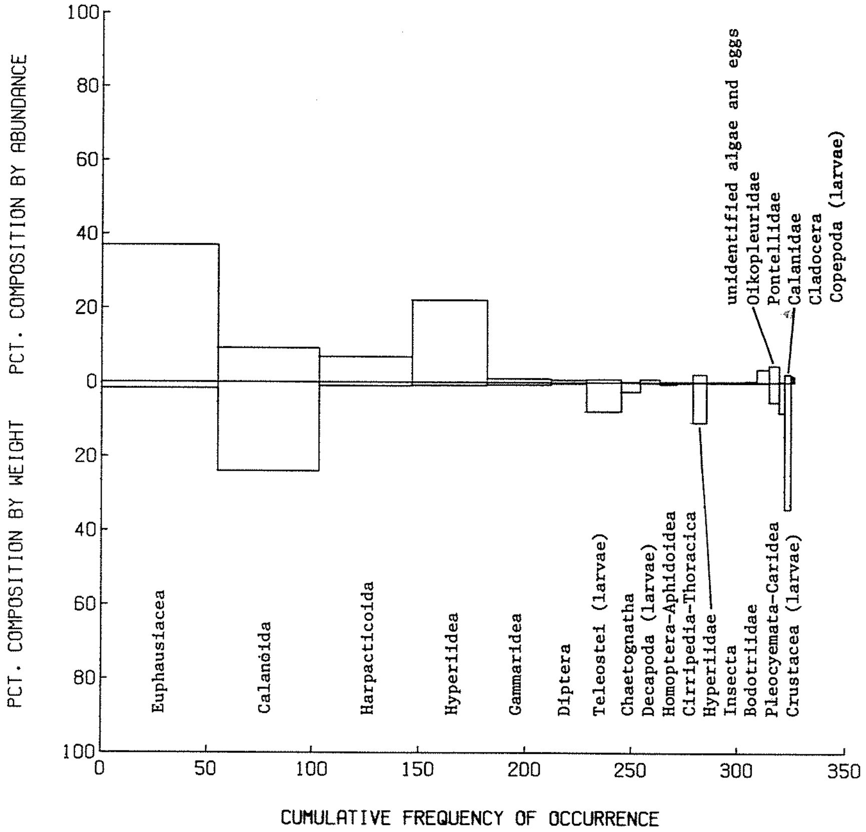
PREY TAXA WITH FREQ. OCCUR. LESS THAN 5 AND NUMERICAL AND GRAVIMETRIC COMPOSITION BOTH LESS THAN 1 ARE EXCLUDED FROM THE TABLE AND PLOT (BUT NOT FROM CALCULATION OF DIVERSITY INDICES)

	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
PERCENT DOMINANCE INDEX		.22	.18		.23
SHANNON-WEINER DIVERSITY		3.01	3.50		2.71
EVENNESS INDEX		.46	.54		.42

Fig. 6. IRI prey spectrum of beach seine-caught juvenile chum salmon in Hood Canal, Washington, 1977-1979. Prey taxa have been pooled to the phylogenetic level of family or above.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. 77-79 . STATION TNBCD

PREDATOR 8755010202 - ONCORHYNCHUS KETA
(CHUM SALMON) ADJUSTED SAMPLE SIZE = 109



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
EUPHAUSIACEA	55.05	37.04	1.68	2131.0	39.38
CALANOIDA	47.71	9.27	24.03	1588.4	29.36
HARPACTICOIDA	44.04	6.87	.90	342.4	6.33
AMPHIPODA-HYPERIIDEA	34.86	22.20	.72	798.7	14.76
GAMMARIDEA	30.28	.97	.62	48.2	.89
DIPTERA	16.51	.75	.34	18.0	.33
TELEOSTEI	16.51	.86	7.83	143.5	2.65
CHAETOGNATHA	9.17	.18	2.54	25.0	.46
DECAPODA	9.17	.95	.19	10.5	.19
HOMOPTERA-APHIDOIDEA	8.26	.27	.51	6.4	.12
CIRRIPEDIA THORACICA	7.34	.25	.15	3.0	.05
HYPERIIDAE	6.42	2.15	10.79	83.1	1.54
INSECTA	6.42	.19	.13	2.1	.04
NANNASTACIDAE	6.42	.30	.13	2.8	.05
PLEOCYEMATA-CARIDEA	5.50	.21	.11	1.8	.03
CRUSTACEA	5.50	.36	.11	2.6	.05
BODOTRIIDAE	5.50	3.50	.11	19.9	.37
OIKOPLEURIDAE	4.59	4.63	5.27	45.4	.84
PONTELLIDAE	2.75	.28	8.10	23.0	.43
CALANIDAE	2.75	2.19	34.08	99.8	1.84
CLADOCERA	.92	1.88	.02	1.7	.03
COPEPODA	.92	1.64	.02	1.5	.03

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	.21	.20	.27
SHANNON-WEINER DIVERSITY	3.09	2.90	2.38
EVENNESS INDEX	.53	.50	.41

Fig. 7. IRI prey spectrum of townet-caught juvenile chum salmon in Hood Canal, Washington, 1977-1979. Prey taxa have been pooled to the phylogenetic level of family or above.

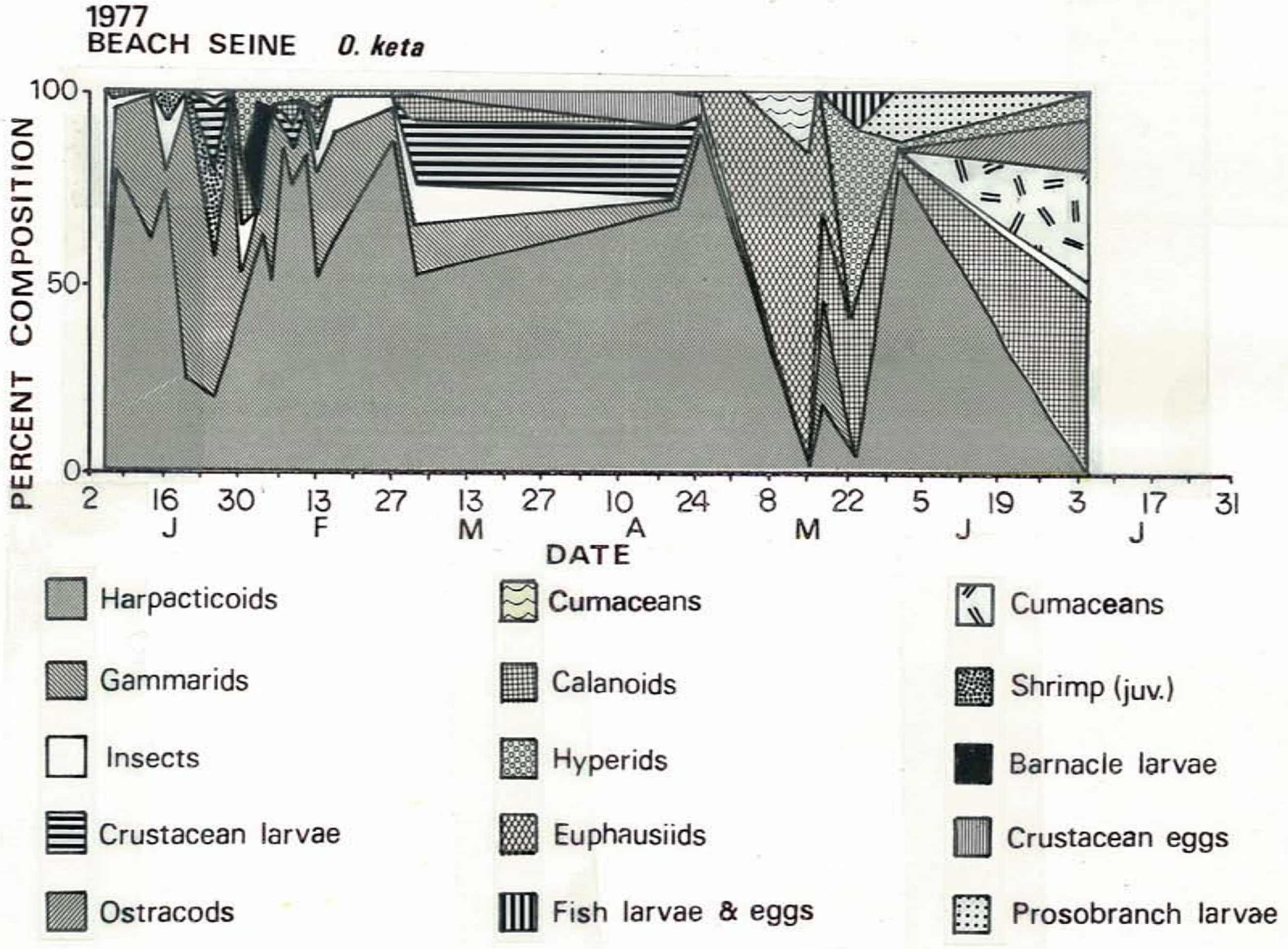


Fig. 8. Prey composition (% total Index of Relative Importance) of beach seine-caught juvenile chum salmon migrating through Hood Canal, Washington, 1977.

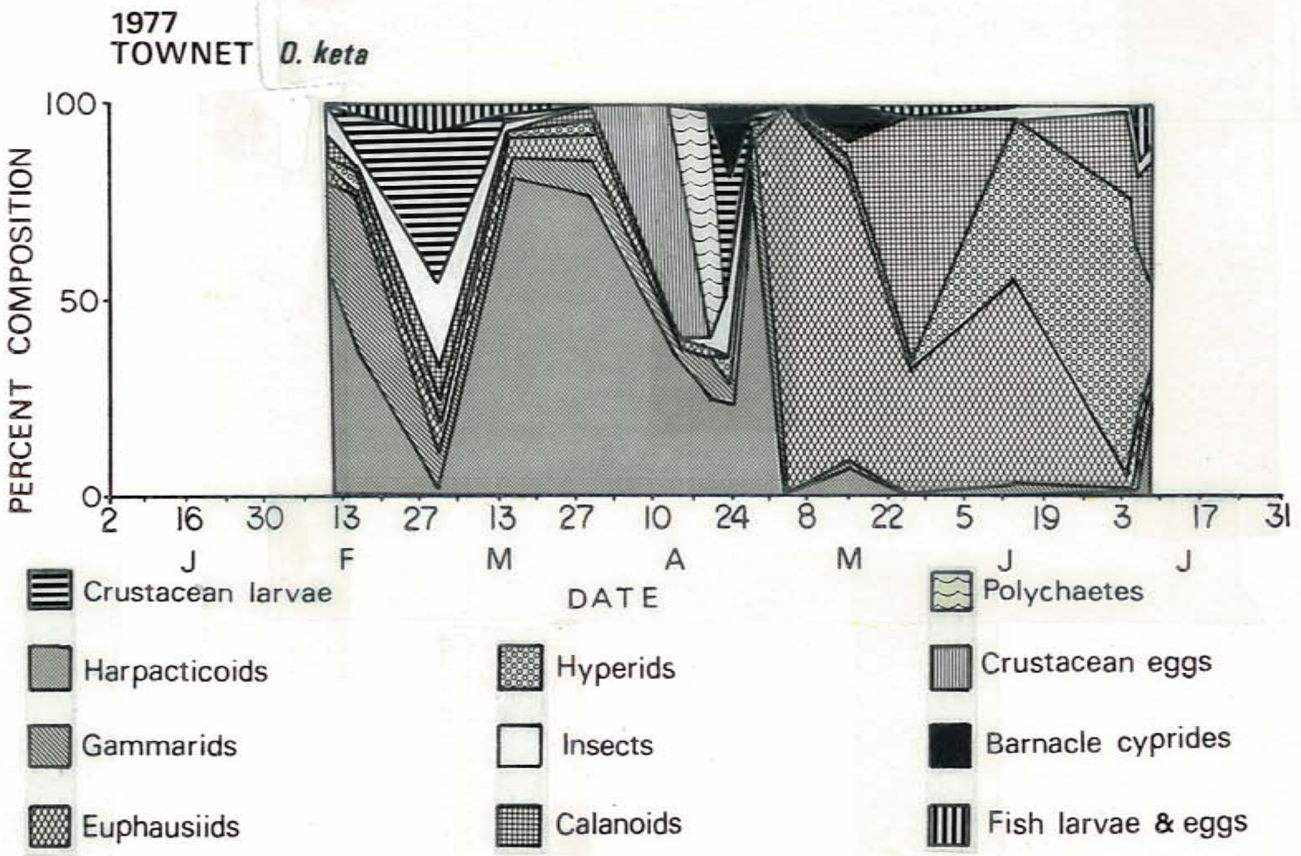


Fig. 9. Prey composition (% total Index of Relative Importance) of townet-caught juvenile chum salmon migrating through Hood Canal, Washington, 1977.

Table 3. Overlap (percent similarity index, Sanders 1960) in prey composition (percent total IRI) within site and between sites within year of collection.

Between years, within site

	Month	1977 vs. 1978	1977 vs. 1979	1978 vs. 1979	$\bar{x}$
Carlson Point	April	17.70	7.18	41.37	22.08
	May				
	June		4.88		4.88
Devils Hole Delta	April	33.58	20.69	30.65	28.31
	May				
	June				
Brown Point	April		50.81		50.81
	May				
	June				
	$\bar{x}$ =	25.64	20.89	36.01	25.78

Between sites, within years

	Month	Carlson Pt. vs. Devils Hole Delta	Carlson Pt. vs. Brown Pt.	Devils Hole Delta vs. Brown Pt.	$\bar{x}$
1977	April	28.06	85.84	26.35	46.75
	May			86.60	86.60
	June				
1978	April	57.45			57.45
	May				
	June				
1979	April	50.45	17.70	22.58	30.24
	May				
	June	83.03	78.83	85.87	82.58
	$\bar{x}$ =	54.75	60.79	55.35	60.72

Table 4. Overlap (Percent Similarity Index) in prey composition of marked and unmarked chum fry, according to size interval, during three periods of the 1979 outmigration.

Date			40-49 mm	50-59 mm		60-69 mm		70-79 mm
			marked	marked	unmarked	marked	unmarked	marked
February 6, 1979								
	30-39 mm	unmarked	15.06	22.69				
	40-49 mm	marked		71.78				
April 25, 1979								
	40-49 mm	unmarked			21.62		8.50	
	50-59 mm	unmarked					62.35	
June 5, 1979								
	40-49 mm	marked		91.95	67.97	90.72	90.05	85.54
	50-59 mm	marked			63.62	83.55	86.92	90.25
		unmarked				65.44	65.57	59.92
	60-69 mm	marked					87.42	84.31
		unmarked						84.83

3.1.2 Juvenile Pink Salmon

Pink salmon fry appeared to prey more upon neritic organisms than did chum fry. In 1978, the only year pink fry were caught, adult calanoid copepods and copepod larvae dominated the prey composition while epibenthic organisms were not prevalent in the stomach contents of pink fry captured in shallow sublittoral habitats (Fig. 10). The principal calanoids were *Calanus* sp., *Epiladocera amphitrites* and *Pseudocalanus* sp.. Despite their prevalence in the prey spectra of co-ocurring chum fry, *Oikopleura* sp. were not consumed frequently by pink fry.

3.1.3 Diet Overlap Between Juvenile Chum and Pink Salmon

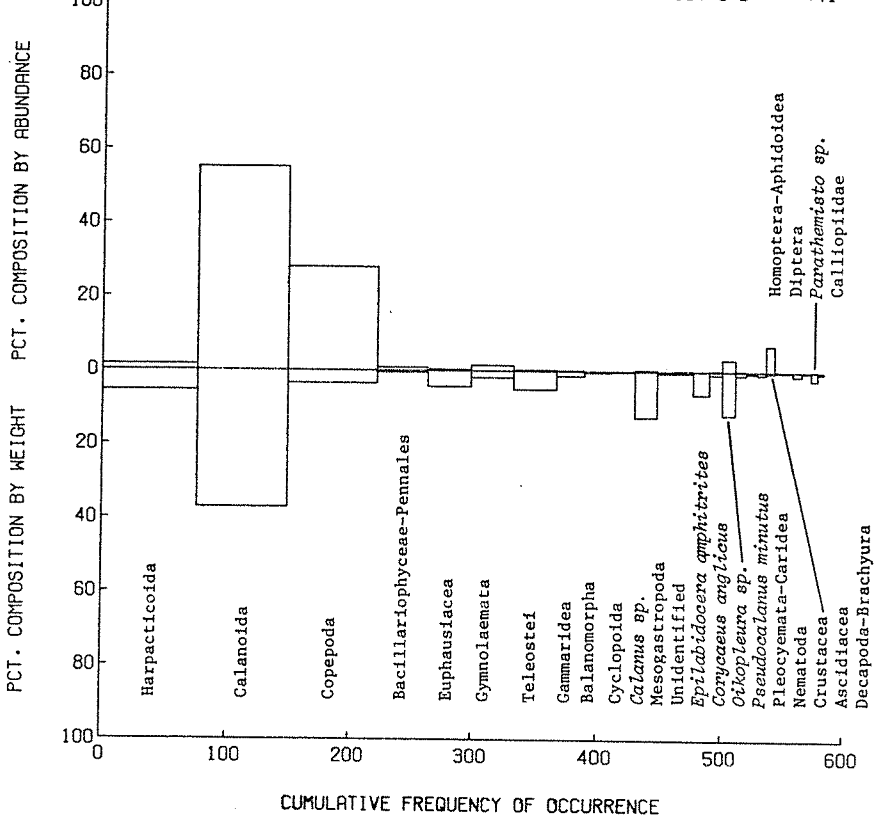
Despite over 1 cm differences in length of co-occurring juvenile chum and pink captured in shallow sublittoral habitats in late April 1978, the overlap in their prey spectra approached or exceeded 50% (Table 5; Appendix C, Table 5). At Carlson Point chum had consumed predominantly hyperiid amphipods and pinks had fed extensively on calanoid copepod larvae (nauplii). Diet overlap was higher at Devil's Hole Delta, where harpacticoid copepods formed the major dietary component in samples of both species. By early May, when the two species were approximately the same size, overlap had increased to almost 75% as both species foraged upon neritic larvaceans and calanoid copepods. The only difference in the two diet spectra at this time was the predominance of gymnolaemata (bryzoan cyphonautes larvae) in the prey spectrum of the pinks but not in chums. In mid-May, chums were almost exactly the same size as co-occurring pinks but diet overlap in samples was relatively low (23.44%) because chums had fed on calanoid copepods and hyperiid amphipods and pinks had fed on larvaceans; all prey were neritic zooplankters, however. By late May, both species were foraging

Table 5. Diet overlap (PSI) of co-occurring juvenile chum and pink salmon migrating through Hood Canal, Washington, 1978. *See* Appendix C, Table 5, for diet composition.

Date	Site	Sample size Chum	Sample size Pink	Fish length (FL mm ± 1 s.d.) Chum	Fish length (FL mm ± 1 s.d.) Pink	Diet overlap PSI(%)
April 26, 1978	Carlson Point	5	6	43.2 ± 11.9	34.8 ± 0.8	43.40
April 25/26 1978	Devils Hole Delta	5	4	47.2 ± 6.1	33.0 ± 0.8	53.82
May 1, 1978	Carlson Point	6	5	56.5 ± 6.2	54.6 ± 4.4	74.03
May 15, 1978	Carlson Point	13	5	54.4 ± 3.8	54.6 ± 4.4	23.44
May 31, 1978	Carlson Point	5	5	48.2 ± 4.9	50.4 ± 2.9	84.23

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. 1978 , STATION AL BS

PREDATOR 8755010201 - ONCORHYNCHUS GORBUSCHA
(PINK SALMON) ADJUSTED SAMPLE SIZE = 55
LENGTH.MM X= 43.0, S.D.= 7.4 WT.GMS X= .68, S.D.= .41



PREY ITEM	FREQ OCCUR	NUM. COMP.	GRAV. COMP.	PREY I.R.I.	PERCENT TOTAL IRI
HARPACTICOIDA	76.36	1.61	5.42	536.9	5.02
CALANOIDA	72.73	55.20	37.06	6711.5	62.70
COPEPODA	72.73	28.10	3.42	2292.7	21.42
BACILLARIOPHYCEAE PENNALES	41.82	.80	.50	54.3	.51
EUPHAUSIACEA	34.55	.32	4.25	157.6	1.47
GYMNOLAEMATA	34.55	1.62	1.71	115.1	1.08
TELEOSTEI	34.55	.33	5.02	184.6	1.72
GAMMARIDEA	21.82	.12	1.31	31.1	.29
BALANOMORPHA	21.82	.08	.27	7.7	.07
CYCLOPOIDA	18.18	.06	.23	5.1	.05
CALANUS SP.	18.18	.34	12.36	231.1	2.16
MESOGASTROPODA	14.55	.07	.38	6.6	.06
UNIDENTIFIED	14.55	.21	.38	8.7	.08
EPILABIDOCERA AMPHITRITES	12.73	.08	6.30	81.2	.76
CORYCAEUS ANGLICUS	10.91	.18	.74	10.1	.09
OIKOPLEURA SP.	10.91	3.21	11.72	162.9	1.52
PSEUDOCALANUS MINUTUS	9.09	.17	.95	10.1	.09
PLEOCYEMATA-CARIDEA	9.09	.02	.52	4.9	.05
NEMATOCERA	7.27	.02	.74	5.5	.05
CRUSTACEA	7.27	7.01	.29	53.1	.50
ASCIDIACEA	7.27	.04	.09	.9	.01
DECAPODA-BRACHYURA	7.27	.01	.09	.6	.01
HOMOPTERA-APHIDOIDEA	7.27	.02	1.13	8.3	.08
DIPTERA	7.27	.01	.09	.6	.01
PARATHEMISTO SP.	5.45	.18	2.25	13.3	.12
CALLIOPIIDAE	5.45	.03	.47	2.7	.03

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	.16		.44
SHANNON-WEINER DIVERSITY		1.89	3.34		1.83
EVENNESS INDEX		.34	.60		.33

Fig. 10. IRI prey spectrum of beach seine-caught juvenile pink salmon migrating through Hood Canal, 1978.

primarily upon calanoid copepods (Calanus pacificus x marshallae, and Epilabidocera amphitrites) and had the highest diet overlap (84.23%).

3.1.4 Diel Feeding Chronology Experiment

While the pink fry captured at Carlson Point over the diel period (May 15, 1978) were approximately the same size (32-39 mm fork length), sizes of the chum fry varied considerably (34-70 mm fork length), declining from night to day (Fig. 11a).

The degree of stomach fullness followed the same trend for both species, but pinks appeared to maintain a much higher (over 50% full) stage of stomach fullness through the day (Fig. 11b). The fluctuating and larger sizes of chum fry may have confounded this difference. The general state of digestion of the stomach contents was almost identical for the two species, i.e., increasing digestion until early morning and, coincident with an increase in stomach fullness, decreasing digested material to a constant state through the latter half of the daylight period (Fig. 11e).

Mean total stomach contents biomass generally declined during daylight hours (Fig. 11d). When normalized to stomach contents weight as a percentage of total fish weight (ration), chum illustrated a mid-day increase in ration, which was unapparent in the pinks, and both species indicated a generally greater increase in ration at dusk (Fig. 11d). The mean total abundance of identifiable prey organisms in the stomachs showed quite a different pattern. After an early morning decline there was rapid increase in prey items until noon but thereafter the number of prey in chums declined through the remainder of the sampling period while in the pinks the number of prey continued to climb to an maximum of 1400 organisms/stomach by late evening (Fig. 11e).

An interpretation of these data is that both juvenile pinks and chums tend to feed in a relatively crepuscular manner. Peak feeding did occur at dusk but feeding did not resume until mid-morning and both species continued to feed at a reduced level throughout the day.

Diel shifts in prey composition were evident (Table 6). The diet of chums in the morning was large calanoid copepods (Calanus spp.) nauplii supplemented by copepod eggs, decapod larvae, and copepod nauplii but predominantly large calanoids in afternoon and evening hours. Hyperiid amphipods (Parathemisto pacifica) were prominent in the stomachs of chum feeding at dusk and dawn. Juvenile pinks also fed upon calanoid copepods during early morning hours but concentrated more upon the smaller species, principally Pseudocalanus sp.; by 0800 however, their foraging had shifted to cyclopoid copepods, primarily Oithona similis and Oncaea sp. Copepod nauplii and small calanoids reappeared in the stomachs in the evening hours and at dusk. Size distributions of prey organisms did not vary dramatically over the diel period (measurable

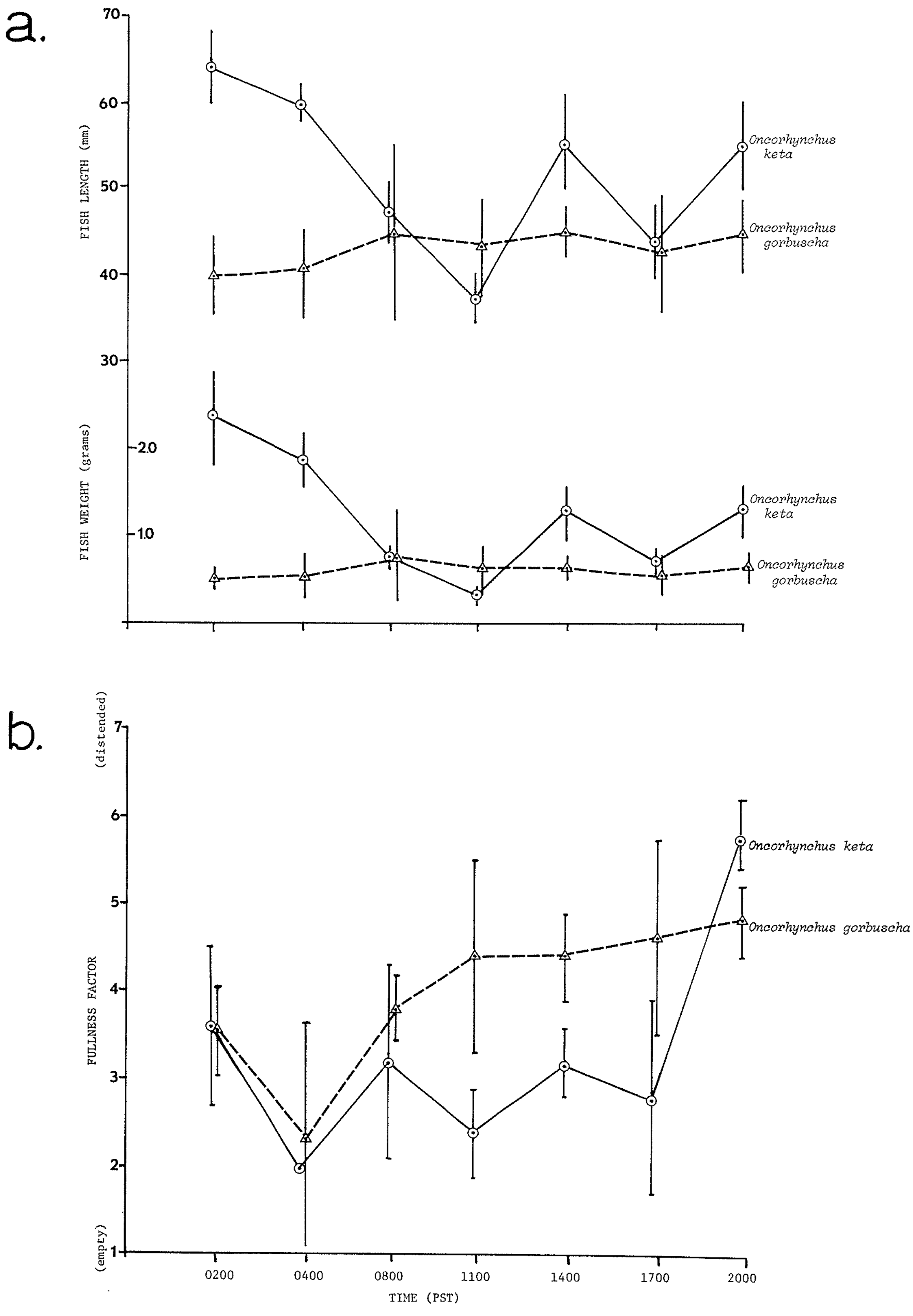


Fig. 11. Fish length and weight (a), stomach fullness (b), stage of digestion of contents (c), stomach contents weight (d), and abundance (e) of prey organisms of juvenile chum and pink salmon during diel period, 15 May 1978, Carlson Point, Hood Canal, Washington.

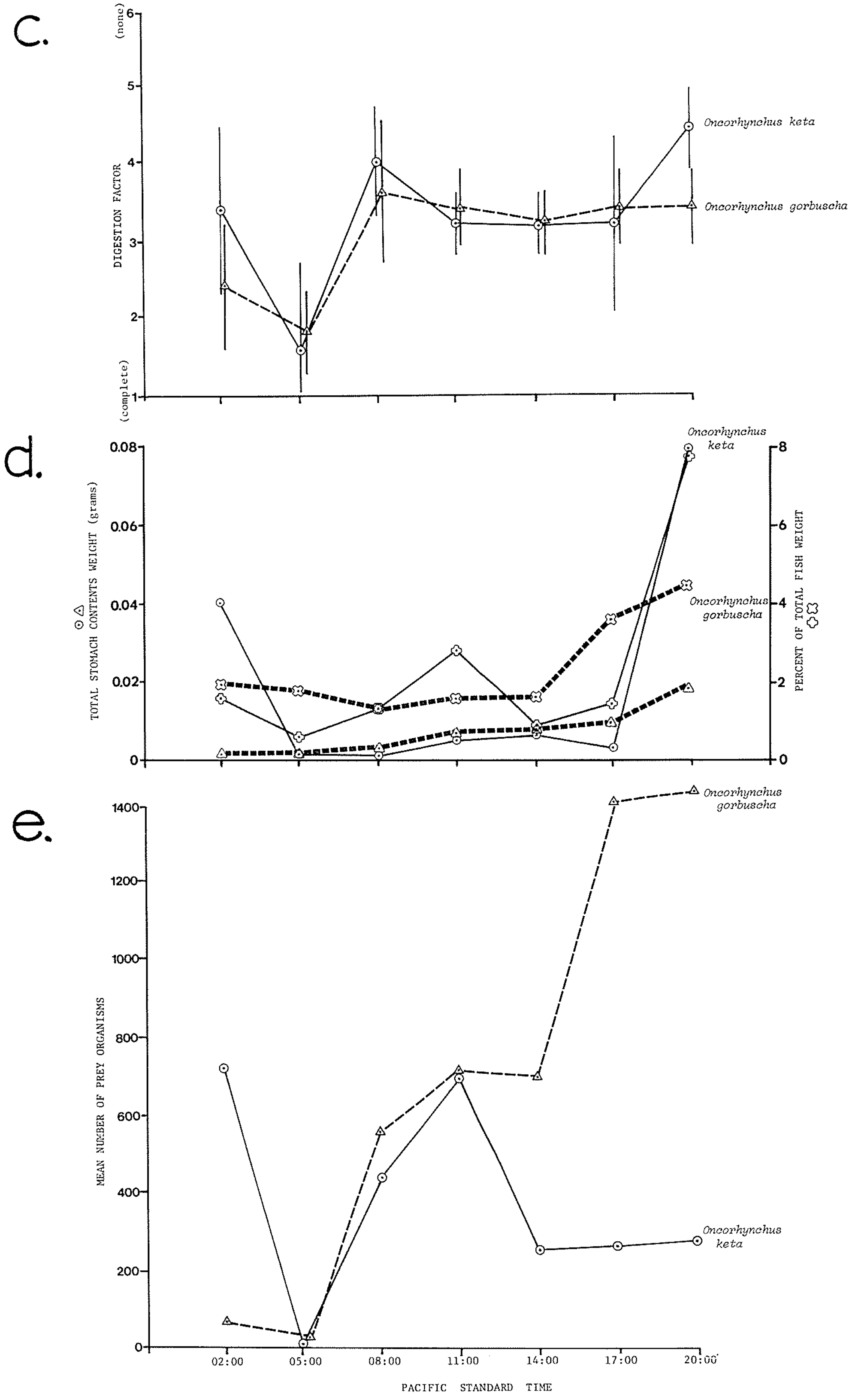

c.
(none)
6
5
4
3
2
1
(complete)
DIGESTION FACTOR
Oncorhynchus keta
Oncorhynchus gorbuscha
d.
0.08
0.06
0.04
0.02
0
TOTAL STOMACH CONTENTS WEIGHT (grams)
Oncorhynchus keta
Oncorhynchus gorbuscha
8
6
4
2
0
PERCENT OF TOTAL FISH WEIGHT
e.
1400
1200
1000
800
600
400
200
0
MEAN NUMBER OF PREY ORGANISMS
Oncorhynchus gorbuscha
Oncorhynchus keta
02:00
05:00
08:00
11:00
14:00
17:00
20:00
PACIFIC STANDARD TIME

Fig. 11 (cont.)

Table 6. Diet composition of juvenile chum and pink salmon over diel period, May 14-15, 1978, at Carlson Point, Hood Canal, Washington.

Time (PST)	Prey Organisms	Chum		Pink	
		% Abundance	% Biomass	% Abundance	% Biomass
0200	Calanoid copepods	31.02	54.63	72.40	57.14
	Copepod eggs	58.27	20.28	0.00	0.00
	Hyperiid amphipod eggs	9.88	24.08	0.00	0.00
	Harpacticoid copepods	0.00	0.00	14.84	9.52
	Copepod nauplii	0.00	0.00	8.07	11.90
0500	Decapod zoea	44.44	2.33	0.00	0.00
	Hyperiid amphipods	22.22	69.77	0.00	0.00
	Calanoid copepods	22.22	4.65	82.98	20.00
	Chaetognaths	11.11	23.26	0.00	0.00
	Harpacticoid copepods	0.00	0.00	9.93	30.00
0800	Calanoid copepods	49.00	52.44	7.53	9.10
	Copepod nauplii	48.64	28.05	28.47	7.47
	Cyclopoid copepods	0.05	1.22	60.25	72.82
1100	Copepod nauplii	77.51	3.13	14.55	2.28
	Calanoid copepods	0.20	62.50	4.07	4.48
	Gammarid amphipods	0.14	13.54	0.00	0.00
	Cyclopoid copepods	20.53	4.17	77.29	85.03
1400	Calanoid copepods	83.00	56.15	5.77	5.65
	Calanoid nauplii	9.57	1.54	13.11	2.60
	Harpacticoid copepods	3.00	3.85	0.60	1.83
	Cyclopoid copepods	0.16	1.54	76.61	75.08
	Decapod zoea	0.56	15.38	0.00	0.00
1700	Calanoid copepods	80.88	63.54	5.97	7.59
	Copepod nauplii	11.98	3.13	45.02	19.68
	Harpacticoid copepods	4.15	4.17	0.65	1.61
	Cyclopoid copepods	0.23	3.13	43.80	55.63
	Gammarid amphipods	0.54	3.13	0.29	6.77
2000	Calanoid copepods	57.68	17.22	25.91	35.57
	Hyperiid amphipods	30.25	61.60	0.71	13.21
	Decapod zoea	1.72	7.10	0.00	0.00
	Fish larvae	1.34	5.48	0.13	4.18
	Chaetognaths	0.52	7.31	0.00	0.00
	Cyclopoid copepods	0.00	0.00	22.13	30.39
	Copepod nauplii	1.86	0.03	21.77	9.98

prey in pink stomachs were available in sufficient numbers only from 0800 to 2000) except from the fish feeding at night and dusk, when larger calanoid copepods were consumed (Fig. 12A and B). Overlap (PSI) in prey composition of pink and chums over the diel period was highest ($PSI_{biomass} = 54.6\%$) at night (0200 PST). Overlap in prey biomass declined at dawn but remained relatively constant for prey abundance through mid-day, and increased through the evening to dusk (Fig. 13). The night and late evening overlap values, however, may be artificially high because the sizes of some zooplankton taxa consumed by the two species did not overlap as much (Fig. 12).

3.1.5 Estimates of Daily Ration

Using the mean body weights of the chum and pink fry (1.23 ± 0.73 g and 0.61 ± 0.26 g, respectively) captured during the diel feeding chronology experiment and assuming an average ambient water temperature of 11.0°C[*], we estimated the instantaneous rate of gastric evacuations to be 0.350 and 0.384 for the juvenile chums and pinks, respectively. This indicated that their stomach contents were being evacuated approximately twice daily. Accordingly, with mean stomach contents weights of 0.03 ± 0.03 and 0.02 ± 0.01, respectively, for chums and pinks over the diel cycle, we estimated daily rations of 0.25 g (20.5% of total body weight) for chums and 0.18 g (30.2% of total body weight) for pinks. These estimates are somewhat higher than those derived by Healey (1979) for juvenile chum of similar size. He used both active metabolism and gastric evacuation rate models to estimate a daily ration of 10-18% body weight per day; Healey settled on 15% as a "conservatively high" estimate. Our estimate for chum fry is, however, very close to that obtained by Lebrasseur (1969), especially early in his experiments when the experimental fish were of the same general size as those sampled in Hood Canal.

The higher daily ration estimate for pinks than for chums would appear to be related to their smaller size, and a corresponding higher instantaneous rate of gastric evacuation (Fange and Grove 1979). Our estimate is, however, higher than any reported for juvenile salmonids either in captivity or under natural conditions; no previous estimate has been generated for juvenile pink salmon per se.

3.1.6 Otolith Microstructure

The analysis of juvenile chum otoliths was performed without *a priori* knowledge of recent life history events. Three hatchery-reared, marked,[**] and recaptured chum fry were used in the analysis (Table 7).

---

[*] Based upon the nearshore surface water temperatures measured during the Hood Canal outmigration studies (Bax et al. 1979).

[**] Spray marked with fluorescent pigment (Salo et al. 1980).

Table 7. History of chum fry examined for daily growth pattern on otoliths, Hood Canal, Washington.

Date Released	Area	Date Captured	Area	$\bar{x}$ Fork Length (mm)	Otolith Total Age (Days)	True Freshwater Age **(Days)	Otolith Saltwater Age (Days)	True Saltwater Age (Days)
*	Big Beef Creek	March 21	Big Beef Creek Estuary*	40.1	40	45-55	3	?
*	Big Beef Creek	March 21	Big Beef Creek Estuary*	38.6	37	45-55	3	?
*	Big Beef Creek	March 21	Big Beef Creek Estuary*	36.8	49	45-55	4	?
May 9	S.EHW	June 7	N. Brown Point	75.0	73	107	30	30
May 9	S.EHW	June 7	Spit 6	79.0	75	107	35	30

* Native chum fry incubated in Big Beef Creek.
** From hatching.

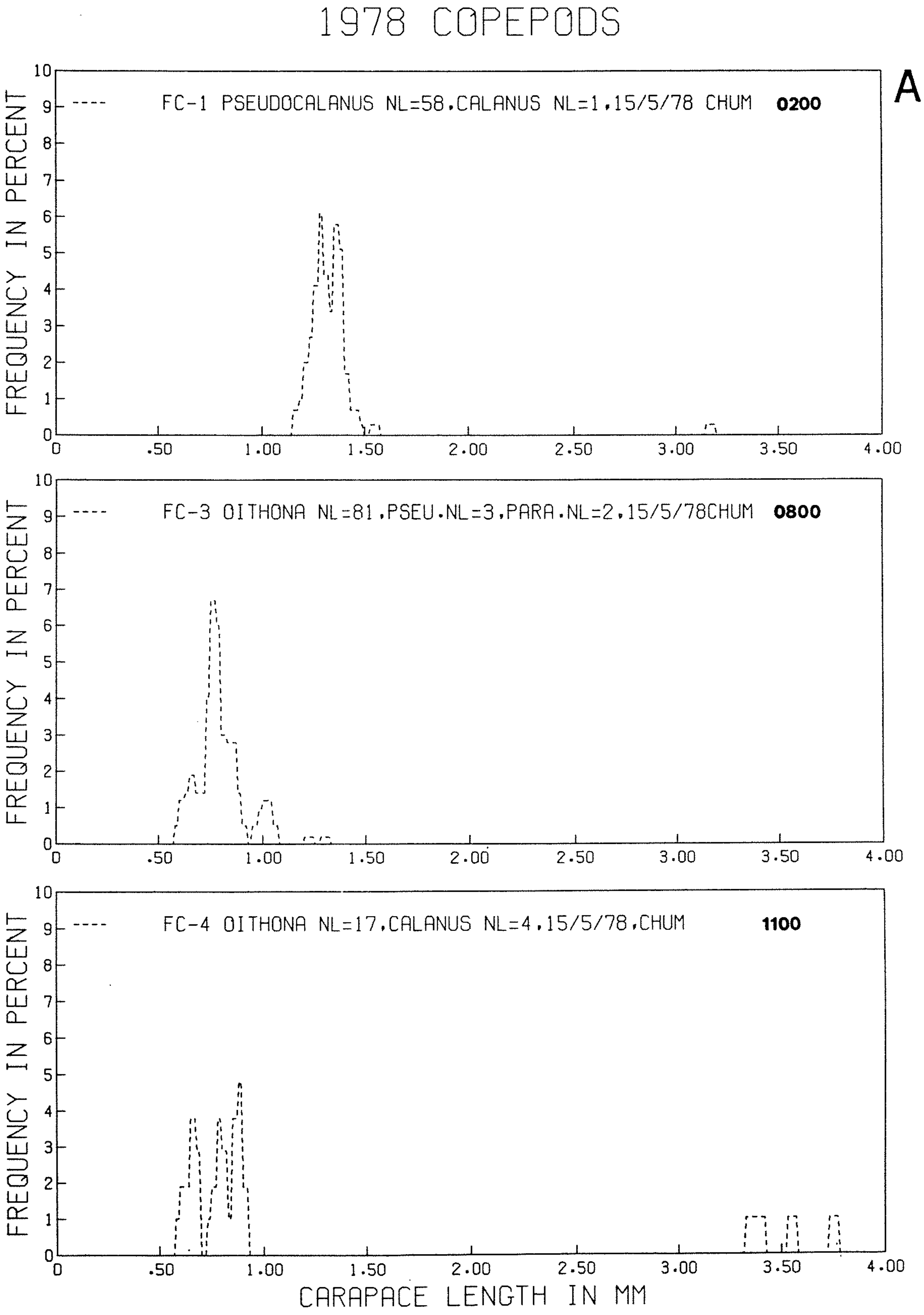


Fig. 12. **Prey size composition of organisms consumed by juvenile chum salmon (A) and pink salmon (B) over diel period, 15 May 1978, at Carlson Point, Hood Canal, Washington.** Times in upper right corner of plots are PST and NL is the number of measurements.

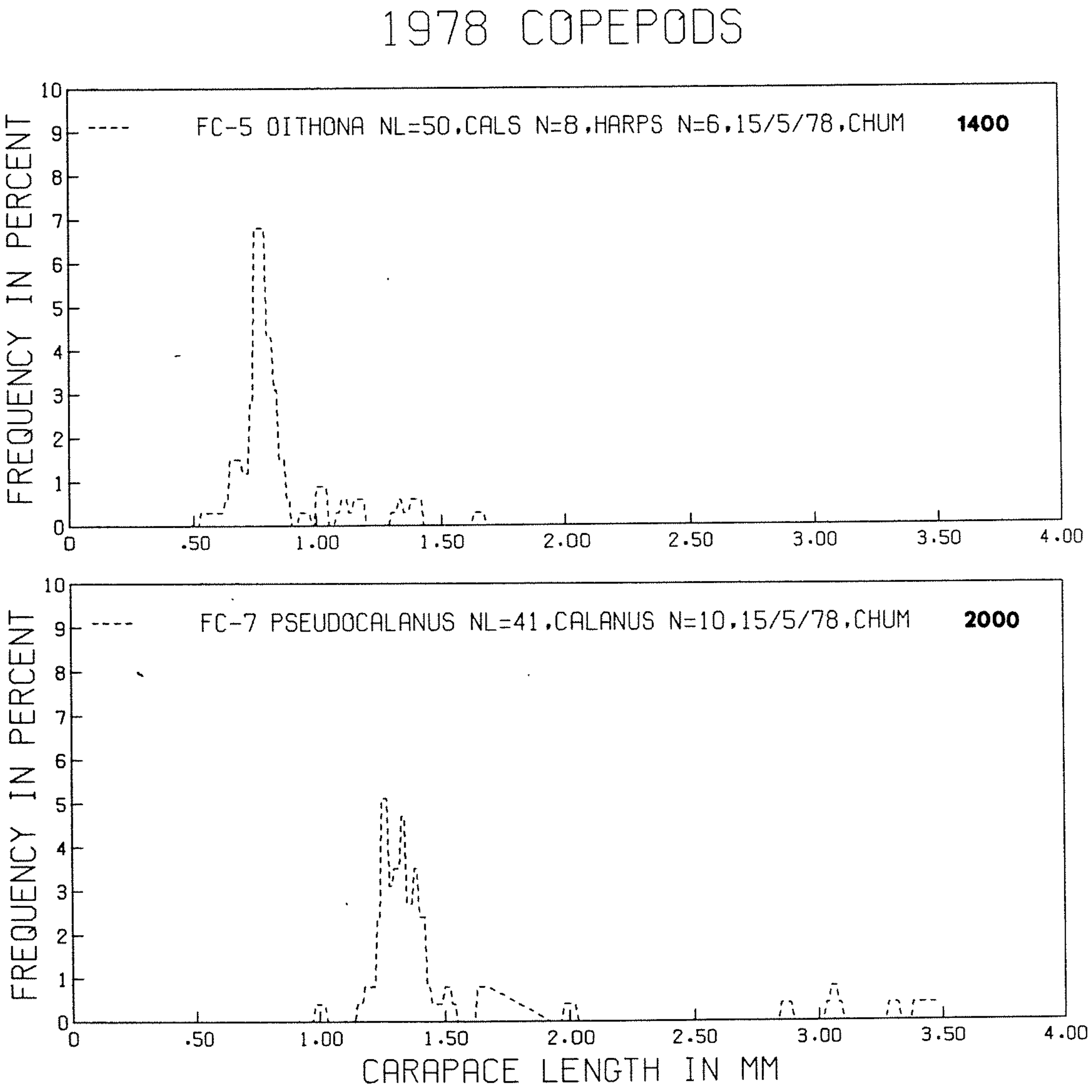

1978 COPEPODS
FREQUENCY IN PERCENT
FC-5 OITHONA NL=50,CALS N=8,HARPS N=6,15/5/78,CHUM
1400
FC-7 PSEUDOCALANUS NL=41,CALANUS N=10,15/5/78,CHUM
2000
0
1
2
3
4
5
6
7
8
9
10
0
.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
CARAPACE LENGTH IN MM

Fig. 12. (cont.)

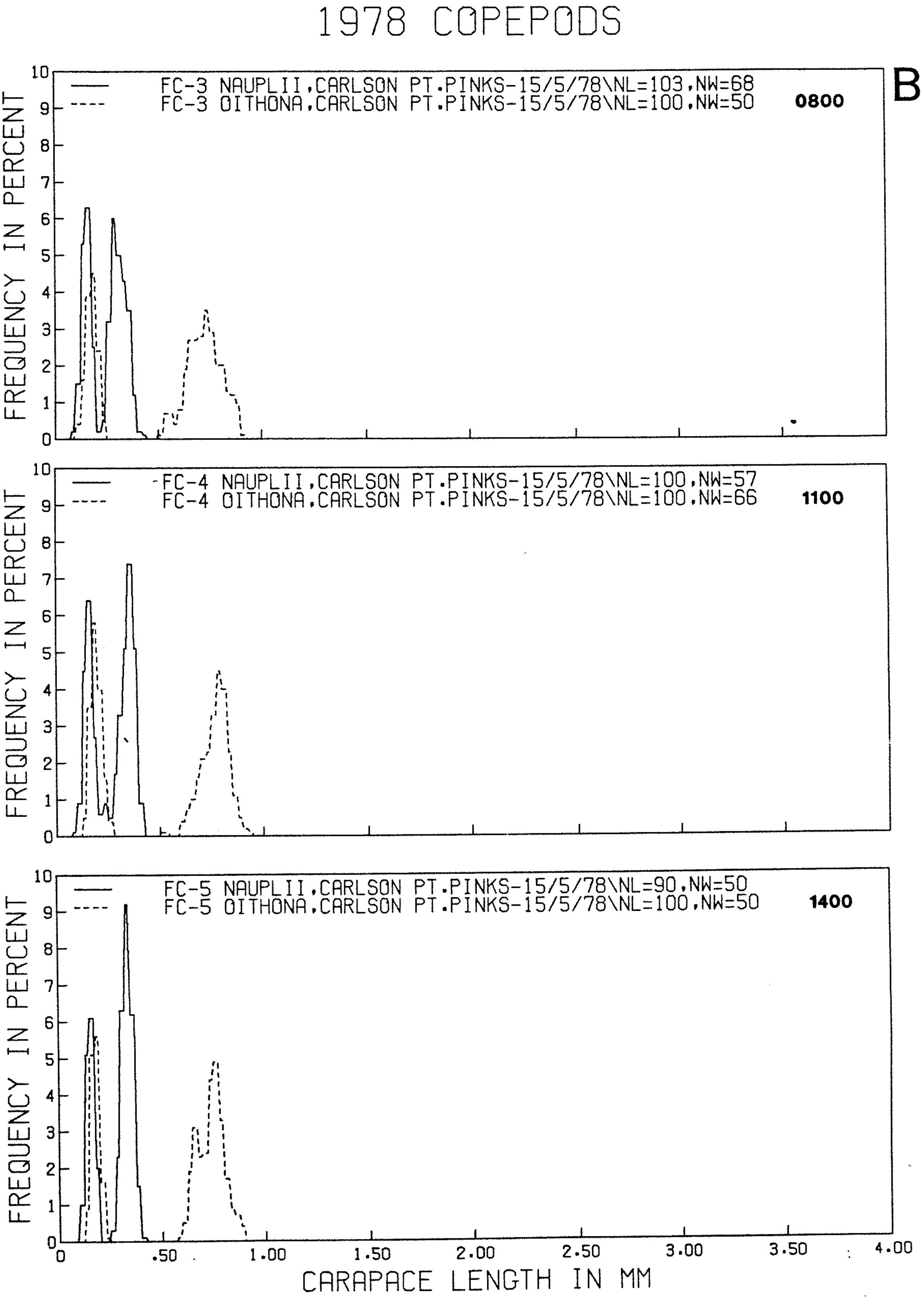

1978 COPEPODS
B
FC-3 NAUPLII,CARLSON PT.PINKS-15/5/78\NL=103,NW=68
FC-3 OITHONA,CARLSON PT.PINKS-15/5/78\NL=100,NW=50
0800
FC-4 NAUPLII,CARLSON PT.PINKS-15/5/78\NL=100,NW=57
FC-4 OITHONA,CARLSON PT.PINKS-15/5/78\NL=100,NW=66
1100
FC-5 NAUPLII,CARLSON PT.PINKS-15/5/78\NL=90,NW=50
FC-5 OITHONA,CARLSON PT.PINKS-15/5/78\NL=100,NW=50
1400
FREQUENCY IN PERCENT
0
1
2
3
4
5
6
7
8
9
10
CARAPACE LENGTH IN MM
0
.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

Fig. 12. (cont.)

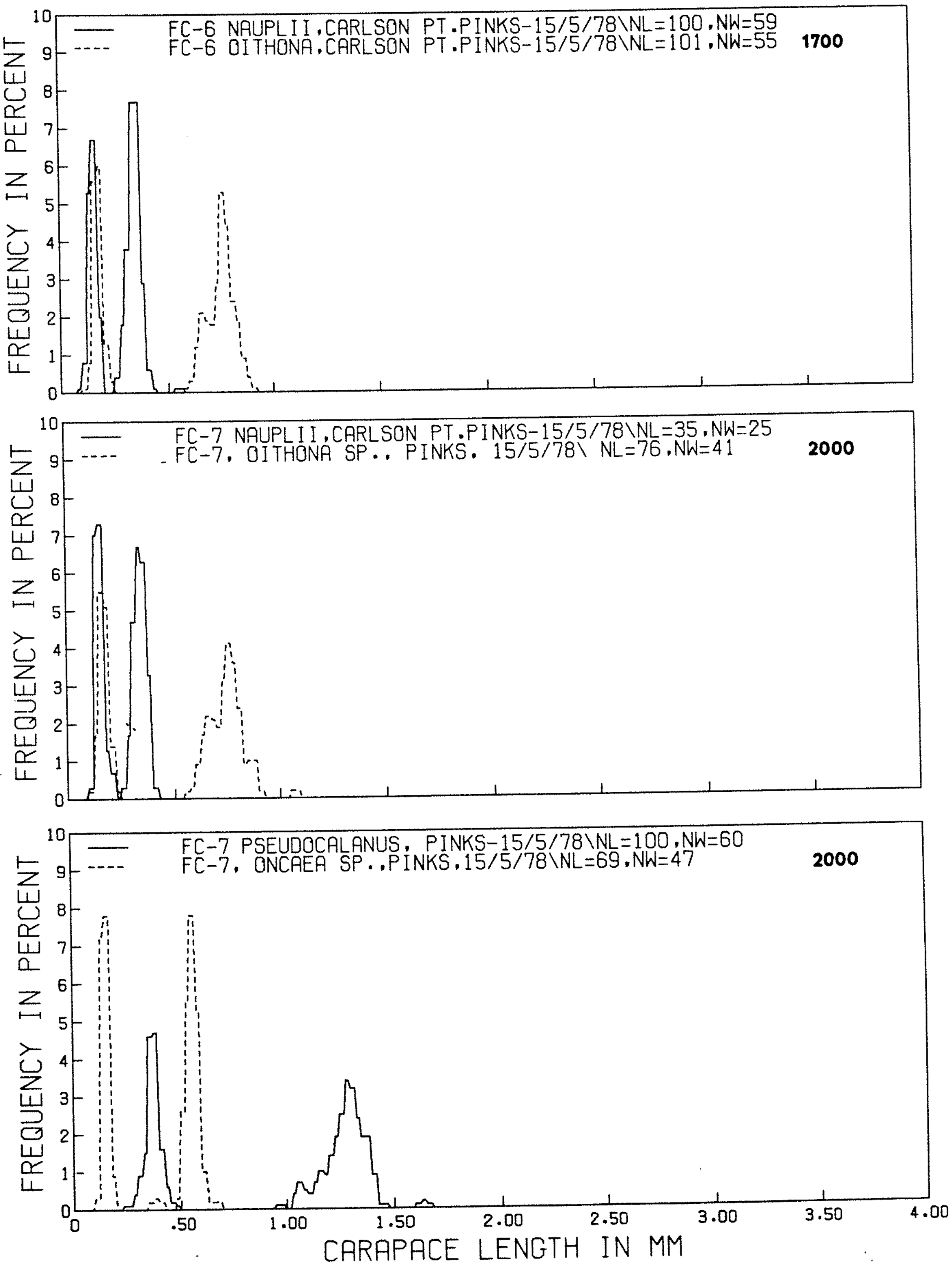

FC-6 NAUPLII,CARLSON PT.PINKS-15/5/78\NL=100,NW=59
FC-6 OITHONA,CARLSON PT.PINKS-15/5/78\NL=101,NW=55
1700
FC-7 NAUPLII,CARLSON PT.PINKS-15/5/78\NL=35,NW=25
FC-7, OITHONA SP., PINKS, 15/5/78\ NL=76,NW=41
2000
FC-7 PSEUDOCALANUS, PINKS-15/5/78\NL=100,NW=60
FC-7, ONCAEA SP.,PINKS,15/5/78\NL=69,NW=47
2000
FREQUENCY IN PERCENT
0
1
2
3
4
5
6
7
8
9
10
0
.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
CARAPACE LENGTH IN MM

Fig. 12. (cont.)

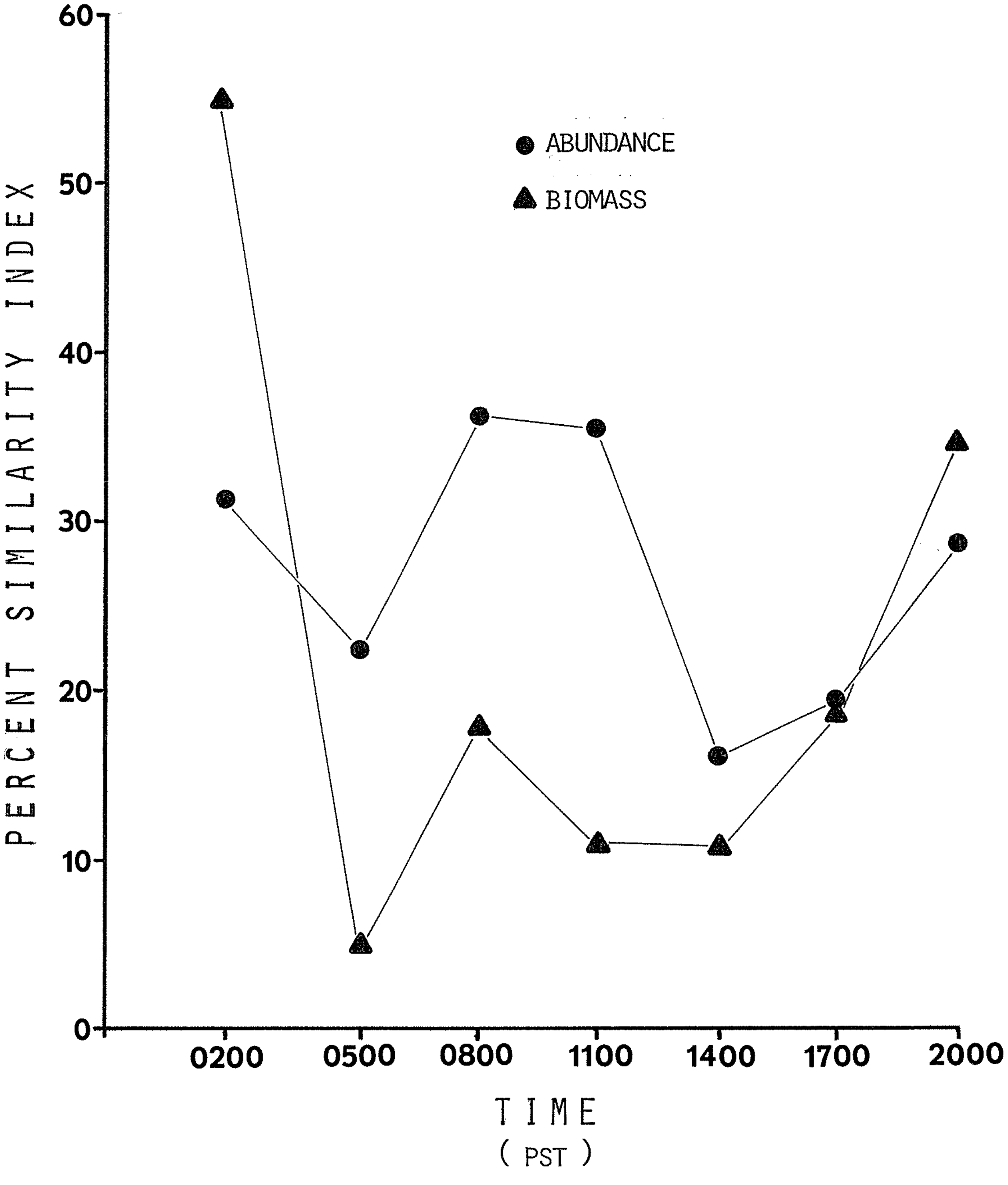


Fig. 13. Similarity (PSI) in diet, based on abundance and biomass of predominant prey taxa, of juvenile chum and pink salmon during diel period, 15 May, 1978, at Carlson Point, Hood Canal, Washington.

Sample otoliths of these naturally-spawned juvenile chum were weakly calcified throughout the interior field and daily growth increments were poorly defined, which, without individual growth histories, precluded a confident estimate of age (days) since hatching. A notable and consistent "check" was observed near the margin of each otolith, with 3-4 well-defined and uniform increments proceeding from this check to the margin. The check appeared as an abnormally wide increment of matrix uninterrupted by calcium deposition. Marshall and Parker (1979) described a similar pattern on otoliths of sockeye salmon fry and related it to first feeding. We suggest, in comparing otoliths from naturally-spawned chum with those from the hatchery fish which had spent 30 days in Hood Canal, that this check corresponds rather to entry of the juvenile chum into estuarine waters.

Otoliths of the two larger hatchery-reared fry displayed patterns similar to those of the native chum. The interior portion of each otolith was weakly calcified and growth increments therefore were difficult to follow. A distinct check was visible on each otolith, followed by 30 to 35 well-calcified growth increments spaced uniformly to the margin. Ages of these fry were estimated by increment counts to be 73 days and 75 days, suggesting a period of 43-45 days during which calcification of the otoliths was severely reduced or absent prior to check formation. This compares well with the estimated number of days before check formation in otoliths from the native chum (34-45 days).

Known growth histories of the recaptured hatchery chums verified that: 1) the number of visible otolith increments which formed prior to the check was not an accurate record of freshwater residence time; and 2) the number of increments deposited after check formation closely coincided with residence time in Hood Canal. Juvenile chums actually reared in the Big Beef hatchery for 3 weeks rather than the 38-43 days estimated from otolith ring counts. They were recaptured 30 days after their release (May 9) into Hood Canal and possessed 30 and 37 distinct growth increments between margin and check, strong circumstantial evidence that the check forms during the physiological adjustment required of fry as they encounter elevated salinities.

More detailed analyses, including experiments controlling temperature, daily food ration and salinity, are needed before the validity of the estuarine check and daily marine growth ring relationship can be verified.

3.1.7 Relationship Between Fish Size and Mouth Gape

The morphometric relationship between fish size and maximum mouth gape was illustrated by the measurements made of 179 juvenile chum salmon captured during beach seine and townet collection at Carlson Point on 24-25 May 1978 (Fig. 14). There were few fish between 30 and 40 mm FL, but the maximum gape width (mm) does not change much over that interval. Thereafter, the gape increases relatively linearly with fish length

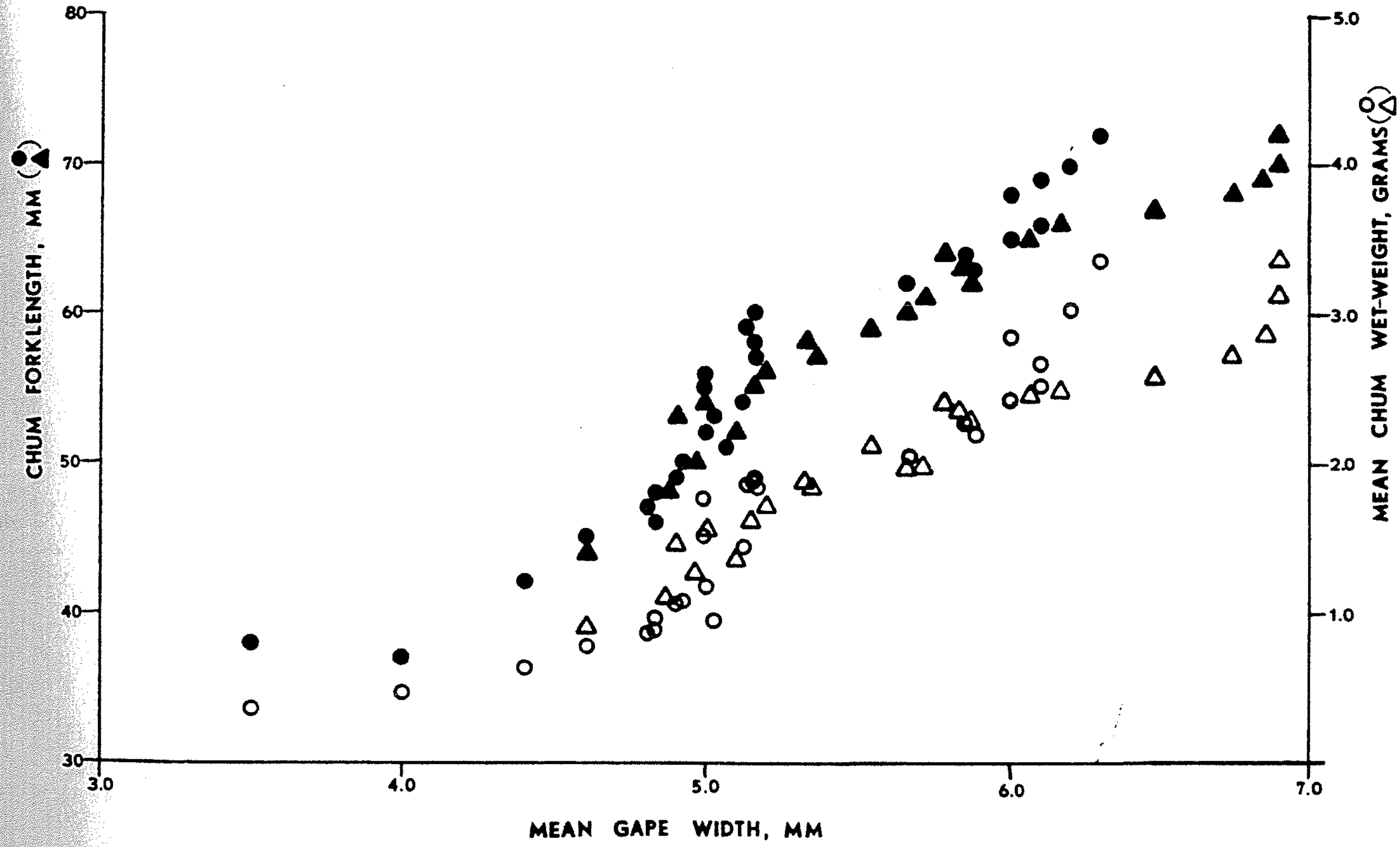


Fig. 14. Mean mouth gape (mm) of juvenile chum salmon, caught in beach seine (circles) and townet (triangles) collections, as a function of fish length (FL, mm; solid symbols) and weight (g wet; open symbols), 24-25 May 1978, at Carlson Point, Hood Canal, Washington. Total sample size, N = 179.

and weight. There is a slight indication of a transition, e.g., a jump in gape width, (especially relative to weight) between 50 mm and 60 mm FL; this may also be a function of the uneven distribution of samples among lengths in that interval relative to the others. This inflection does, however, coincide with the size interval where most juvenile chums are transcending between epibenthic and neritic feeding behaviors and corresponds to a dramatic transition in prey length also described by Okada and Taniguchi (1971).

3.2 Composition and Standing Stock of Epibenthic and Neritic Zooplankton

3.2.1 Epibenthic Community Composition

Crustaceans predominated in the epibenthic community. As illustrated by the Carlson Point collections (Table 8) crustaceans comprised 48% of the epibenthic organisms in 1977, 64% in 1978 and 67% in 1979. Harpacticoid copepods were the numerically dominant members of the community, accounting for between 56.1% (1979) and 67.0% (1977) of the total numbers of organisms. Gammarid amphipods (2.9-6.1%), harpacticoid eggs (2.0-5.9%), calanoid copepods (2.9-8.1%), other crustacean eggs (0.5-3.7%), ostracods (3.7%-4.2%), cyclopoid copepods (0.1-5.9%), and asellot isopods (1.7%-5.8%) were other numerically important members of the epibenthic community. Gammarid amphipods usually dominated the community composition on the basis of biomass, representing from 12.3% (1978) to 30.8% (1977) of the total biomass. Other taxa, however, often predominated or contributed a significant proportion of the total biomass. These included caprellid amphipods (1.9-24.6%), harpacticoid copepods (5.7-17.3%), juvenile shrimp (0.4-37.7%), calanoid copepods (1.3-5.3%) and mesogastropods (4.0-5.1%).

While the harpacticoid copepods were not typically identified to species due to taxonomic difficulties, the families Tegastidae and Porcellidiidae were readily identifiable. The abundant harpacticoid copepods in subsamples from 1977, identified by Ms. Beverly Kask of the Pacific Biological Station, Nanaimo, B.C., Canada, included Harpacticus sp., Dactylopodia sp. Amphiascopsis cinctus and species of the families Ectinosomidae and Laophontidae (Table 9). In similarly detailed analyses performed by J. Cordell on the epibenthic pump samples from Carlson Point on May 15, 1978 Zaus sp., Ectinosoma melaniceps, and Diarthrodes sp. were numerically predominant (Table 10).

The extensive collections (14 sampling dates) at Carlson Point indicated that Aoroides columbiae, Pontogeneia sp. and Synchelidium shoemakeri were the numerically prominent gammarid amphipods, while Photis sp., Amphithoe sp., Paracalliopiella pratti, Podoceropsis sp., and Westwoodilla caecula occurred frequently, but less abundantly (Table 11). Over the five monthly samples collected at Carlson Point in

Table 8. Taxonomic, life history, numerical, and gravimetric composition of epibenthic zooplankton collected at Carlson Point, Hood Canal, Washington, 1977-1979.

Taxon	Life history stage				1977		1978		1979	
					% Composition		% Composition		% Composition	
	Eggs/ egg cases	Larvae	Juveniles	Adults	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Hydroida			x		0.01	0.35				
Platyhelminthes				x	0.01	0.01				
Turbellaria				x					0.01	0.72
Nemertea			x	x			0.01	0.07	0.01	0.02
Nematoda			x	x	1.63	0.23	0.88	0.81	0.31	0.29
Polychaeta		x	x	x	0.47	5.34	0.07	0.20	0.20	0.28
Polynoidae		x	x	x	0.18	2.05	0.06	0.11	0.09	0.18
Harmothoe imbricata			x	x			0.01	0.12	0.01	0.12
Sigalionidae										
Pholoe minuta			x	x			0.01	0.17	0.01	0.07
Phyllodocidae			x	x	0.02	0.57				
Anaitides sp.			x	x	0.01	0.15	0.01	0.03		
Hesionidae										
Ophiodromus pugettensis			x	x			0.01	0.09		
Pilargidae			x	x	0.01	0.14				
Micropodarke dubia			x	x			0.01	0.01		
Syllidae			x	x	0.01	0.20	0.02	0.06		
Exogone sp.			x	x			0.01	0.01		
E. verugera			x	x			0.01	0.01		
Sphaerosyllis sp			x	x					0.03	0.06
Nereidae				x	0.01	0.02				
Nereis sp.				x	0.01	0.01				
Platynereis bicanaliculata			x	x	0.01	0.03	0.03	1.00	0.03	0.14
Micronereis nanaimoensis			x	x			0.01	0.14		
Sphaerodoridae										
Sphaerodorum gracilis				x					0.01	0.07
Sphaerodoropsis minuta			x	x			0.01	0.05		
Spionidae			x	x	0.02	0.70	0.04	0.09	0.03	0.05
Prionospio sp.				x			0.01	0.04		
P. cirrifera			x	x					0.01	0.01
P. pinnata			x	x			0.01	0.09		
Opheliidae			x				0.14	0.06		
Armandia brevis			x	x			0.02	0.09	0.06	0.54
Serpulidae			x	x			0.01	0.01		
Oligochaeta			x	x	0.01	0.30	0.01	0.03	0.11	0.18
Enchyraeidae			x	x			0.01	0.03		
Tubificidae			x	x	0.01	0.02	0.13	0.13		
Gastropoda	x	x	x	x	0.30	1.68	0.17	0.37	0.21	0.33
Archaeogastropoda	x		x						0.01	0.01
Acmaeidae			x		0.01	0.01	0.01	0.01		
Trochidae										
Margarites pupillus			x		0.01	0.01	0.01	0.02	0.01	0.01
Lirularia lirulatus			x		0.01	0.01	0.01	0.07		
Mesogastropoda	x	x	x	x	0.48	2.09	0.37	0.73	1.29	1.43
Lacunidae										
Lacuna sp.			x	x	0.34	0.12	0.27	2.78	0.41	2.73
Littorinidae										
Littorina sp.			x		0.01	0.01				
Rissoidae										
Alvinia sp.			x	x	0.01	0.05	0.01	0.32	0.01	0.23
Thais sp.			x		0.01	0.01				
Euthyneura										
Pyramidellidae										
Turbonilla sp.			x				0.01	0.03		
Scaphandridae										
Cylichna sp.			x	x			0.01	0.01		
Sacoglossa			x	x	0.04	0.54	0.01	0.08	0.70	1.45
Oleidae										
Olea hansineensis			x	x	0.01	0.02				
Nudibranchia			x		0.01	0.01	0.01	0.03	0.02	0.05
Onchidiidae			x						0.01	0.01
Prosobranchia			x		0.02	0.62				
Opisthobranchia			x	x	0.06	1.58	0.04	0.12	0.01	0.03
Bivalvia			x	x	0.04	0.82	0.86	0.35	0.13	0.23
Mytilidae			x		0.01	0.15	0.01	0.01		
Mytilus edulis			x		0.01	0.24	0.01	0.01	0.01	0.01
Modiolus sp.			x		0.01	0.01				
M. rectus			x		0.01	0.02				
Veneroida			x	x	0.01	0.15	0.02	0.05	0.01	0.01
Kellia suborbicularis			x		0.01	0.01				
Montacutidae										
Mysella tumida			x	x	0.01	0.03	0.01	0.12	0.01	0.01
Cardiidae										
Clinocardium nuttallii			x		0.01	0.01	0.02	0.06		
Veneridae										
Transennella tantilla			x	x			0.01	0.04		
Protothaca staminea			x				0.01	0.01		
Arachnida										
Araneae				x			0.01	0.01		
Halacaridae			x	x	0.21	3.06	0.06	0.18	0.02	0.05
Crustacea	x	x	x		5.01	3.92	0.52	0.50	9.74	0.65
Cladocera										
Polyphemidae										
Evadne sp.			x	x			0.05	0.09		
Podon sp.			x	x			0.04	0.12		
Ostracoda			x	x	1.13	1.60	0.01	0.03		
Myodocopa			x	x	0.01	0.05	0.05	0.11		
Halocyprididae										

Table 8. (cont.)

Taxon	Life history stage				1977 % Composition		1978 % Composition		1979 % Composition	
	Eggs/ egg cases	Larvae	Juveniles	Adults	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Conchoecia sp.				x					0.01	0.01
Podocopa			x	x	1.54	4.39	3.65	1.39	4.15	0.71
Copepoda	x	x	x	x	0.46	2.35	4.09	1.60	1.83	0.37
Calanoida		x	x	x	2.63	6.35	1.18	0.77	6.06	1.85
Calanidae										
Calanus sp.		x		x			0.01	0.12	0.01	0.08
C. pacificus			x	x			0.01	0.09		
C. plumchrus		x							0.00	0.02
Paracalanidae										
Paracalanus parvus			x	x			0.65	0.19		
Pseudocalanidae			x	x			0.04	0.03		
Pseudocalanus sp.				x			0.02	0.03		
P. minutus		x	x	x			1.00	0.68	1.88	0.44
Aetideidae			x	x					0.01	0.01
Metridiidae										
Metridia sp.		x		x			0.01	0.01	0.01	0.01
M. lucens		x	x	x			0.03	0.08	0.01	0.01
Pontellidae										
Epilabidocera amphitrites		x							0.01	0.01
Acartiidae										
Acartia longiremis		x	x	x			0.16	0.18	0.13	0.25
Tortanidae										
Tortanus discaudatus		x							0.01	0.01
Harpacticoida	x	x	x	x	69.15	15.43	64.64	18.13	56.05	13.13
Tegastidae			x	x	0.08	0.61	0.49	0.31	0.02	0.05
Porcellidiidae			x	x	0.01	0.25	0.27	0.37	0.21	0.18
Porcellidium sarsi			x	x			0.01	0.01	0.08	0.14
Cyclopoida			x	x			3.20	0.85	0.82	0.18
Oncaeidae										
Oncaea sp.			x	x					0.07	0.05
Corycaeidae										
Corycaeus anglicus		x	x	x	0.07	0.49	0.36	0.56	0.06	0.14
Oithonidae										
Oithona sp.		x	x	x			1.34	0.61	2.59	0.42
Cyclopinidae										
Cyclopina sp.		x	x	x	0.05	0.49	1.03	0.38	1.83	0.56
Monstrilloida										
Monstrillidae										
Monstrilla sp.			x	x					0.02	0.05
Argulidae										
Argulus sp.			x		0.01	0.14				
Cirripedia			x	x	0.01	0.02				
Balanomorpha		x	x	x	1.69	2.51	0.71	0.29	0.45	0.37
Balanus sp.				x	0.01	0.02				
Leptostraca										
Nebaliidae										
Nebalia sp.			x	x	0.01	0.15				
N. pugettensis			x	x					0.01	0.03
Peracarida										
Mysidacea										
Mysidae			x	x	0.01	0.39				
Acanthomysis sp.			x	x	0.01	0.01	0.01	0.02	0.01	0.02
Cumacea			x	x	0.05	1.25				
Lampropidae			x	x			0.09	0.71	0.05	0.12
Lamprops sp.			x	x	0.10	2.03	0.23	0.87		
Diastylidae										
Leptostylis sp.			x				0.01	0.01		
Nannastacidae										
Cumella sp.			x	x	0.11	1.75	0.20	0.40	0.42	0.57
Tanaidacea				x	0.01	0.03				
Paratanaidae										
Leptochelia dubia			x	x	0.04	0.95	0.07	0.19	0.03	0.08
Isopoda										
Flabellifera			x	x	0.03	0.56	0.01	0.01		
Sphaeromatidae			x	x	0.01	0.05				
Exosphaeroma media			x	x	0.70	0.51	0.01	0.05		
Valvifera			x	x	0.01	0.24				
Idoteidae			x		0.01	0.01				
Idotea sp.			x		0.01	0.02	0.01	0.03	0.01	0.05
Asellota			x	x	0.07	1.20				
Munnidae										
Munna sp.			x	x	0.02	0.23	0.01	0.03	0.25	0.19
M. ubiquita		x	x	x	1.28	3.69	5.77	6.10	1.91	1.39
Epicaridea				x	0.02	0.35				
Criptonicidae										
Liriopsis pygmaea				x	0.02	0.49				
Bopyridae			x	x	0.03	0.70	0.08	0.20	0.14	0.29
Amphipoda										
Gammaridea	x		x	x	9.96	20.61	0.22	0.37	0.07	0.14
Ampeliscidae							0.01	0.01		
Ampelisca pugetica			x						0.02	0.05
Amphilochidae			x				0.01	0.03		
Amphilochus littoralis			x	x			0.01	0.01	0.01	0.01
Gitanopsis vilordes			x	x						
Amphithoidae							0.01	0.08	0.01	0.01
Amphithoe sp.			x							

Table 8. (cont.)

Taxon	Life history stage				1977		1978		1979	
	Eggs/ egg cases	Larvae	Juveniles	Adults	% Composition		% Composition		% Composition	
					Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
Aoridae			x				0.01	0.01		
Aoroides columbiae			x	x			0.89	1.58	0.58	2.06
Atylidae										
Atylus collingi			x	x			0.01	0.01		
Calliopiidae										
Calliopius sp.			x				0.01	0.01		
Calliopiella pratti			x	x			0.03	0.27	0.30	0.89
Corophiidae										
Corophium sp.			x				0.01	0.01		
Dexaminidae			x	x			0.02	0.03		
Guerniea sp.			x	x			0.01	0.01	0.02	0.04
Eusiridae										
Pontogeneia sp.			x	x			0.44	6.32	1.35	10.69
Gammaridae			x	x	0.10	0.14				
Melita sp.			x				0.01	0.01	0.01	0.07
M. dentata			x	x			0.01	0.06	0.01	0.07
M. desdichata			x				0.01	0.01		
Isaeidae			x						0.02	0.05
Photis sp.			x	x			0.26	0.47	0.25	0.28
P. brevipes			x	x			0.01	0.17		
Podoceropsis sp.			x	x			0.07	0.29	0.34	0.77
Ischyroceridae										
Ischyrocerus sp.			x	x			0.09	0.41	0.35	1.09
Lysianassidae										
Orchomene sp.			x	x			0.01	0.01		
Oedicerotidae			x				0.03	0.06	0.04	0.05
Monoculodes sp.			x	x			0.01	0.05	0.01	0.03
Synchelidium sp.			x	x			0.01	0.01		
S. shoemakeri			x	x			0.51	1.24	0.27	0.77
Westwoodilla sp.			x	x			0.01	0.01		
W. caecula			x	x			0.05	0.69	0.18	1.17
Phoxocephalidae			x				0.02	0.06	0.04	0.09
Paraphoxus sp.			x	x			0.01	0.02	0.05	0.12
P. spinosus			x	x			0.02	0.05		
Pleustidae			x	x			0.02	0.06	0.01	0.01
Parapleustes nautilus			x	x			0.01	0.02	0.01	0.01
Pleustes sp.			x				0.01	0.01		
P. depressa			x	x			0.01	0.01	0.01	0.03
Pleusirus secorrus			x	x			0.01	0.04		
Stenothoidae				x			0.01	0.04	0.07	0.05
Metopella carinata			x	x			0.14	0.28	0.05	0.15
Hyperiidea			x	x	0.03	0.56	0.01	0.01		
Caprellidea			x		0.02	0.35				
Caprellidae			x				0.06	0.12		
Metacaprella kennerlyi			x	x					0.01	0.05
Caprella sp.			x	x	0.01	0.14	0.06	0.37	0.02	1.98
C. alaskana			x	x			0.01	0.07		
C. laeviuscula			x	x	0.26	2.16	1.39	22.37	0.80	6.77
Eucarida										
Euphausiacea		x					0.01	0.01	0.03	0.05
Decapoda		x			0.08	0.84				
Caridea		x	x	x	0.01	0.21	0.01	0.21		
Hippolytidae		x	x	x	0.03	0.08	0.03	4.76	0.01	0.01
Hippolyte clarki			x	x			0.09	8.36	0.17	22.25
Eualus sp.			x				0.01	0.03		
E. townsendi			x						0.01	0.67
Heptacarpus sp.			x				0.01	2.39	0.07	10.31
H. tridens			x				0.01	0.22		
H. tenuissimus			x				0.01	0.04		
Crangonidae		x	x		0.01	0.07	0.01	0.66	0.01	0.33
Crangon sp.			x	x			0.01	1.28	0.01	1.48
C. alba			x						0.01	0.94
C. communis			x						0.01	0.76
Sclerocrangon alata			x				0.01	0.13		
Anomura										
Paguridae			x				0.01	0.01		
Pagurus sp.			x						0.01	0.07
Brachyura		x	x				0.01	0.03		
Majidae		x			0.01	0.01				
Cancridea		x			0.01	0.01	0.01	0.01		
Cancer sp.		x							0.01	0.01
Pinnotheridae		x					0.01	0.01	0.03	0.05
Insecta										
Collembola				x	0.01	0.14	0.01	0.01		
Diptera			x		0.01	0.05	0.01	0.02		
Nematocera				x			0.01	0.01		
Ectoprocta				x					0.01	0.03
Gymnolaemata		x	x	x			0.71	0.36	0.09	0.14
Cheilostomata					0.01	0.01				
Barentsia sp.			x		0.01	0.01				
Echinodermata										
Ophiuroidea			x	x	0.01	0.01			0.01	0.05
Holothuroidea			x	x	0.03	0.26				
Chaetognatha			x	x			0.01	0.01		
Eukrohnia hamata				x					0.01	0.48
Urochordata			x		0.01	0.23				
Larvacea										
Oikopleura sp.				x			0.01	0.03		
Osteichthys		x			0.01	0.01				
Teleostei	x	x			0.01	0.02	0.01	0.78	0.03	0.07
Sygnathidae										
Sygnatha griseolineatus			x						0.01	2.69
Pleuronectidae		x							0.01	0.01
Unidentified	x	x			0.04	0.79	1.87	0.04	1.89	0.37
Unidentified			x	x	1.12	2.30				
Unidentified parts					0.02	0.14				

Table 9. Percentage composition of harpacticoid copepod taxa identified from seven epibenthic plankton samples, Hood Canal, Washington, 1977.

Date (1977)	March 17			April 21	April 21	May 19	June 16
Site	Brown Pt.	North Carlson Pt.	Devils Hole Delta	Brown Pt.	Devils Hole Delta	Brown Pt.	Brown Pt.
Family Harpacticidae							
Harpacticus sp.	36	5	2	69	24	37	92
Zaus sp.	2	7	2	16	9	18	
copepodites	10			2		2	5
Family Diosaccidae				2			
Amphiascoides sp.	5						
Amphiascoides cinctus		9	35		2		2
Amphiascus sp.	5		4				
Diosaccus Spinatus		5					
Amonardia sp. (probably *perturbata*)					17	6	
unidentified			2				
Family Tisbidae							
Tisbe sp.	7	20	6	4	4	16	
copepodites				2			
Family Thalestridae							
Parathalestris californica	2					2	
Parathalestris sp.		4					
Dactylopodia sp.		15	16		7	2	
Diarthrodes sp.		2	12	2		4	
Family Ameiridae							2
Nitocra sp.	2						
Family Laophontidae	2	25	2			2	
Family Ectinosomidae		2	6	4	35	2	
Family Canuellidae							
Scottolana canadensis			2				
Thalestridae							
Microarthridian littorale					2		
unidentified copepodites	29	5	12			8	

Table 10. Species composition of harpacticoid copepods from epibenthic pump sample, Carlson Point, Hood Canal, May 15, 1978.

Family	Species	Number: Life history stages	Size, mm $\bar{x} \pm 1$ s.d.	Size, mm Range
Ectinosomatidae	*Ectinosoma melaniceps*	7: adult - no sex	0.60±0.05	0.50-0.64
		1: copepodite	0.36	
Harpacticidae	*Harpacticus* sp.	1: adult - no sex	0.76	
	Zaus sp.	10: adult - no sex	0.55±0.02	0.52-0.60
		5: adult - male	0.48±0.05	0.42-0.52
		2: adult - egg-bearing female	0.59±0.04	0.56-0.62
Tisbidae	*Tisbe* sp.	3: adult - no sex	0.55±0.04	0.52-0.60
	Scutellidium sp. "A"	1: adult - no sex	0.90	
Thalestridae	*Diarthsodes unisetosus*	6: adult - no sex	0.44±0.06	0.38-0.52
	Dactylopodia tentatively *D. vulgaris* (male not described)	1: adult - male	0.56	
Diosaccidae	*Robertsonia* sp.	1: adult - no sex	0.82	
	Amphiaseus sp.	2: adult - no sex	0.60±0.03	0.58-0.62
Ameiridae	*Ameira* c.f. *longipes*	1: adult - no sex	0.70	
Laophontidae	*Paralaophonti* c.f. *perplexa*	4: adult - no sex	0.73±0.11	0.60-0.88
		2: adult - male	0.67±0.04	0.64-0.70

Table 11. Density (no./m^3) of epibenthic gammarid amphipods at Carlson Point, Hood Canal, February 21 to December 15, 1978.

Gammarid Taxa	Density (no./m^3)															Mean biomass per individual (mg)	Frequency of occurrence (%)
	Feb 21	Mar 7	Mar 21	Apr 6	Apr 17	May 1	May 31	Jun 14	Jun 28	Jul 13	Aug 10	Oct 24	Nov 17	Dec 15	Grand mean density		
GAMMARIDEA (incl. eggs)	1.7	60.6	66.7		100.0	288.6	33.3	100.0		33.3			50.0		52.5		64
Ampelisca pugetica		1.5													0.1	0.1	7
Amphilocus littoralis							35.0								2.6	0.1	7
Gitanopsis vilordes			1.7				1.7							1.7	0.4	0.1	21
Amphithoe sp.		1.5			3.3	3.3	3.3	8.3	3.3	1.7		3.3			2.1	0.3	57
AORIDAE									1.7						0.1		7
Aoroides columbiae	1.7		71.7	61.9	73.3	18.6	15.0		1.7	3.3	3.4	953.3	2480.0	96.7	216.1	0.2	86
Guernea sp.			3.7		68.4		3.3					1.7	5.0		0.6	<0.1	21
Caliopius sp.									1.7						0.2	0.1	14
Calliopiella pratti	8.3	33.3	9.1		5.0	10.0		1.7	38.3	1.7					7.9	0.4	57
Corophium sp.								1.7							0.1	0.1	7
Pontogeneia sp.	171.7	92.4	91.6	70.6	230.0	77.7	108.3	110.0	146.7	136.7	81.9	6.7	7.5	126.7	106.5	0.6	100
Melita sp.								1.7							0.1	0.1	
M. dentata		1.5		2.0			1.7						2.5		0.5	1.3	29
M. desdichata				1.7											0.1	0.1	7
Photis sp.		1.5	281.5	342.8	181.7			35.0	1.7		1.8	5.0	2.5		62.4	0.3	64
P. brevipes			5.4		1.7	4.2									0.8	1.2	21
Podoceropsis sp.		33.3	10.2	7.8	5.0	1.7	40.0		1.7			36.7	60.0	51.7	16.7	0.2	71
Ischyrocerus sp.	10.0	69.7	38.3	3.9	103.3	6.7	10.0	1.7	8.3	1.7		33.3	2.5		21.5	0.2	86
Orchomene sp.				2.0		1.7									0.3	0.1	14
OEDICEROTIDAE					100.0		1.7								7.4	0.1	14
Monoculodes sp.	8.3	12.1		1.7	1.7										1.7	0.2	29
Synchelidium sp.						10.0									0.7	0.2	7
S. shoemakeri	6.7	86.4	90.2	250.9	88.3	12.1	38.3	1.7	5.0	1.7	110.4	680.0	200.0	175.0	122.9	0.2	100
Westwoodilla sp.						6.7									0.5	<0.1	7
W. caecula		25.8	51.5	36.9	8.3	3.4	3.3						12.5	45.0	13.4	0.6	57
PHOXOCEPHALIDAE				39.2	33.3										5.3	0.1	14
Paraphoxus sp.													7.5	1.7	0.5	0.2	14
P. spinosus		1.5	33.3		3.3	2.5	23.3		1.7						4.8	0.1	43
PLEUSTIDAE	1.7							33.3					52.5	1.7	5.2	0.1	29
Parapleustes nautilus		1.5	5.0	2.0											0.6	0.2	21
Pleustes depressa								1.7							0.1	0.1	7
Pleusirus secorrus	5.0			2.0	1.7		1.7							1.7	0.9	0.4	36
STENOTHOIDAE		18.2													1.3	0.3	7
Metopella carinata	13.3	142.4	17.0	235.0	33.3								50.0		34.7	0.1	43
Total mean density (no./m^3)	228.4	583.2	776.8	1060.4	1041.6	447.2	319.9	296.8	211.8	180.1	197.5	1725.0	2935.0	501.9	696.8 750.69±768.25		

1979, *Podoceropsis* sp. and *Ischyrocerus* sp. were more predominant than in 1978 (Table 12). Taxonomic identification of gammarid amphipods from the 1977 collections were not comparable with the detailed, specific compositions documented for 1978 and 1979 because of the change in sampling methodology. A complete taxonomic characterization of epibenthic pump collections at Brown Point between March 17 and July 22, 1977, however, identified an undescribed *Pontogeneia* sp. (near *P. rostrata*), *Calliopius* sp., *Paracalliopiella pratti*, and *Anisogammarus pugettensis* (Table 13); the latter species was not found in the 1978 and 1979 collections.

Among the other contributory species, *Paracalanus parvus*, and *Pseudocalanus* spp. were the dominate calanoid copepods, *Munna ubiquita* the asellot isopods, *Cumella* sp. the cumaceans, *Caprella laeviuscula* the caprellid amphipods and *Lacuna* sp. the mesogastropods. Among these, the calanoids are assumed to be neritic species which resided in the near-surface water column incidentally captured by the pump.

3.2.2 Density of Epibenthic Organisms

Between December 30, 1976 and June 22, 1977, the biweekly density of epibenthic zooplankton at the three sampling sites averaged 23,434 ± 39,513 individuals (including eggs) per m^3. Densities at Carlson Point fluctuated broadly between 4,962 ± 5,520/m^3 on February 17 and 118,628 ± 108,933/m^3 on April 21 (Fig. 15). In 1978, after modification of the sampling technique to reduce sample contamination, monthly densities averaged 24,302 ± 18,249/m^3 with several minima: 10,000 ± 4,690/m^3 on February 21, another of 11,426 ± 2.530/m^3 on June 28 and 11,021 ± 2,660/m^3 on December 15. The maxium in early spring of 50,854 ± 36.566/m^3 on April 6 was generally sustained at that level between August and November. Density estimates between mid-January and early June 1979 averaged 29,948 ± 18,488/ m^3 over the 6-month period with a maximum of 59,643 ± 6,618/m^3 on March 9, approximately one month earlier than in 1978.

While most of the fluctuations in density epibenthic of zooplankton were a function of the density of harpacticoid copepods (Fig. 15), calanoid copepods, gammarid amphipods, crustacean eggs, cyclopoid copepods, cladocerans, ostracods, and isopods often comprised a significant proportion of the total numbers of epibenthic zooplankton during the outmigration period (Fig. 16).

Densities of total epibenthic organisms followed a similar trend at the three principal sampling sites during the 1977 outmigration period, with all sites showing similar density maxima from mid-April to early May. Densities of harpacticoid copepods, however, tended to be more variable (Fig. 17). Devil's Hole Delta, with its extensive eelgrass habitat, typically had the highest densities while the community at Carlson Point showed more frequent and extreme fluctuations than the other sites. Densities of gammarid amphipods also varied considerably between sites and were especially variable at Brown Point.

Table 12. Density (no./m^3) of epibenthic gammarid amphipods at Carlson Point, Hood Canal, during the 1979 outmigration of juvenile chum salmon.

	Density (no./m^3)						
Gammarid taxa	Jan 17	Feb 6	Mar 9	Apr 27	Jun 5	Grand mean density	Frequency of occurrence (%)
GAMMARIDEA (incl. eggs)			33.3	33.3		20.0	40
AMPHILOCHIDAE	35.1					7.0	20
Gitanopsis vilordes	1.8					0.4	20
Amphithoe sp.			1.7			0.3	20
Aoroides columbiae	53.1	81.7	166.7	288.3	283.3	174.6	100
Calliopiella pratti	15.8	6.7		10.0	420.0	90.5	80
Guernea sp.	12.3	10.0	5.0	3.3		6.1	80
Pontogeneia sp.	74.7	23.3	231.7	320.0	1371.7	404.3	100
Melita sp.	3.4			1.7		1.0	40
M. dentata		1.7				0.3	20
ISAEIDAE			33.3			6.7	20
Photis sp.			101.7	36.7	235.0	74.7	60
Podoceropsis sp.	47.2		120.0	10.0	326.7	100.8	80
Ischyrocerus sp.	71.8	33.3	163.3	145.0	110.0	104.7	100
OEDICEROTIDAE			66.7			13.3	20
Monoculodes sp.			5.0	3.3		1.7	40
Synchelidium shoemakeri	55.6	93.3	50.0	168.3	40.0	81.5	100
Westwoodilla caecula	123.3	91.7	51.7	3.3		54.0	80
PHOXOCEPHALIDAE		66.7				13.3	20
Paraphoxus sp.	38.4		35.0	1.7	1.7	15.4	80
PLEUSTIDAE				1.7		0.3	20
Parapleustes nautilus		1.7				0.3	20
Pleustes depressa		1.7	1.7			0.7	40
STENOTHOIDAE		101.7				20.3	20
Metopella carinata	40.4		36.7	1.7		15.7	60
Total mean density (no./m^3)	537.8	513.5	1103.5	1028.3	2610.0	1207.9 1158.62±655.59	

Table 13. Percent composition of epibenthic gammarid amphipods at Brown Point, Hood Canal, Washington, from 17 March - 22 July 1977.

Species		Percent composition											
	Date:	17 Mar	31 Mar	14 Apr	21 Apr	4 May	19 May	2 Jun	13 Jun	8 Jul	22 Jul	Total number	Total %
	Sample size, n:	61	61	54	56	35	56	58	15	60	78		
Allorchestes augustus						6					9	15	1
Ampithoe sp.									7			7	1
Aoroides columbiae			2				9	9	7			27	3
Anisogammarus pugettensis		16	5	7	46	6	4		13		5	102	10
Pontogeneia sp. (undescribed)		67	85	93	36	11	61	74	27	95	31	580	58
Calliopidae													
Paracalliopeilla pratti		5	7		18	57	14	2		5	4	112	11
Calliopius sp.		12				20	7		33		51	123	12
Isaeidae							4					4	0.4
Podoceropsis sp.								16	7			23	2
Paraphoxus spinosus							2					2	0.2
Photis brevipes									7			7	1
Synchelidium shoemakeri			2									2	0.2
												1004	

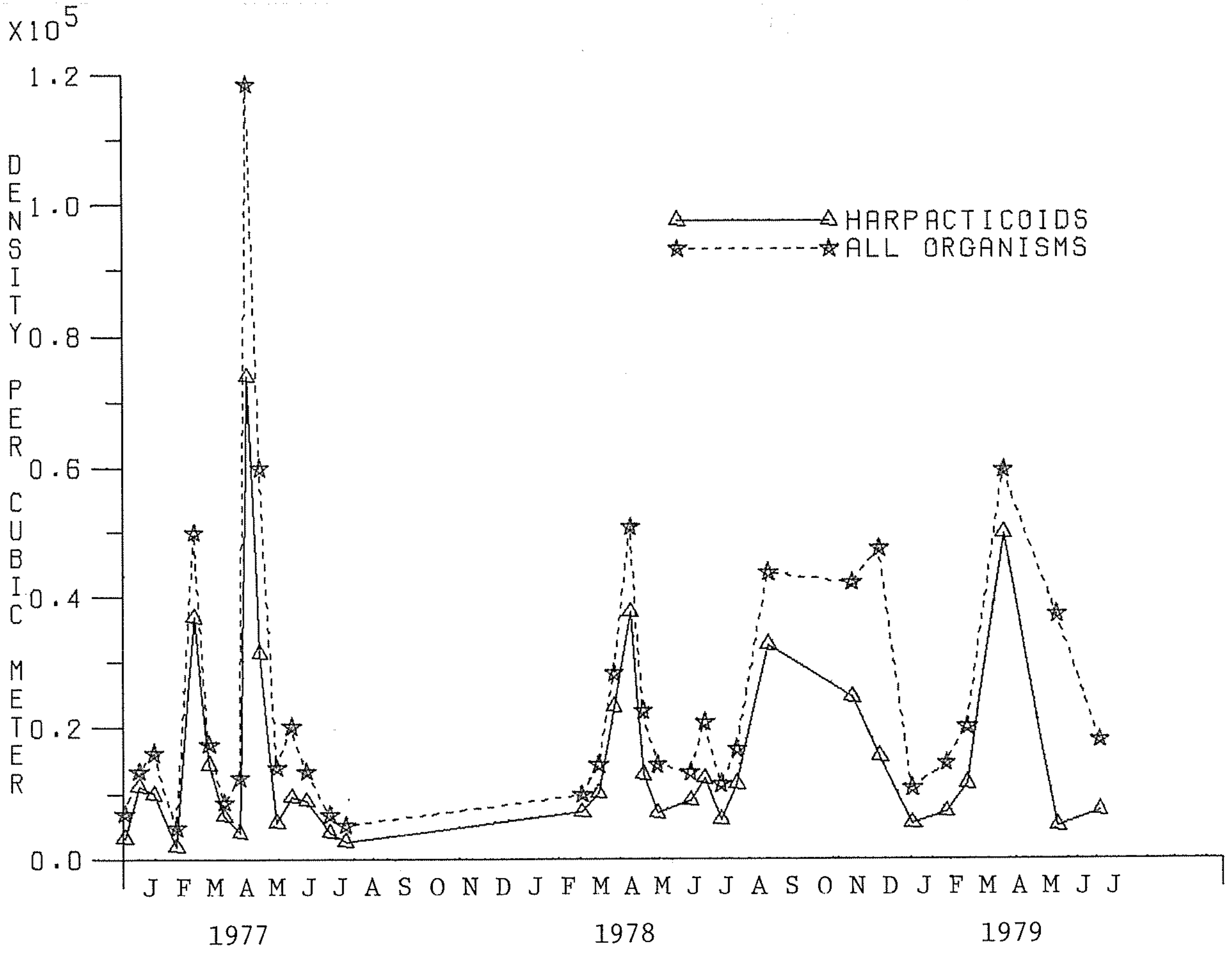


Fig. 15. Mean total density (no./m^3) of epibenthic zooplankton at Carlson Point, Hood Canal, Washington, 1977-1979.

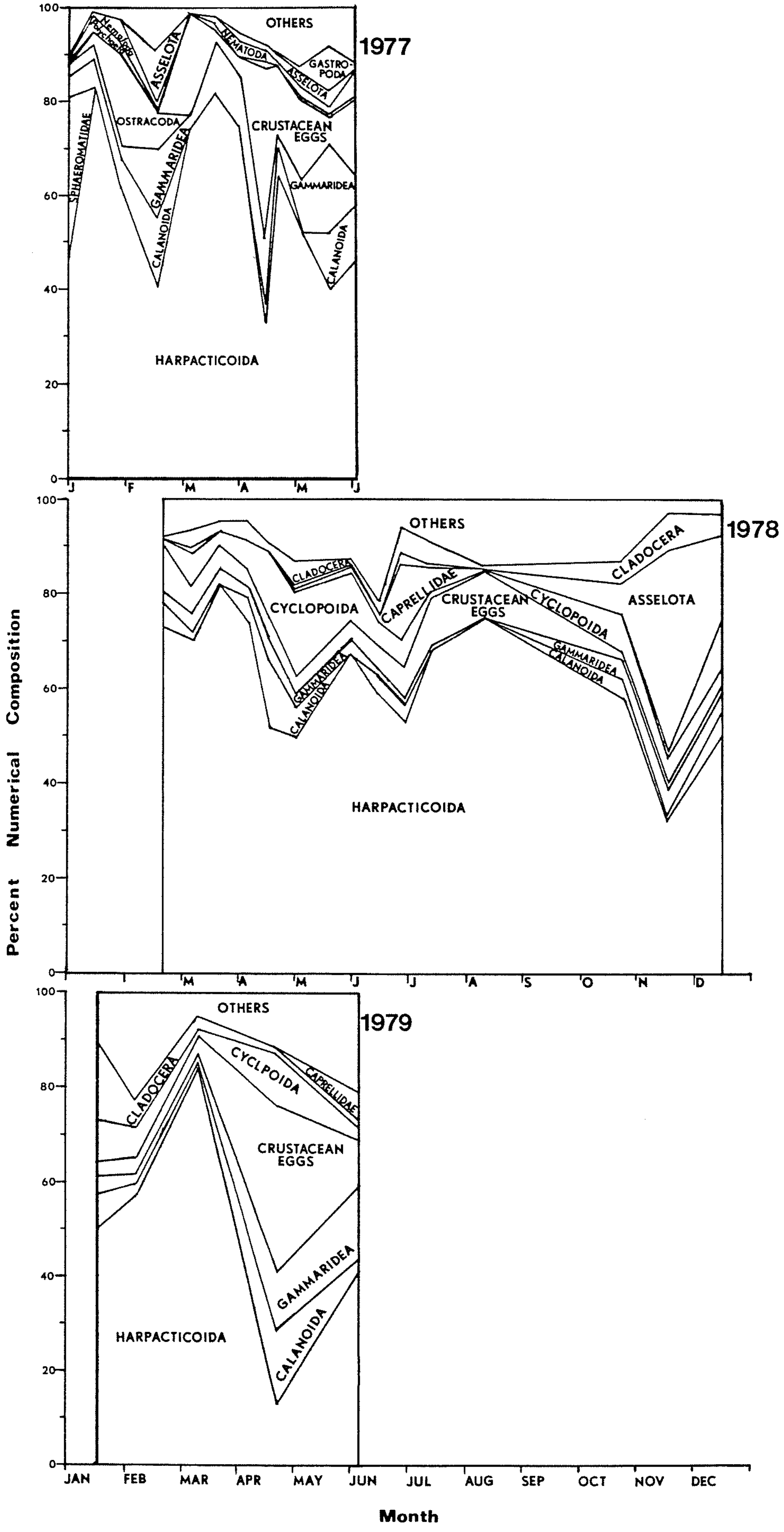


Fig. 16. Percent numerical composition of epibenthic zooplankton at Carlson Point, Hood Canal, Washington, 1977-1979.

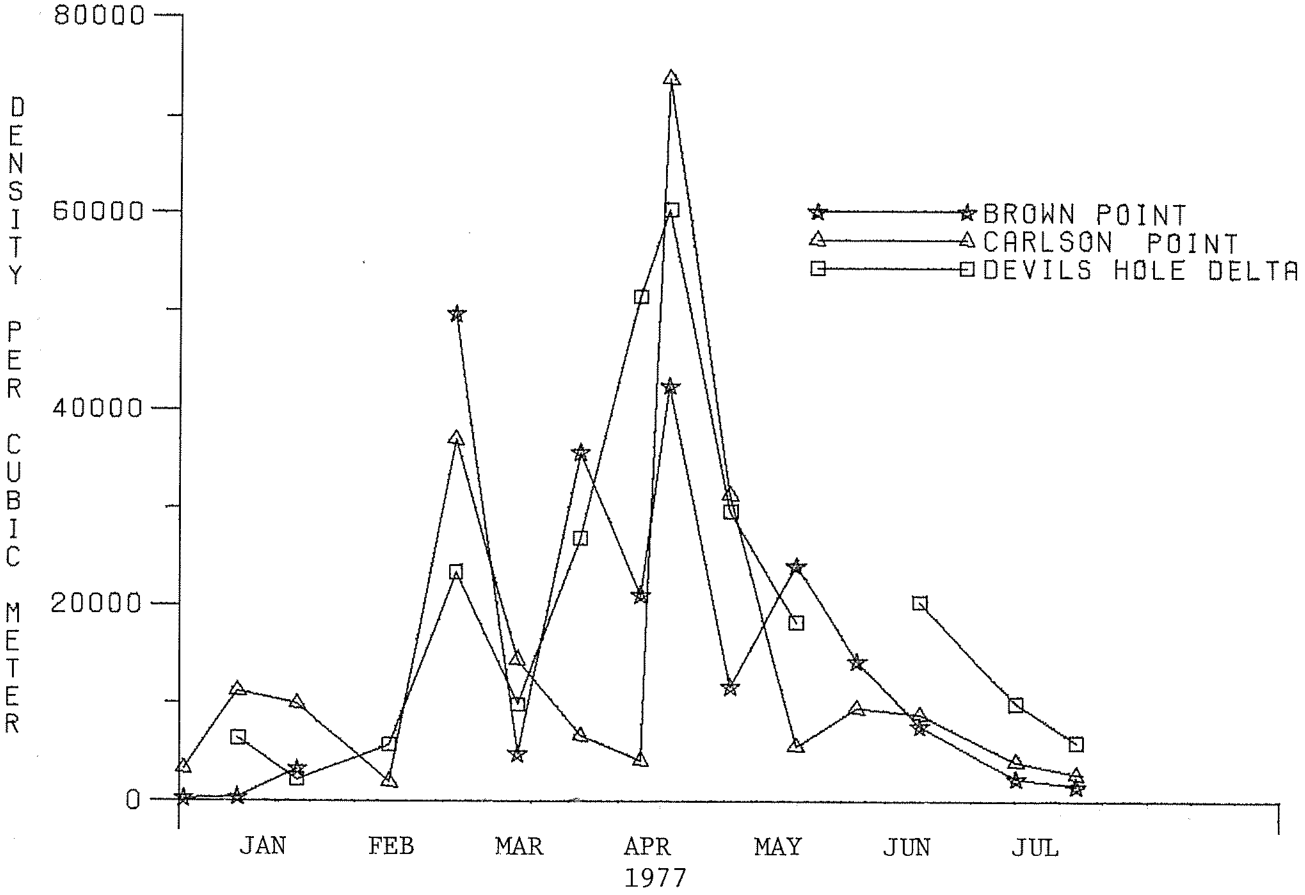


Fig. 17. Mean total density (no./m^3) of harpacticoid copepods at three shallow sublittoral sites in Hood Canal, Washington, 1977.

3.2.3 Standing Crop of Epibenthic Organisms

Estimates of epibenthic zooplankton standing crop (g/m^3) varied considerably over the 3 years (Fig. 18). Using the less effective sampling methodology in 1977, the mean standing crop ranged from 0.063 ± 0.120 g/m^3 in early January and late March to 0.025 g/m^3 in early May. Following the improvements in sampling efficiency, standing crop estimates were dramatically higher in 1978, averaging 0.801 ± 0.814 g/m^3. A late winter-early spring maximum of approximately 0.8 g/m^3, associated with the increase in harpacticoid copepod abundance, was followed by a general depression between early April and mid-July that we correlated with a decrease of harpacticoid copepods (Fig. 19). From July through November the standing crop increased (maximum of 2.59 g/m^3 on November 17) due in part to a reoccurrence of high densities of harpacticoid copepods and the appearance of relatively large zooplankters such as juvenile shrimp and caprellid amphipods. Standing crop estimates in 1979 followed a somewhat different pattern than those in 1978. There was an early decline from a maximum of 1.9 g/m^3 in January and February to a minimum of 0.78 g/m^3 in late April. This trend also coincided with the increase in abundance of juvenile shrimp and the decline in harpacticoid copepod densities.

The 1977 estimates may have been compromised by less accurate biomass measurements than were obtained for the latter two years because the improvements in the 1978-1979 sampling methodology appear to have resulted in more effective collection of large zooplankters such as gammarid amphipods and juvenile caridean shrimp, which may have been able to escape the epibenthic pump's suction during the 1977 sampling.

3.2.4 Relationship Between Epibenthic Zooplankton Community Composition and Stomach Contents of Juvenile Chum Salmon

Comparison of zooplankton composition in coincident epibenthic pump samples and stomach contents samples from beach seine-caught juvenile chum was limited due to the general lack of such concomitant samples; on only ten occasions were direct comparisons possible (Table 14). A general trend of decreasing overlap (PSI) with increasing fish length and period in the outmigration is evident from these few comparisions, however. Due to the numerical predominance of harpacticoid copepods in the epibenthic pump samples, the overlap values primarily reflected the proportional representation of harpacticoids in the stomach contents of the juvenile chum salmon. Low overlap usually resulted from either, 1) a high proportion of gammarid amphipods in the stomach contents of the juvenile chum, reflecting selectivity toward these large epibenthic zooplankters, or 2) a high proportion of calanoid copepods in the stomach contents, indicating feeding had occurred in neritic waters rather than in the shallow sublittoral habitats where they were caught.

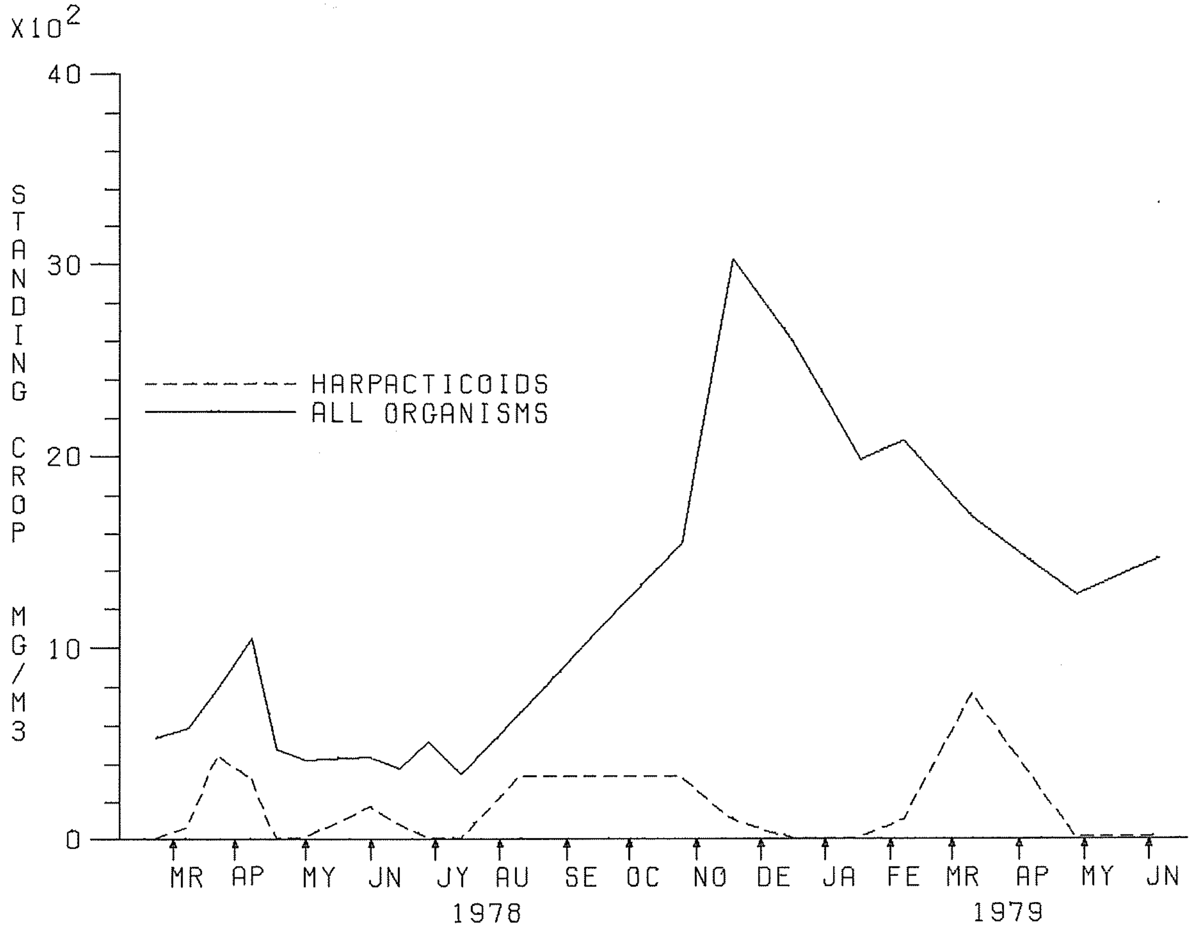


Fig. 18. Total mean standing crop (g/m^3) of epibenthic zooplankton at Carlson Point, Hood Canal, Washington, 1977-1979.

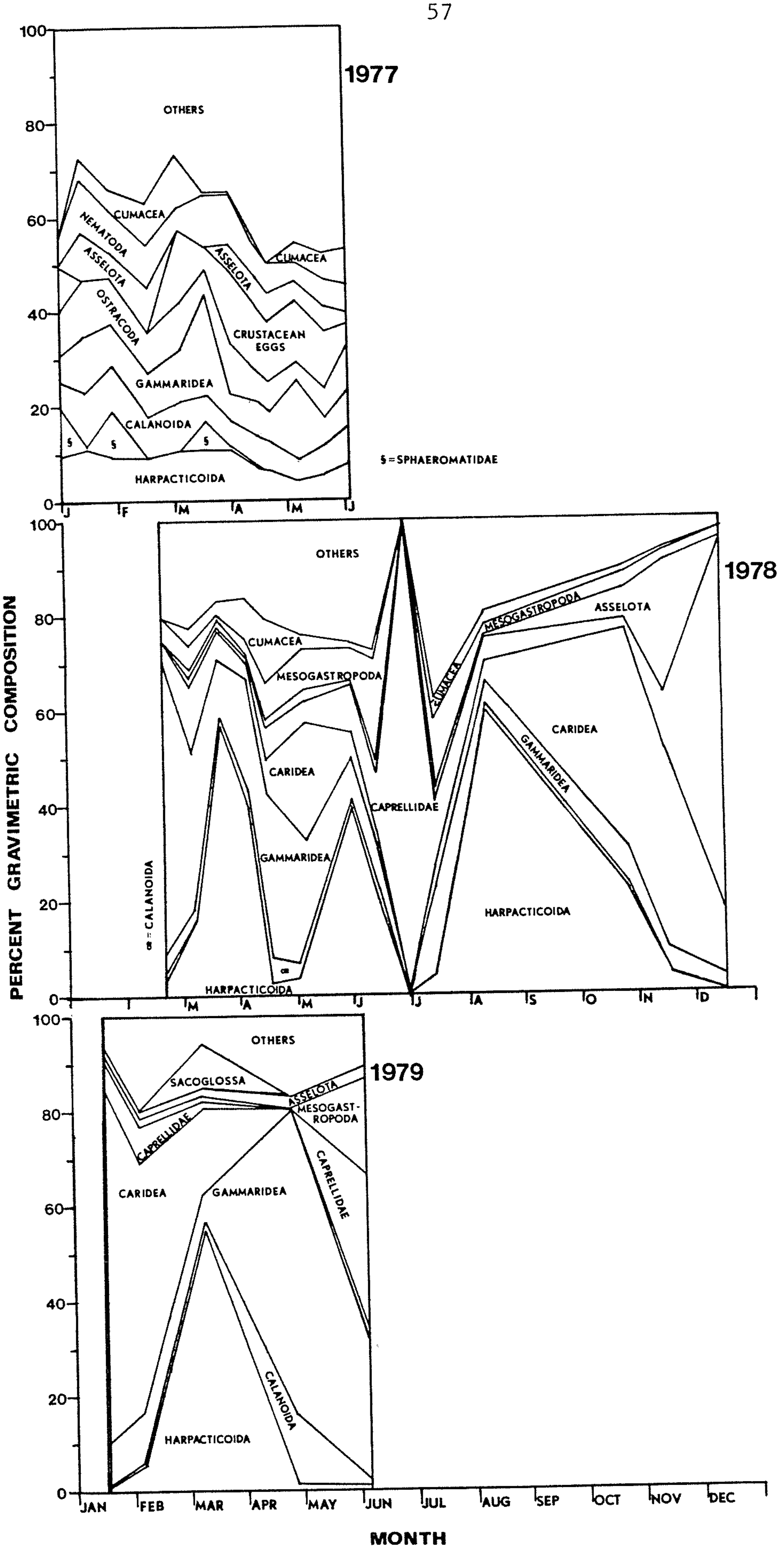


Fig. 19. Percent gravimetric composition of epibenthic zooplankton at Carlson Point, Hood Canal, Washington, 1977-1979.

Table 14. Numerical overlap (PSI) between epibenthic zooplankton community composition and stomach contents of juvenile chum salmon from coincident epibenthic pump and beach seine samples in Hood Canal, Washington, 1977-1979.

Length interval (FL,mm)	Month					
	Feb	Mar	Apr	May	Jun	Jul
35-39	61.83					
40-44	40.61		25.01			
45-49				6.71		
50-54			26.44	27.71*		17.52
55-59				8.29		
60-64					4.86	

*Mean of two samples.

3.2.5 Relationship Between Epibenthic Zooplankton Abundance and Abundance of Juvenile Chum Salmon

In all 3 years the general decline in harpacticoid copepod densities in early spring appeared to coincide with the peak densities (CPUE) of juvenile chum salmon in shallow sublittoral habitats (Fig. 20). The extended sampling in 1978, however, showed an increase in harpacticoid density after the period of chum and pink salmon outmigration, suggesting that epibenthic-feeding chums could be involved in depressing harpacticoid populations during the most intensive outmigration period. This cannot be verified, however, without more detailed taxonomic, population biology, and ecological studies of the harpacticoid community.

3.2.6 Neritic Community Composition

Although the sampling of neritic zooplankton was conducted monthly between June 1978 and June 1979, sample processing was limited to the June and July 1978 and February, April, and June 1979 collections at Carlson Point. All but 7 of the 42 taxa identified from the June-July 1978 neritic samples were crustaceans, predominantly calanoid (9 families, 12 species) and cyclopoid copepods (two families, two species Table 15). The prevalent species were the calanoids, Paracalanus parvus and Pseudocalanus sp. (complex of species including P. minuta) and unidentifiable juvenile caridean shrimp. Calanoid copepods completely dominated the more comprehensive collections made between early February and early June 1979. Compared to the previous year's collections, however, Paracalanus sp. were relatively rare during that period and Pseudocalanus sp. and Acartia longiremis constituted the most common neritic species. Pelagic larvacea, Oikopleura sp., were rare in the 1978 collections, but were third most abundant among the identifiable species in 1979.

3.2.7 Density of Neritic Organisms

The density of neritic organisms at Carlson Point on two dates in July 1978 averaged $407.6 \pm 480.8/m^3$ but, as indicated by the high coefficient of variation (0.848), varied considerably between the two sampling dates. The three collections at Carlson Point during the 1979 chum outmigration averaged $993.9 \pm 952.1/m^3$, with the maximum density, $2120.9 \pm 674.3/m^3$, occurring in late April.

During the 1979 outmigration the numerical dominance of Pseudocalanus in the surface waters declined by May and was replaced by Acartia (Fig. 21a). In early June, when our sampling terminated, the proportional representation of Calanus, Tortanus, and Paracalanus had calanoid community documented by the 15-m deep oblique tows (Fig. 21b) was somewhat different than the surface tows. Paracalanus declined through the sampling period while Pseudocalanus and Paracalanus were notably more abundant. Calanoid eggs were equally distributed in both types of neritic zooplankton collections.

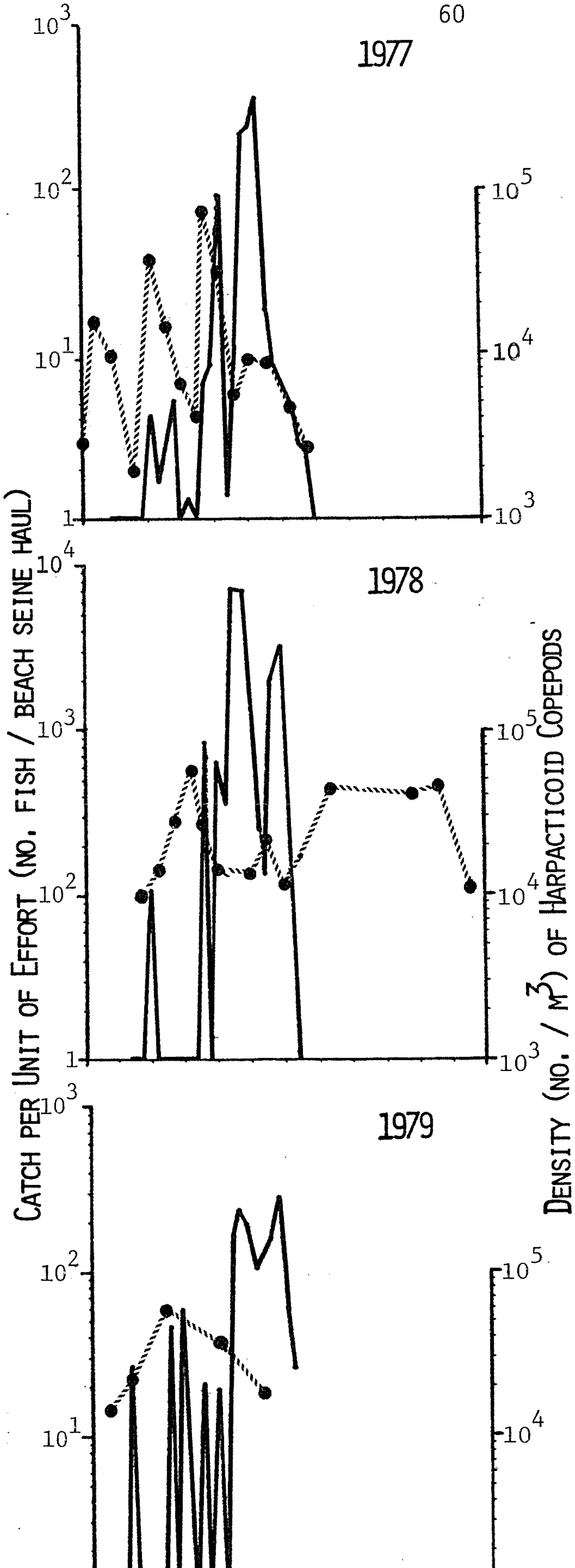


Fig. 20. Density of epibenthic harpacticoid copepods (no./m^3; ‴‴‴) and juvenile chum salmon (C.P.U.E. of 37-m beach seine; ——) at Carlson Point, Hood Canal, Washington, 1977-1979.

Table 15. Taxonomic, life history, numerical and gravimetric composition of neritic zooplankton collected at Carlson Point, Hood Canal, Washington, during 1978 and 1979 chum salmon outmigration.

Taxa	Eggs/ egg cases	Larvae	Juveniles	Adults	1978 % Composition Abundance	1978 % Composition Biomass	1979 % Composition Abundance	1979 % Composition Biomass
CNIDARIA			J	A	< 0.01	0.03		
HYDROIDA		L					0.20	4.46
ANTHOMEDUSAE		L					< 0.01	< 0.10
LEPTOMEDUSAE		L					0.01	0.20
SIPHONOPHORA				A			0.03	0.10
CTENOPHORA			J	A			0.06	17.27
TURBELLARIA			J				< 0.01	0.01
NEMATODA				A	0.04	0.02		
POLYCHAETA		L					< 0.01	0.01
Polynoidae			J				< 0.01	< 0.01
Spionidae			J	A			0.09	0.11
GASTROPODA	E						0.11	0.01
ARCHAEOGASTROPODA			J				0.47	0.64
MESOGASTROPODA			J				0.04	0.10
NEOGASTROPODA			J				0.04	0.04
CEPHALOPODA			J				< 0.01	0.25
CRUSTACEA								
OSTRACODA								
MYODOCOPA				A	0.01	0.06		
COPEPODA								
CALANOIDA	E	L	J	A	1.27	0.32	52.68	25.99
Calanidae								
Calanus sp.		L	J	A	4.36	14.73	0.55	3.22
C. pacificus		L	J	A	0.45	0.30	0.08	0.44
C. plumchrus			J	A			0.04	0.33
Eucalanidae								
Eucalanus sp.			J		0.01	0.12		
Paracalanidae			J	A			0.21	0.16
Paracalanus sp.				A	24.76	21.53		
P. parvus			J	A	0.25	0.01	0.21	0.16
Pseudocalanidae			J	A			9.80	12.72
Pseudocalanus sp.			J	A	39.30	32.39		
Pseudocalanus minutus			J	A			9.80	12.72
Aetidius armatus				A			0.01	0.01
Metridiidae								
Metridia sp.				A	0.05	0.12		
Metridia lucens		L	J	A			0.32	0.56
Centropagidae								
Centropages sp.				A	0.51	0.66		
C. abdominalis		L	J	A	0.06	0.01	0.05	0.06
Eurytemora americana				A			<0.01	0.01

Table 15(cont.).

Taxa	Eggs/ egg cases	Larvae	Juveniles	Adults	1978 % Composition Abundance	1978 % Composition Biomass	1979 % Composition Abundance	1979 % Composition Biomass
Pontellidae								
Epilabidocera amphitrites		L	J	A	0.03	0.26	0.05	0.10
Acartiidae				A	0.60	0.39		
Acartia clausi			J	A			0.53	0.26
A. longiremus			J	A	0.11	0.01	7.78	6.86
Tortanidae								
Tortanus discaudatus		L	J	A	0.03	0.01	0.41	0.53
HARPACTICOIDA			J	A	0.04	0.02	0.05	0.03
Porcellidiidae				A			<0.01	<0.01
CYCLOPOIDA								
Corycaeidae								
Corycaeus sp.		L	J	A	2.41	0.49	0.02	0.01
C. anglicus		L	J	A			0.34	0.15
Oithonidae								
Oithona sp.			J	A	0.75	0.12	0.39	0.07
MONSTRILLOIDA								
Monstrilla sp.							>0.01	>0.01
BALANOMORPHA		L	J		0.07	0.01	1.02	0.59
MALACOSTRACA			J		0.01	0.01		
MYSIDACEA			J		0.01	0.01		
Mysida			J		< 0.01	< 0.01		
ISOPODA								
EPICARIDEA								
Bopyridae			J	A			< 0.01	0.01
AMPHIPODA								
GAMMARIDEA			J		0.01	0.01	< 0.01	< 0.01
Calliopiidae			J		0.15	0.23		
Calliopius sp.			J	A	0.01	0.23	0.01	0.21
Corophidae								
Corophium sp.			J				< 0.01	< 0.01
Hyalidae			J				< 0.01	< 0.01
HYPERIIDEA			J		0.28	0.19		
Hyperiidae			J				0.06	0.18
Hyperoche sp.				A			< 0.01	0.07
Parathemisto pacifica			J	A	0.63	0.25	0.02	0.05
CAPRELLIDEA								
Caprellidae			J		< 0.01	< 0.01		
EUCARIDA		L			0.15	0.03		
EUPHAUSIACEA		L	J		0.81	1.04	0.63	0.36
Euphausiidae		L					0.11	0.03
DECAPODA		L			0.01	0.12	0.01	< 0.01
PLEOCYEMATA								
CARIDEA		L			12.96	18.00	0.01	0.01

Table 15(cont.).

Taxa	Eggs/ egg cases	Larvae	Juveniles	Adults	1978 % Composition Abundance	1978 % Composition Biomass	1979 % Composition Abundance	1979 % Composition Biomass
Hippolytidae		L			X	X	0.04	0.20
Crangonidae		L					0.07	0.18
ANOMURA								
Callianassa sp.		L					0.01	0.02
Paguridae		L			0.01	0.18	0.02	0.15
Galatheidae		L					< 0.01	0.01
Porcellanidae		L			0.03	0.12		
BRACHYURA		L			1.84	3.67	0.01	0.01
Pugettia sp.		L					0.01	0.10
Cancridae		L					0.01	< 0.01
Cancer sp.		L					0.18	3.70
BRACHYRHYNCHA								
Lophopanopeus bellus		L					0.04	0.10
Pinnotheridae		L			1.56	2.62	0.91	2.31
Grapsidae								
Hemigrapsus sp.		L					0.01	< 0.01
INSECTA								
PSOCOPTERA				A			< 0.01	0.02
NEMATOCERA				A			< 0.01	< 0.01
ECTOPROCTA								
GYMNOLAEMATA		L			0.02	0.02	1.58	0.46
CHAETOGNATHA			J	A	0.23	1.13		
Sagitta sp.			J	A			0.21	4.32
S. elegans			J	A			< 0.01	0.21
LARVACEA								
Oikopleura sp.			J	A	0.06	0.02	5.72	3.93
TELEOSTEI	E	L			0.16	0.09	0.10	0.79
Cottidae		L					< 0.01	0.10
UNIDENTIFIED EGGS	E				5.97	0.34	14.80	7.12

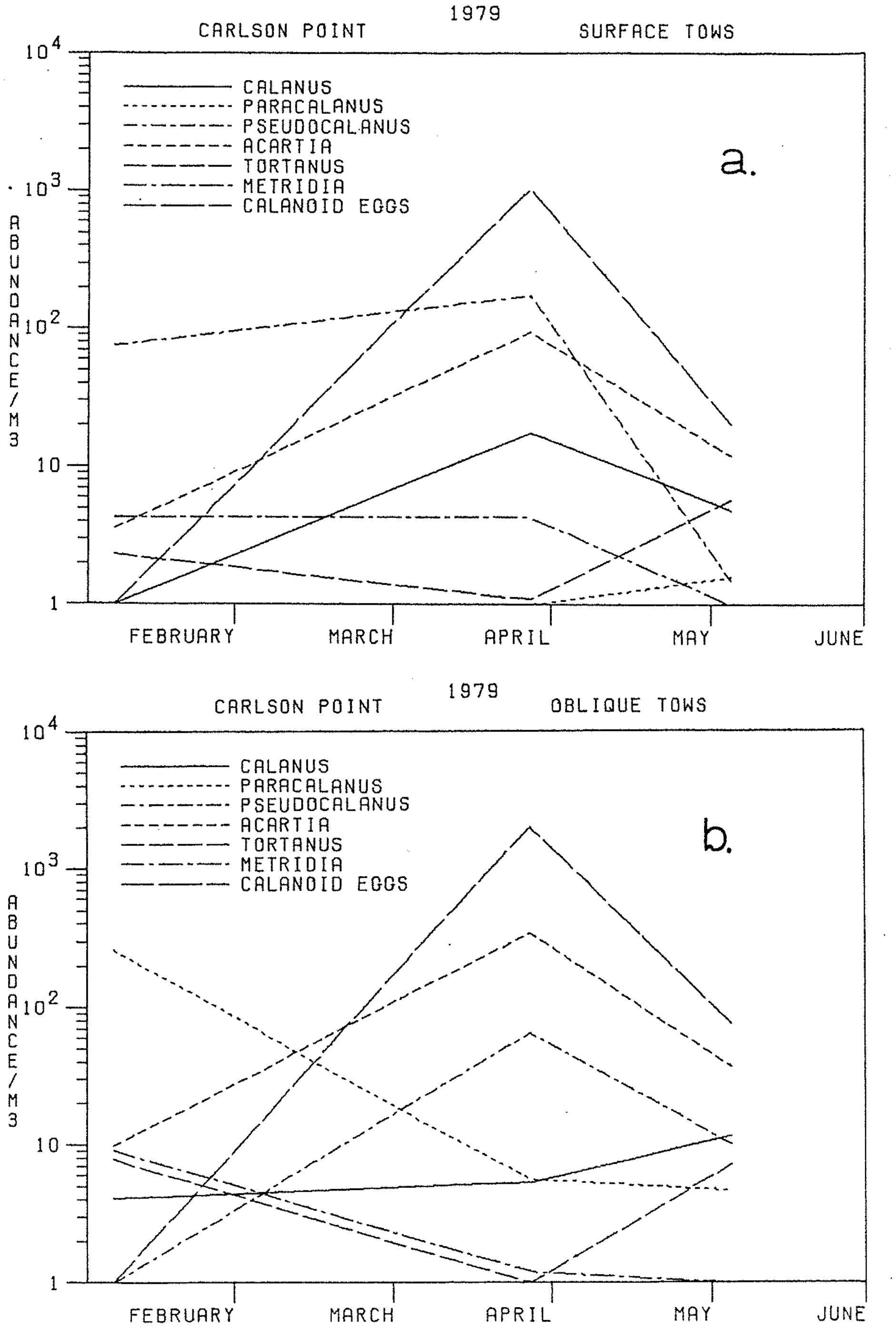


Fig. 21. Density (no./m^3) of dominant neritic zooplankton taxa collected by surface (a) and 15-m deep oblique (b) 60-cm bongo net collections at Carlson Point, Hood Canal, Washington, during the 1979 juvenile chum salmon outmigration.

3.2.8 Standing Crop of Neritic Organisms

The mean total standing crop from the 1978 neritic samples was 0.026 ± 0.015 g/m^3, 0.840 g/m^3 in late April, decreasing to 0.050 ± 0.051 g/m^3 by early June.

Based on standing crop, *Pseudocalanus* was the only predominant calanoid in early February (Fig. 22). In late April, *Pseudocalanus* had increased and *Calanus*, *Pseudocalanus* and calanoid eggs were abundant in surface waters (Fig. 22a). But by early June the standing crop of all but *Calanus* had declined in both surface and 15-m deep oblique collections.

3.3 Evidence and Characteristics of Prey Selectivity

Size selection of harpacticoid copepods and gammarid amphipods by juvenile chum salmon was readily apparent. As a representative illustration, the mean length of harpacticoids sampled by epibenthic pump in late April 1977 at Brown Point was 0.72 ± 14 mm while those consumed by beach seine-caught chum were 1.0 ± 0.22 mm and those consumed by townet-caught chum were 1.20 ± 11 mm in length (Fig. 23). In some instances the largest harpacticoids consumed by the chum were completely out of range of those sampled by the plankton pump. This suggests that either (1) the epibenthic plankton pump was completely unable to sample harpacticoids much larger than 1.0 mm in length, (2) the large harpacticoids were not available within the shallow sublittoral habits sampled by the pump (i.e., in the epibenthos deeper than -1 m or in neritic habitats), or (3) such large harpacticoids are so rare than our limited sampling area and frequency did not adequately assess their distribution and abundance. The prospect of sampling bias would seem to be negated by the fact that larger, even more mobile fauna, such as gammarid amphipods and isopods, were effectively sampled by the pump. Neither does the literature on harpacticoid distribution or our neritic sampling support the argument of chums foraging upon harpacticoids outside of shallow sublittoral habitats. Thus, we conclude this size difference to be an effect of juvenile chum selecting an extremely rare component of the epibenthic plankton community rather than a sampling bias.

The mean harpacticoid sizes were typically larger in the stomach contents of juvenile chum caught in neritic waters than from those caught in shallow sublittoral habitats. This may reflect size selective predation as a function of predator size since the chums caught in neritic waters with the townet averaged 7 mm larger than those caught in shallow sublittoral habitats by the beach seine (Fig. 23).

There was also some evidence, though far from conclusive, that intense size-specific predation was depressing the mean size distributions of harpacticoids during the peak outmigration period of juvenile chum (Fig. 24), suggesting overexploitation of the larger size component

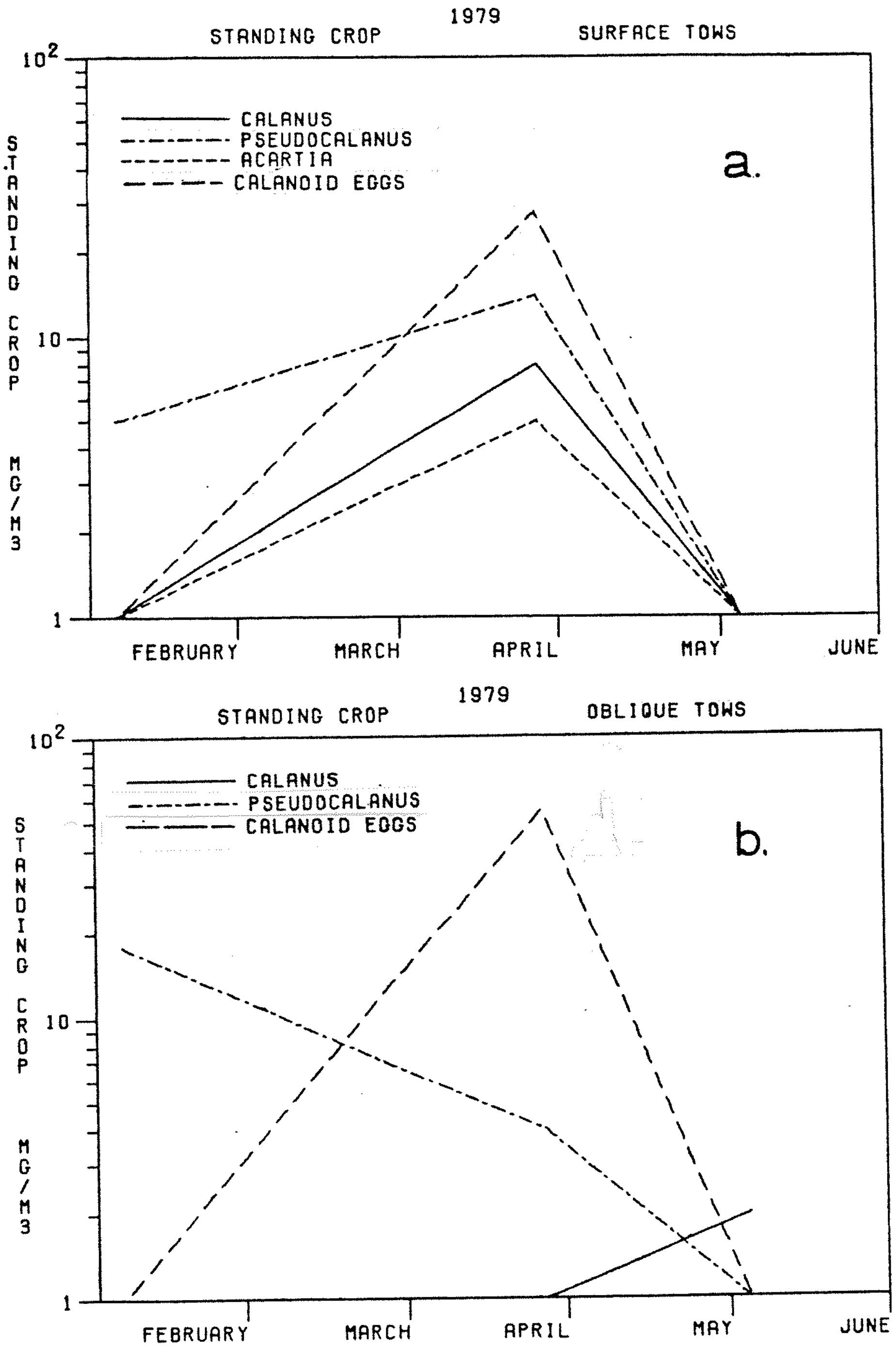


Fig. 22. Standing crop (mg/m^3) of dominant neritic zooplankton taxa collected by surface (a) and 15-m deep oblique (b) 60-cm bongo net collections at Carlson Point, Hood Canal, Washington, during the 1979 juvenile chum salmon outmigration.

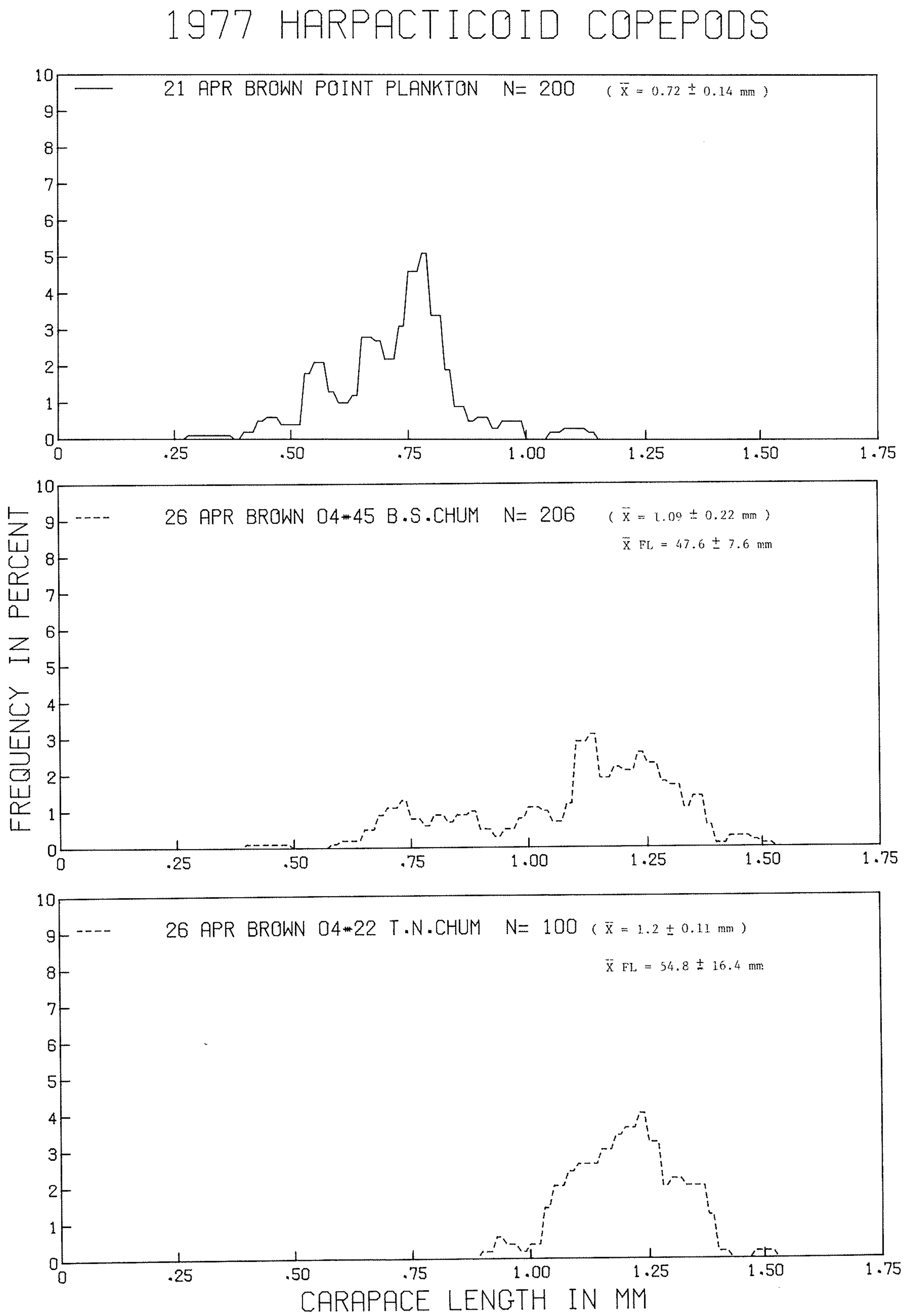


Fig. 23. Harpacticoid copepod size (metasome length) distributions from epibenthic plankton community (a), and from stomach contents of outmigrating juvenile chum salmon caught in shallow sublittoral (b) and neritic (c) environments in Hood Canal, Washington, late April, 1977.

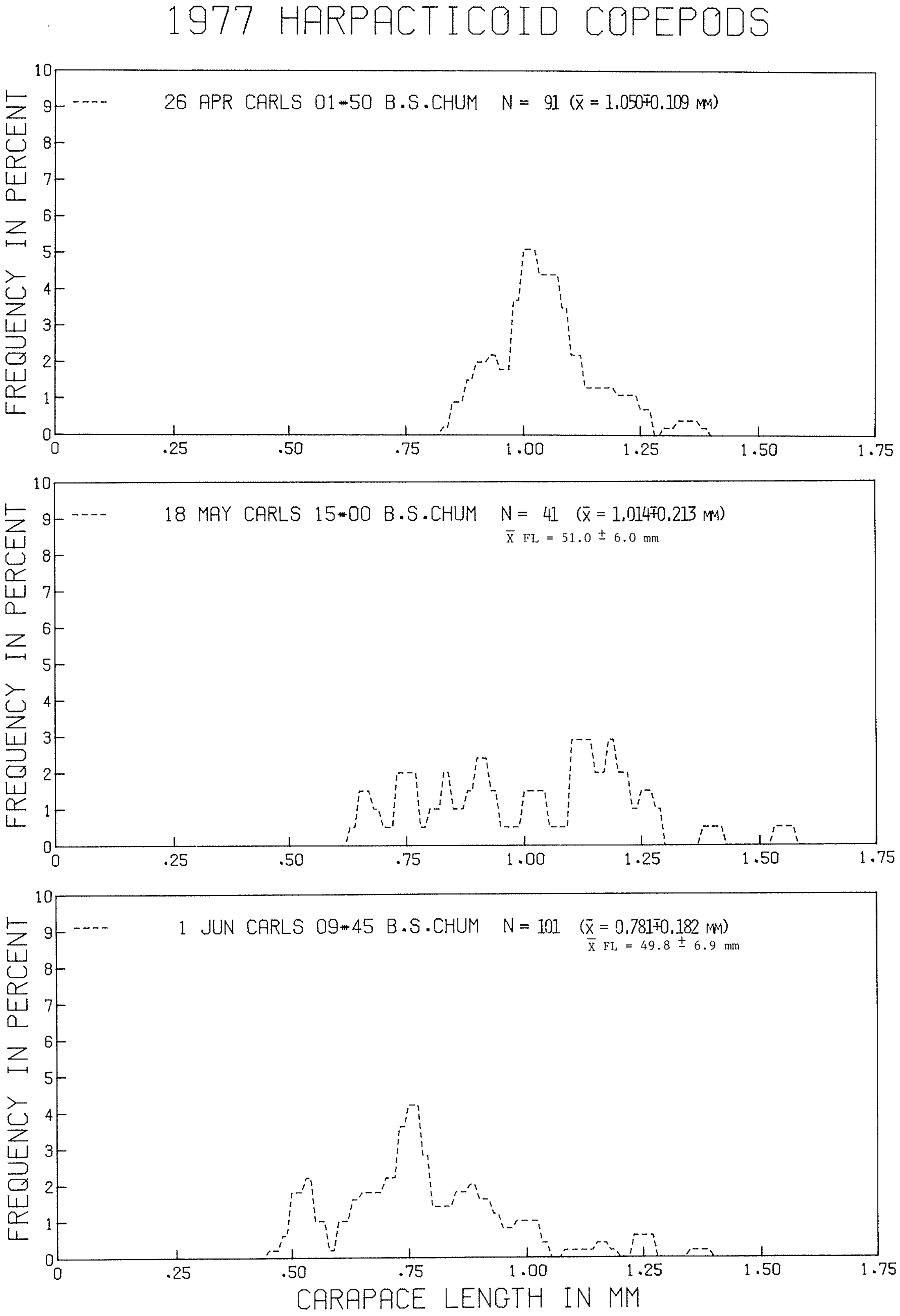


Fig. 24. Harpacticoid copepod size (metasome length) distribution from stomach contents of outmigrating juvenile chum salmon caught in shallow sublittoral habitats in Hood Canal, Washington, late April-early June, 1977.

of the prey resource. This cannot be verified, however, without more complete knowledge of the species composition and life history patterns of the prominent harpacticoid copepods.

Size-selective predation upon gammarid amphipods was also suggested, although sample sizes for measurable organisms in the contents of chum fry stomachs were not sufficient to compare with individual epibenthic plankton samples. In one instance, May 18, the size distribution of amphipods consumed by chum fry contained distinctly larger amphipods (Fig. 25). Unlike harpacticoid copepods, gammarids did not decline in mean size during the peak outmigration period of juvenile chum in Hood Canal.

Size-selective predation of gammarid amphipods could also be inferred from prey species composition in the stomach contents of juvenile chum. The larger gammarids, including *Calliopiella pratti* ($\bar{x}$ biomass/individual = 0.4 mg), *Pontogeneia* sp. ($\bar{x}$ = 0.6 mg), and *Ischyrocerus* sp. ($\bar{x}$ = 0.2 mg), were the principal species consumed while the most abundant amphipod species *in situ* were much smaller, i.e., <0.1 mg/individual.

Feeding behavior of juvenile chum in neritic waters also appeared to be highly selective. Comparisons between prey spectra of chum and surface (where the fish were assumed to feed) neritic zooplankton collected in June and July 1978 generated overlap indices of 40.1 and 49.4, respectively (Table 16). Larvaceans (*Oikopleura* sp.), chaetognaths, fish eggs, juvenile euphausiids and shrimp, and hyperiid amphipods (*Parathemisto pacifica*) were apparently selected preferentially by the chum salmon. Calanoid copepods, even though they were the principal prey, were not preyed upon in proportion to their abundance. When species and size frequency distributions of calanoids in the prey spectra of the juvenile chum and the environment are compared, however, selectivity for large calanoid species is quite apparent (Fig. 26; see also Figs. 11 and 12). The two largest species, *Calanus* sp. and *Epilabidocera amphitrites* were extremely rare in the daytime, neritic zooplankton collections as compared to the abundant but smaller *Pseudocalanus*, *Paracalanus*, and *Centropages*, and cyclopoid copepod, *Corycaeus* sp..

There are a number of alternatives to these selectivity curves: 1) The bongo net and sampling design do not representatively sample the plankton community in the top 3 m of the water column, e.g., zooplankters avoid the net; 2) the townet collections do not capture fish feeding in the surface plankton community; or 3) the daytime composition of the plankton community is not spatially or temporally characteristic of that in which the chum fry have fed. Of these hypotheses, the first two are the least plausible: The capture of highly motile crustaceans such as hyperiid amphipods in the bongo net and the townet's effective capture of marked chum fry suggests that inefficient sampling by the bongo net and townet will not explain these discrepancies. The most valid hypothesis, therefore, is that the chum fry collected by the townet had fed either in a deeper stratum where larvaceans, hyperiid amphipods, and

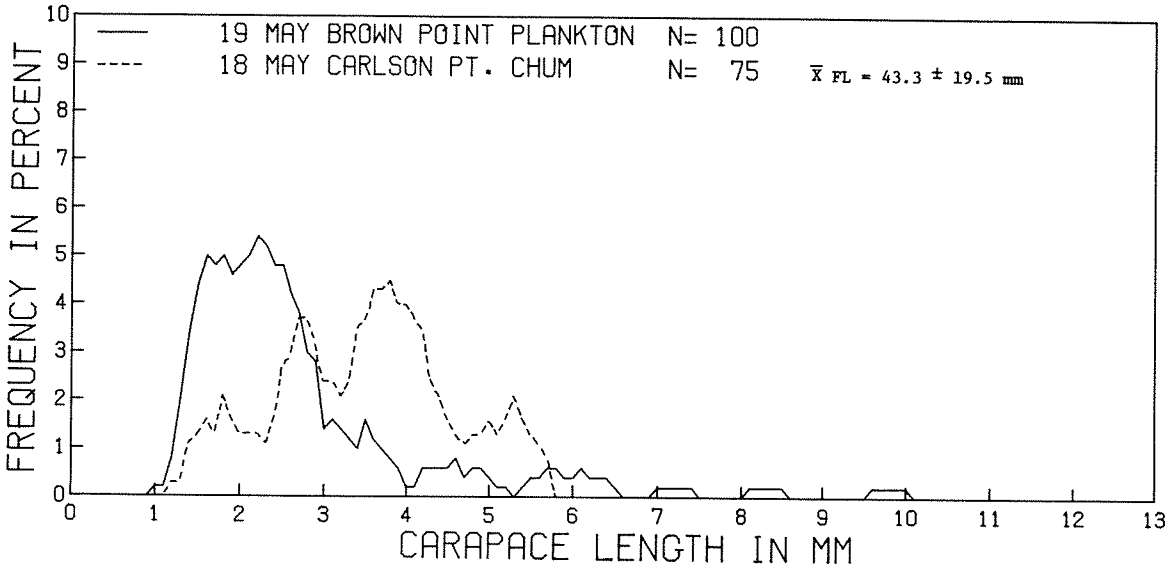


Fig. 25. Gammarid amphipod size (carapace length) distributions from the epibenthic zooplankton community (solid line) and in the stomach contents of juvenile chum salmon (dashed line) in Hood Canal, Washington, mid-May, 1977.

Table 16. Overlap between numerical composition of surface neritic zooplankton and stomach contents of juvenile chum salmon at two locations in Hood Canal, June and July 1980.

	Neritic zooplankton			Chum salmon		
Location	Collection Date	Taxa	Numerical composition (%)	Collection date	Length ($\bar{x}$ FL, mm)	Numerical composition (%)
Brown Point	27 June 1978	Calanoid copepods	83.1	21 June 1978	70.7	36.5
		Shrimp larvae	5.2			0.7
		Egg cases (unident.)	3.3			-
		Cyclopoid copepods	2.5			-
		Crab zoea	1.8			0.7
		Euphausiid juveniles	1.7			2.4
		Eggs (unident.)	1.2			-
		Hyperiid amphipod juveniles	0.5			0.7
		Insects	-			3.1
		Larvaceans	-			52.6
		Chaetognaths	-			0.5
		Fish larvae	-			1.7
	PSI = 40.1					
Carlson Point	12 July 1978	Calanoid copepods	51.1	12 July 1978	100.0	35.9
		Egg cases (unident.)	13.9			-
		Hyperiid amphipods	13.2			26.1
		Cyclopoid copepods	7.5			-
		Shrimp larvae	5.5			0.1
		Gammarid amphipods	2.3			0.1
		Crab zoea	1.8			0.1
		Caligoid copepods	0.9			-
		Larvaceans	-			32.3
		Insects	-			0.5
		Fish larvae	-			3.7
	PSI = 49.4					

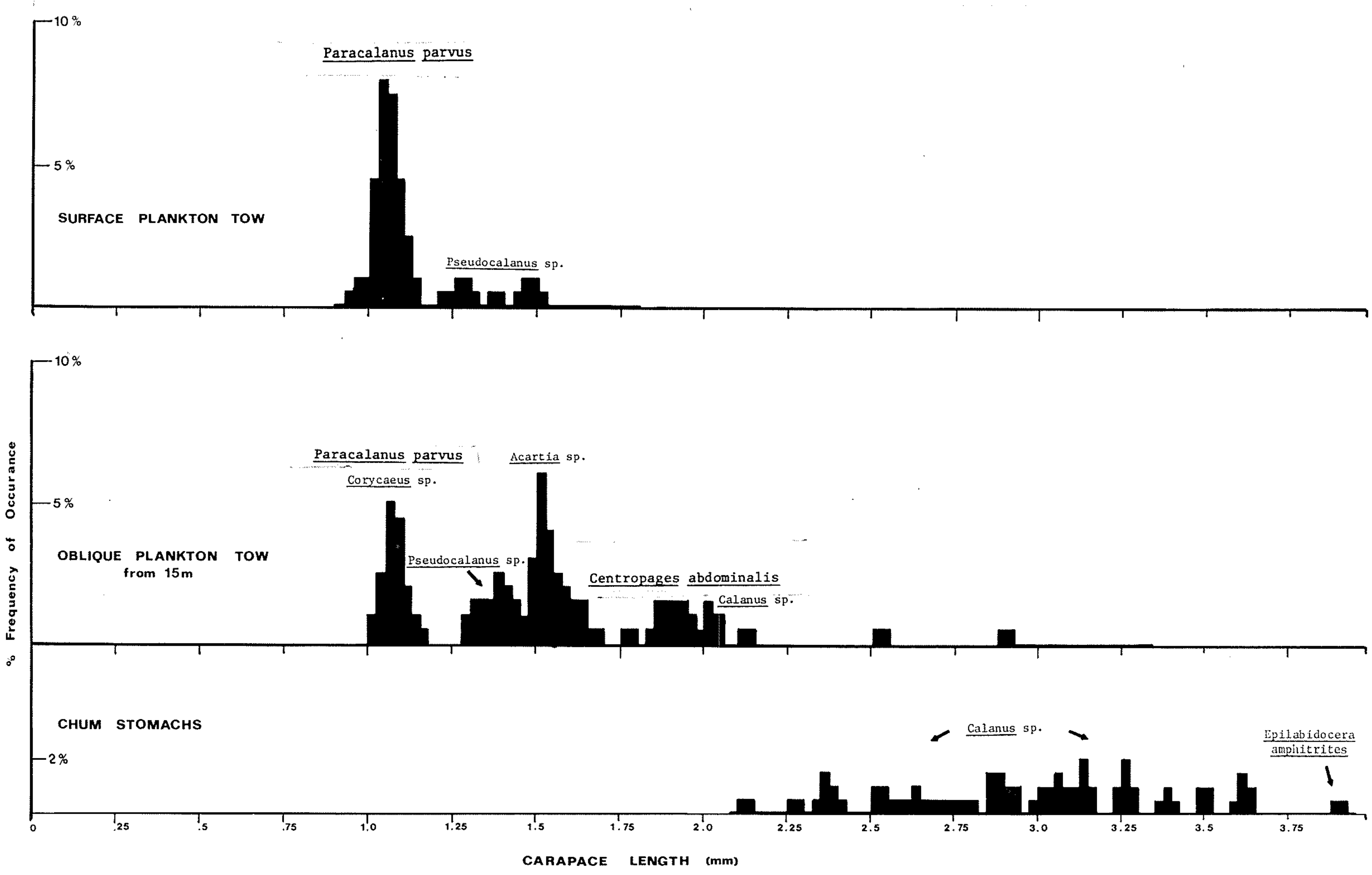


Fig. 26. Size frequency of copepods from neritic zooplankton collections and from the stomachs of juvenile chum salmon caught by townet at Brown Point, Hood Canal, Washington, 27 June 1978.

large calanoid species were more abundant, or the fish limited their foraging to dusk and dawn when that plankton community had vertically migrated closer to the surface. Stober and Salo (1973) illustrated that 87% of the juvenile chum salmon migrating through northern Skagit Bay were near the surface (<3 m), while 10% occurred at 9 m and 3% were 18 m. Cooney (1971), Damkaer (1964), and Frost (Dept. Oceanography, University of Washington, unpublished data) provide evidence that *Calanus* are typically most abundant in the diffuse scattering layer which usually occurs deeper than 50 m during daylight in Hood Canal. Although Marshall and Orr (1955) provide strong documentation of the diel vertical migration of this genus, the behavior of the Hood Canal population is not well known, so it will require further, more detailed sampling to determine whether these zooplankters migrate into surface waters, within range of the predominantly crepuscular-feeding chum fry, or the chum are actually feeding in deeper strata. It would appear from Damkaer's (1964) collections in Dabob Bay, while limited to December 1960, that there was some diel migration of *Calanus*, although the highest densities still resided well below the pycnocline (vertical density stratification). Of the common prey species, only *Epilabidocera*, a large neusstonic, swarming calanoid, occured predominantly in the surface waters: the smaller species which were not fed upon by juvenile chum salmon, i.e., *Pseudocalanus* sp. and *Paracalanus* sp., occurred primarily in the surface layers and *Coryceaus* sp. to just below the pycnocline. Thus, if the calanoid copepod taxa exploited by the chum were consumed within the top 5 m of the water column, their densities were orders of magnitude lower than the smaller calanoid taxa. Unless the chum were feeding upon the larger calanoids below the pycnocline, which we feel is unlikely, the implication of high selectivity toward large zooplankton is substantiated even during periods when the juvenile chums and their prey overlap spatially at night.

4.0 DISCUSSION

4.1 Relationship Between Migration Behavior and Prey Resources

The migration behavior of juvenile chum and pink salmon, in terms of residence in shallow sublittoral and neritic habitats and speed of outmigration through northern Hood Canal, appears to be related directly to the availability and density of preferred food organisms. Juvenile chum and pink salmon entering the Canal early in the outmigration period (February-March), especially native chums and pinks <40 mm FL, encounter a relatively impoverished state of prey resources in both shallow sublittoral and neritic environments. The very short residence times (rapid outmigration rates) documented for these small juvenile chum during this period suggest that one behavioral response to low prey availability might be immediate migration out of the canal. Salo et al. (1980) estimated migration rates of 13 km/day for marked chums in February and March 1977. Migration rate estimates for the same months in 1978 were considerably slower, 4 km/day in February 1978 and 5 km/day in March. Prinslow et al. (1979) hypothesized that the slower migration rate during 1978 may have been an artifact arising from the newly-installed security lighting at an extensive pier facility on the Bangor Naval Base. The expanded mark-recapture studies in 1979 showed a definite decline in migration rate (increased residence time) as the outmigration developed: 8 km/ day in February, 14 km/day in March, 7 km/day in April, and 3 km/day in June (Salo et al. 1980).

It appears that even larger chums (e.g., those fed and released by hatcheries on Hood Canal) are behaviorally inclined to feed initially upon large epibenthic organisms such as gammarid amphipods in the absence of large neritic zooplankters, i.e., *Calanus* copepods. These larger chums may vary their migration rate according to the availability of the larger neritic zooplankters such as *Calanus* and *Epilabidocera*. Salo et al. (1980) described marked chum (48-53 mm FL) released from the WDF Hoodsport hatchery as migrating at a rate of approximately 8 km/day in April compared to 5 km/day in June. The preliminary results of a similar experiment conducted during May 19-23, 1980 indicated a similar migration rate (8 km/day), although the majority of the released fish remained in the southern Hood Canal area for 4 days after release and congregated in the estuarine delta at the mouth of the Skokomish River (personal communication, C. Whitmus, FRI).

Although they initiate feeding upon epibenthic zooplankton in the shallow sublittoral habitats, schools of juvenile chums appear to disperse at night and move slightly offshore (Schreiner et al. 1977). Until reaching 45-50 mm fork length, however, they continue to migrate through shallow sublittoral habitats during the day. Juveniles that continue to reside and grow in Hood Canal, including predominantly those immigrating into the Canal after April (Salo et al. 1980), gradually shift from feeding upon epibenthos to feeding on neritic organisms (Figs. 8 and 9).

While the mechanism(s) explaining the transition from epibenthic to neritic feeding has not been firmly established, one hypothesis relates prey size as a function of the ontogeny of the juvenile salmon during their outmigration (Foskett 1951; Okada and Taniguchi 1971; LeBrasseur 1969). Our data indicate that the Hood Canal chum fry 30-45 mm in length feed extensively upon the small, densely distributed harpacticoid copepods, appearing to select the largest copepods available. This is consistent with much of the recent literature for other zooplanktivorous fish species (Brooks and Dodson 1965; Confer and Blades 1975; Werner and Hall 1974; Galbraith 1967), but contrary to the findings of Feller and Kaczynski (1975) who documented selection for the smaller fraction of the available size distribution of harpacticoids, as measured using an epibenthic pump. As Feller and Kaczynski examined mostly smaller fish (33.0 - 52.3 mm FL) than we did, the apparent selection they observed may represent the lower extreme in a rapidly changing size selection on the part of the rapidly growing salmon fry. An alternative explanation is that the two epibenthic pumps had opposite biases in sampling representative size distributions. Composition of the two harpacticoid size distributions, however, indicated no differences. Another investigator (B. Marcotte, McGill University, personal communication) has acquired evidence that the visual focal point of juvenile salmonids may actually migrate from a ventral (epibenthic) orientation to dorsal (neritic) orientation during their early ontogeny.

Another explanation of the transition from epibenthic to neritic feeding is suggested by the apparent depletion of harpacticoid copepod populations (Fig. 19). During some periods the juvenile chums may encounter a declining frequency of preferred (size) epibenthic zooplankters and as an option to rapid migration along the shallow sublittoral zone may search for similarly-sized prey in adjacent neritic waters. This hypothesis, however, does not account for the usually consistent size demarkation between epibenthic and neritic-feeding fish found by ourselves and others (Okada and Taniguchi 1971).

A third explanation for the transition from shallow sublittoral to neritic habitats is that the shallow sublittoral habitats, with their eelgrass and algae meadows, offer the smaller juvenile chums an important refuge from predation. Empirical evidence of extensive predation by potential predator species is not supported in either neritic or shallow sublittoral habitats of northern Hood Canal (Simenstad and Kinney 1978; Salo et al. 1980). However, it may not be necessary for the juvenile chums to sustain actual predation in order to maintain such migratory behavior by e.g., perceived predation (the visual presence of a potential predator species) may be sufficient.

We believe most probable mechanism responsible for the transition between shallow sublittoral and neritic habitats is the combined influence of prey selectivity, resource depression and predator avoidance the juvenile chum disperse into the adjacent neritic waters at night in order to exploit the larger and more abundant prey but shift back into the shallows during the day to avoid predation in the neritic habitat. If epibenthic resources are significantly depleted these juveniles must then rapidly migrate further to other shallow sublittoral habitats with adequate prey resources, if available. Thus, even though there may be neritic prey of significant densities and proper sizes to sustain growth, chum fry <45-50 mm (fork length) may be constrained by predators to migrate through and feed within the shallow sublittoral region where prey resources may be depressed or of inadequate sizes for optimal feeding. Thus, depending upon fish size, residence time may be a function of prey abundance in both epibenthic and neritic zooplankton communities. Healey (1979) illustrated rather consistent foraging upon harpacticoid copepods throughout the chum fry outmigration through the Nanaimo River estuary. Residence time in that estuary was considered to be relatively short and would therefore have been confined to epibenthic-feeding fish. Healey also documented that the principal harpacticoid consumed by the chum fry was a comparatively rare species, *Harpacticus uniremis*, which Sibert (1979) noted to be reasonably large (1.5 mm) and distinctively marked as adults. Both Healey and Sibert suggested that the residence and productivity of chum fry in the Nanaimo River estuary was linked in some way to the production of just *H. uniremis*.

4.2 Importance of Nearshore Habitats and Particular Prey Assemblages

As illustrated in Hood Canal and estuarine and nearshore marine regions of southern Puget Sound (Kaczynski et al. 1973; Fresh et al. 1979), Northern Puget Sound and the Strait of Juan de Fuca (Miller et al. 1980), and the Strait of Georgia (Healey et al. 1976; Mason 1974; Sibert et al. 1977; Healey 1979; Levy et al. 1979), epibenthic crustaceans such as harpacticoid copepods and gammarid amphipods which characterize shallow sublittoral habitats constitute essential prey resources for juvenile chum salmon <40-45 mm fork length. The highest standing stock estimates of these organisms generated in our Hood Canal studies occurred at Devil's Hole Delta, a broad, eelgrass covered delta, where the densities of epibenthic crustaceans were usually appreciably higher than at the more exposed, current swept habitats at Carlson and Brown Points. This difference is probably attributable to the high standing stock of harpacticoid copepods specifically associated with the eelgrass, e.g., harbored upon the blades or epiphytic flora of the eelgrass plants or associated with the detritus which tends to accumulate about the base of the plant and its rhizomes.

In a survey of epibenthic zooplankton in 17 habitats, Simenstad et al. (1980) found the highest densities of harpacticoid copepods (239,825 ± 34,042/m^3) in a thick stand of eelgrass in a semi-protected embayment along the Strait of Juan de Fuca; this density was 4 times higher than in an adjacent sand habitat without eelgrass. This also supports Kikuchi (1974), who documented the importance of eelgrass beds as habitat for epibenthic macrofauna. Whether or not the eelgrass-associated harpacticoids are particularly utilized by chum fry has not been determined although we have observed dense schools of chum fry feeding upon and among the eelgrass blades.

The standing stock of gammarid amphipods, on the other hand, appears to be higher in more current swept habitats with coarser (more gravel) substrates, as typified by the gammarid assemblages at Brown Point. Since gammarids are the principal prey organisms of large (45-60 mm fork length) epibenthic-feeding chum early in the outmigration period, these habitats also play a role in providing requisite prey resources. Of importance is the fact that the principal species of gammarids consumed by chum and pink fry tend to be detritivores which are nestling or tubicolous on algae (*see* Simenstad et al. 1980, Appendix B). Thus, the extensive growths of marine macroalgae (*Laminaria*, *Agarum*, *Ulva*) which often typify more current swept, shallow sublittoral habitats contribute significantly to the standing stock of gammarid amphipods.

The neritic habitat, with its abundance of large zooplankters, including calanoid copepods, euphausiids, hyperiid amphipods, and larvaceans, is the principal foraging habitat of juvenile chum >50-55 mm fork length (especially hatchery-produced fish later in the outmigration period, i.e., mid-April through early July). Our knowledge of the distribution, structure and ecology of the preferred prey species is far too limited to directly infer the foraging behavior of the chum juveniles but it appears that they feed most intensively in a crepuscular manner upon large, diel-migrating calanoid copepods (*Calanus* sp.). Daylight feeding appears to be supplemental and restricted to a few large zooplankters (e.g., the calanoid copepod *Epilabidocera amphitrites* and the hyperiid amphipod *Parathemisto pacifica*), smaller calanoids (e.g., *Pseudocalanus* and nauplii) and cyclopoids (e.g., *Oithona*) which characterize the neuston community. The principal contribution to the prey of neritic-feeding fish would then appear to originate from vertically-migrating calanoid populations, suggesting that these components of the diffuse-scattering layer community may be the more limiting resource than the abundant, but much smaller zooplankters co-occurring with the juvenile salmon.

4.3 Mechanisms, Function, and Significance of Prey Selection

The high degree of prey selectivity (at least as a function of prey size, if not taxa) apparently exhibited by outmigrating juvenile chum salmon is undoubtedly a function of a number of predator and prey characteristics which interact, usually in consort, throughout the process of prey acquisition, from search and detection to manipulation and ingestion (Hyatt 1979). Thus, the ingested prey spectrum is a result of the integrated product of such predator characteristics as visual acuity, mouth, jaw, and gill raker morphology and swimming ability and prey variables such as size, shape, color, contrast, movement, and avoidance response. As with many planktivorous fishes which have prey spectra composed of organisms larger than represented in the foraging environment (Hrbacek 1962; Brooks and Dodson 1965; Galbraith 1967), our collections of juvenile chum and pink in Hood Canal indicated that they consumed only the largest of the "available" epibenthic and neritic zooplankters. In the case of the harpacticoid copepods, they even captured animals which were larger than we found *in situ*.

The mechanisms potentially responsible for this selection include: 1) the greater visual perception of large, high contrast, or active prey as compared to small or, less conspicuous prey; 2) more effective escape responses by the small prey; 3) mouth or gill raker morphology of the juvenile chums which limit the retention of small prey; and 4) bioenergetic balancing of pursuit, handling and capture expenditures with the energy obtained from the different prey sizes. While many of these mechanisms have yet to be tested under controlled situations, LeBrasseur (1969), LeBrasseur et al. (1969) and Koeller and Parsons (1977) illustrated that juvenile salmon had greater difficulty obtaining a required daily ration when consuming small prey (copepods *Pseudocalanus minutus*, *Paracalanus parvus*, *Corycaeus anglicus*) than when consuming larger prey (the copepods *Calanus plumchrus* and *Centropages abdominalis*), even if the smaller prey were orders of magnitude more abundant than the larger ones. The principal consequence of this relationship would be increased foraging time for juvenile salmon when the optimally-sized prey are absent or scarce (LeBrasseur 1969) or, in terms of our conceptual model of outmigrating juvenile chums and pinks, more rapid migration rates and decreased residence time. What little data we have on total marine survival rates, as described in the introduction, would suggest that extended estuarine residency provides a greater survival advantage than rapid outmigration. Salo et al. (1980), however, have documented high estimates of early marine mortality for juvenile chum salmon migrating through Hood Canal in February 1978 and 1979, 0.71 and 0.56 for the first two days of marine existence, respectively. How these rates relate to the total marine mortality rate cannot be determined without more extensive research and analysis of existing data.

4.4 Estimated Surplus Carrying Capacity of Hood Canal for Pink and Chum Fry

The argument for prey resource limitation regulating the number of juvenile chum which can successfully rear in Hood Canal rests upon a number of assumptions which are supported, to various degrees, by the existing data:

1) The salmon fry are morphologically and bioenergetically constrained in the sizes and species of prey organisms which they can consume and still obtain a daily ration sufficient to maintain growth;

2) The response of the outmigrating fry to inadequate prey composition or density is an increased migration rate which reduces marine survival, and

3) The availability of these "optimal" prey resources is finite and a function of time and the recent history of predation by outmigrating salmon fry and other planktivorous predators.

Valid estimation of carrying capacity would therefore require determination of a) proportional representation of preferred prey organisms of the overall plankton community, b) the density and standing crop of prey necessary for fry to sustain growth, and c) areal and local vertical and horizontal distribution of prey and juvenile salmon. While we have made some progress in the documentation of (a) and (b), we can see that our basic lack of knowledge of the distributions of predator and prey and of the functional relationships underlying the foraging process severely restrict our ability to realistically estimate the carrying capacity at this stage. The following are, therefore, our first order approximations and will require further refinement pending the result of more directed research.

4.5 Epibenthic Carrying Capacity

In calculating the estimate of harpacticoid copepods available for consumption (in addition to those already consumed by existing fish) we have utilized the density estimates (converted to no./m^2) at Carlson Point in 1978 and, even though the epibenthic pump did not capture high numbers of large harpacticoids, we have adjusted these density estimtes by the biweekly proportions of harpacticoids >0.75 mm in length, the apparent preferred size range of harpacticoids consumed by juvenile chum (Fig. 22).

An average wet weight of 20 μg/harpacticoid was used to generate estimates of average wet biomass from the biweekly density estimates. The daily ration for February-March was estimated to be 25% of body weight per day for fish 35-40 mm FL (0.50 g) and 20% of body weight per day for fish 40-50 mm FL (0.90 g) in April through June (1.00 g). The area of Hood Canal available for epibenthic feeding salmon fry was estimated to be 1.7×10^6 m^2 based on an average 10 m band of shallow sublittoral-eelgrass habitat, including river deltas, which characterize the shoreline of the canal between the Skokomish Rivers delta at the southern end and Foulweather Bluff at the northern end. Although this region of the shallow sublittoral zone varies in width between 1-m to hundreds of meters at river deltas, the 10-m average is probably a good first-order approximation. In addition to harpacticoid copepods which composed 50% to 75% of the prey of epibenthic-feeding chums, gammarid amphipods, cumaceans, ostracods, and juvenile shrimp were included in the total estimate of the available standing crop of epibenthic prey (Table 17). Other than gammarids, we had little indication of size-selective predation on these organisms and we assumed that the total "surplus" standing stock may be available for consumption by the juvenile salmon. Our use of the term "surplus" acknowledges the fact that the pump samples were collected from an epibenthic community already under some predation pressure by juvenile salmon and a variety of other nearshore, epibenthic-feeding fishes and macroinvertebrates.

In generating an estimate of the carrying capacity for epibenthic-feeding juvenile salmon we made the assumption that residence of at least two weeks in Hood Canal was desirable because under adequate feeding conditions two weeks of growth would amount to approximately 20 mm; thus, allowing 30-35 mm FL fish to develop to the stage that they would be able to effectively feed upon neritic organisms. Our usual two-week sampling interval, therefore, facilitated this estimate by providing standing stock estimates of prey prior to the desired residence period. Total production of prey was determined for the biweekly residence period by extrapolating from a (biweekly) turnover ratio (TR)* of 0.38, which was derived from an annual TR value of 10 recommended by Sibert (1979).

Based upon our biweekly (except for the month of May) production estimates of available prey (Table 18), the maximum number of additional

Table 17. Standing crop of epibenthic organisms constituting preferred prey of epibenthic-feeding chum and pink fry over 1978 outmigration period.

	Standing Crop (mg/m^2)					
Date	Harpacticoid copepods	Gammarid amphipods	Cumaceans	Ostracods	Juvenile shrimp	Total
Feb 21	58	744	1	4	12	761
Mar 7	81	132	4	8	49	193
Mar 21	186	107	20	8	36	171
Apr 6	242	148	53	11	20	232
Apr 17	82	137	39	8	25	209
May 1	33	60	9	8	61	138
May 31	29	40	8	9	19	76
Jun 14	20	39	5	11	9	64
Jun 28	19	32	<1	8	<1	40

---

*Turnover ratio, TR = (production + mortality) ÷ standing crop.

Table 18. Estimated surplus carrying capacity of Hood Canal for epibenthic-feeding juvenile chum salmon during the 1978 outmigration.

Date	Total prey wet biomass (mg/m^2)	Total biweekly prey production (mg/m^2)	Estimated biweekly carrying capacity ($fish/m^2$)	Total Hood carrying capacity (no. fish x 10^6)
Feb 21	819	1130	0.65	1.10
Mar 7	274	378	0.22	0.37
Mar 21	357	493	0.28	0.48
Apr 6	474	654	0.26	0.44
Apr 17	291	402	0.16	0.27
May 1	171	236	0.08	0.14
May 31	105	145	0.05	0.09
Jun 14	84	116	0.04	0.07
Jun 28	59	81	0.03	0.05

epibenthic-feeding juvenile chum salmon which could acquire an adequate ration in Hood Canal over a two-week period was estimated to be 1.10 x 10^6 and occurred just prior to an influx of chums into the Canal (Fig. 19), when predation upon the epibenthos was minimal. The major proportion of the prey standing stock at this time was contributed by amphipods (Table 17). The small (30-35 mm FL) naturally-spawned juvenile chums which entered Hood Canal at this time may not have been capable of fully utilizing the large gammarid amphipods and the surplus carrying capacity may be more on the order to 3.0 x 10^6 fish based on the abundance of the other prey taxa. The marked decline in gammarids between February 21 and March 7, however, may be a result of intense epibenthic predation by the juvenile chums. But, again, lack of detailed information about the life history and population ecology of these gammarid amphipods prevents us from determining whether predation is a probable cause for the observed decline. If gammarids were readily available as prey, the rapid outmigration would appear to be unrelated to the standing stock of preferred prey items at this time.

Prey production did increase through March, when juvenile chums were scarce, but began declining again as both the total harpacticoid production and the proportion of large harpacticoids began dropping in April. By late June the estimated surplus carrying capacity of the shallow sublittoral habitats had dropped to less than 0.1 x 10^6 fish.

On a per-unit-basis, this maximum carrying capacity (0.65 fish/m^2) is approximately one-third the density (2.10 fish/m^2) of juvenile chums documented for the Nanaimo River estuary during the period of maximum population of juvenile chum (Healey 1979), although Healey suggested that at this time there was a food shortage and residence times had begun to decline.

As previously mentioned, these estimates are compromised by the fact that they are based upon epibenthic zooplankton communities under predation by both salmon fry and other epibenthic zooplanktivorous organisms. In Hood Canal the latter category would include juvenile English sole (*Parophrys vetulus*), tube-snout (*Aulorhynchus flavidus*), and a variety of nearshore sculpins (Family Cottidae, including *Oligocottus* spp., *Leptocottus armatus* and *Clinocottus* spp.) and shrimps (*Heptacarpus* spp.). And it is highly probable that, although the density of epibenthic-feeding salmon fry usually begins declining by mid-May, the populations of non-salmonid predators are by that time expanding in the shallow sublittoral environs and may be responsible for the continuing decline in the standing stock of epibenthic prey. The only effective method to discriminate the predation influences of the various epibenthic planktivores would involve *in situ* inclusion and exclusion experiments and would also allow a "natural" (unexploited) population development in the harpacticoid copepod community. Monitoring of population density and life history stages in such an unexploited community would provide a direct comparison with the communities we hypothesize to be depressed and restructured by predation. Until these or equivalent experiments are conducted, we have no assurance that we have not monitored a multitude of natural species and life history stage fluctuations in the harpacticoid community. This problem of interpretation does not, however, alter our estimates of the relative availability of an appropriate size spectrum of epibenthic prey to juvenile chums; it does pose the question of whether or not these organisms were consumed beyond the capacity of their populations to be replaced by growth and recruitment. The fact that the juvenile chums are so size-selective in their feeding upon harpacticoids (we have observed egg-bearing females to be especially prominent) suggests that the natural population development of harpacticoids may be affected during the outmigration of juvenile salmon.

4.5.2 Neritic Carrying Capacity

Considering our restricted sampling of the neritic zooplankton community, direct estimation of the potential carrying capacity for neritic-feeding chum and pink is impossible. Samples processed were limited to three, widely spaced sampling dates (February 6, April 27, June 5, 1979) and we have virtually no information on the vertical or temporal distribution of prey in the water column or on the vertical feeding behavior of the salmon fry. The importance of this information gap is evident when we consider that the preferred prey, Calanus sp., were consumed by the salmon fry on a crepuscular periodicity, when the calanoids may have migrated vertically into the feeding realm of the salmon. Unfortunately, we have neither estimates of Calanus density during the period when they were presumably available near the surface of the water column nor estimates of the standing stock of the Calanus population in the diffuse scattering layer (much less an idea of the proportion which vertically migrates each diel period).

Using our daytime collections in the surface water, where the salmon fry are assumed to feed, we have generated order-of-magnitude estimates of the carrying capacity based upon the densities of the five principal prey of neritic-feeding salmon (Table 19). The same basic assumptions concerning desirable residence time (two weeks) and daily production used for the epibenthic feeding fish were also applied to the neritic fish. They were also assumed to be fully recruited to the neritic waters at 50 mm FL. Daily rations were estimated at 15% of total body weight for 50-60 mm FL (1.5 g) fish the first week and 10% for 60-70 mm FL (2.5 g) fish the second week of residence. Extrapolating over the top 10 meters of the water column, the carrying capacity was estimated to be 0.01 fish/m^3 in early February, and late April and 0.03 fish/m^3 in early June. With a rough estimate of 100 x 10^{7}m^2 neritic feeding area in Hood Canal north of the Skokomish River delta, these estimates project to range from 1 to 7.1 x 10^6 neritic-feeding juvenile salmon which could be supported over a two-week period in Hood Canal at these times. We have no way of knowing how the supposed diel availability of Calanus would change these figures, but based upon Damkaer's (1964) data, it would not be unreasonable to consider them an underestimate by at least an order of magnitude.

Table 19. Estimated surplus carrying capacity of Hood Canal for neritic-feeding juvenile chum salmon over 1979 outmigration.

Date	*Calanus*	*Epilabidocera*	*Parathemisto*	*Oikopleura*	*Corycaeus*	Total neritic prey (mg/m^3)	Total biweekly prey production (mg/m^3)	Biweekly neritic carrying capacity (fish/m^3)	Total Hood Canal neritic carrying capacity (no. X 10^6)
Feb 6	2.5	-	1.8	2.2	0.6	1.71	4.10	0.010	1.0
Apr 27	9.6	-	-	118.1	7.0	1.73	4.15	0.010	1.0
Jun 5	8.2	1.4	0.6	51.4	3.3	12.43	29.83	0.071	7.1

4.5.3. Relationship between Carrying Capacity Estimates and Chum Salmon Outmigration

These estimates of the total carrying capacity inherently assume uniform distributions of salmon fry and prey which is more than likely an invalid assumption. Juvenile chum and pink salmon, especially those feeding in the shallow sublittoral zone, tend to aggregate in dense schools during daylight; schools of up to tens of thousands of fry may be present during the peak of the outmigration (Bruce Snyder, FRI, personal communication). Similarly, harpacticoid copepods, gammarid amphipods and some calanoid copepods (Epilabidocera) are known to swarm in dense patches, although the mechanisms responsible for aggregation are relatively unknown. Such patchy distributions of predator and prey may functionally reduce the carrying capacity, depending upon the frequency of prey encounter by the schools of salmon fry and the density, size and distribution of the prey swarms. Eggers (1975) has theorized that while schooled predators have a greater probability of encountering a patch of prey (due to the greater total visual field of the school) large schools of predators would have to encounter a large number of prey patches, if these patches were small, for all members to receive an adequate ration. Considering the offsetting efficiencies of large schools preying upon small or large patches, it is probable that the effects of patchy predator and prey distributions balance out over the course of the outmigration.

These results suggest a number of strategies which could be advanced for optimizing the carrying capacity of Hood Canal for juvenile chum and pink salmon, since the variables influencing the foraging and migrating behavior of the juvenile salmon--time, size and density of release--are all manipulated by the artificial propagation facilities which liberate 20 to 40 x 10^6 juvenile chum salmon into the canal each year.

The relationship between our estimates of surplus carrying capacity of epibenthic-feeding chums and the total abundance of juvenile chum salmon in Hood Canal during the 1978 outmigration is illustrated in Fig. 27; the three estimates of the carrying capacity of neritic-feeding fish generated from the 1979 outmigration are also denoted. Weekly introductions of chum into the canal were derived from the sum of hatchery releases (Appendix C, Table 1) and estimates of naturally-spawned fry; the latter were based upon 1) Washington Department of Fisheries (WDF) escapement figures for 1978 (James Ames, WDF, personal communication), 2) 50:50 male:female ratio, and mean fecundity values of 3364/female, 3259/female for early and late Hood Canal stocks (Koski 1975), 3) 1.5% egg retention and 4.25% survival to emergence (Hunter 1959), and 4) a mean 45% outmigration survival (Hunter 1959; Fresh et al. 1980). Residence time was calculated on a weekly basis using Salo et al.'s (1980) emigration rate estimates and an assumed 78 km migration out of the Canal; daily survival during this period was calculated to be 0.69, based upon the survival rates of 0.51 for 2 days and 0.20 for 4 days documented experimentally during FRI's 1980 studies (Nic Bax, FRI, unpublished data).

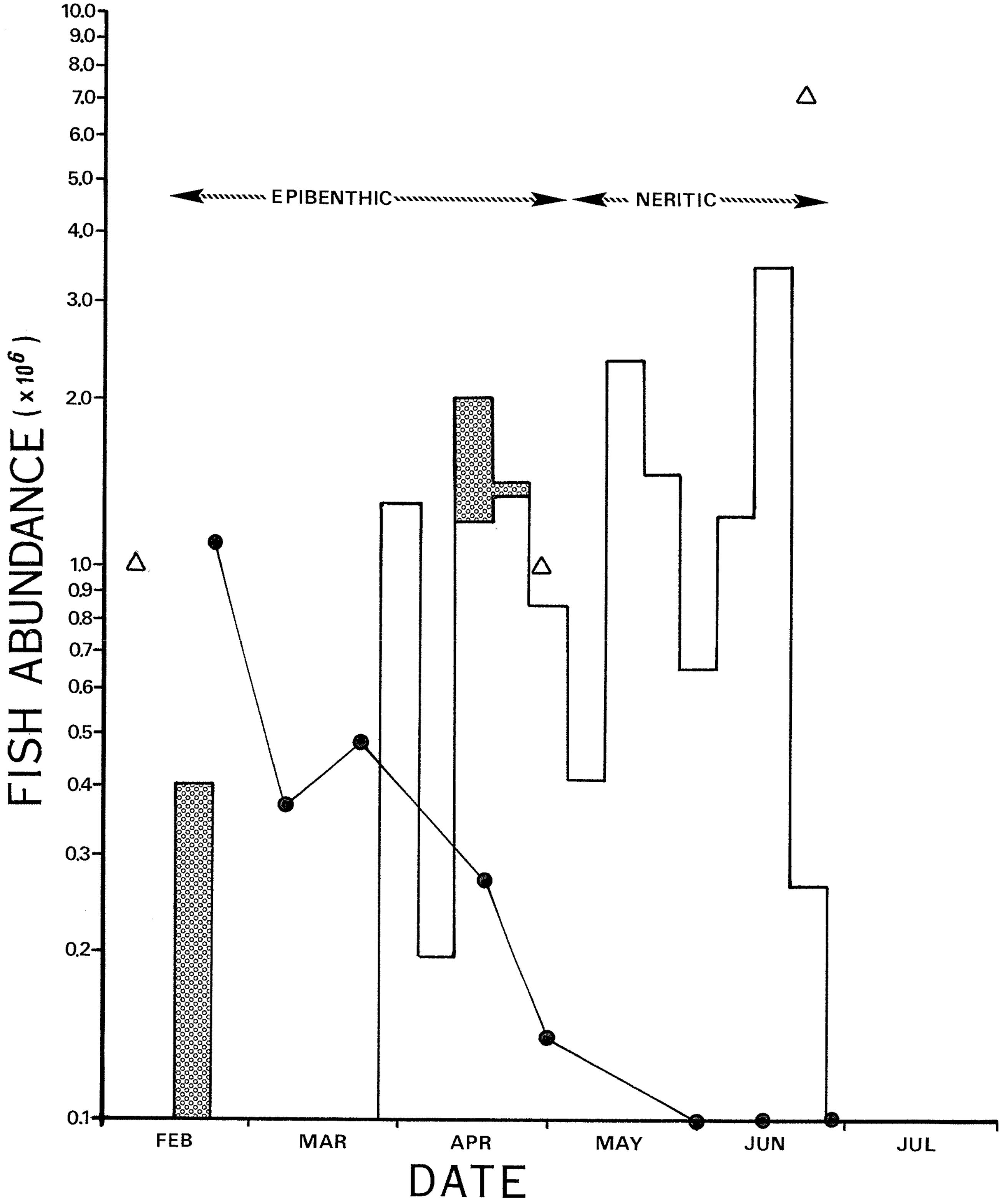


Fig. 27. Estimated abundance of juvenile chum salmon during 1978 Hood Canal outmigration and relative estimates of surplus carrying capacity of epibenthic-feeding fish (●); estimates of surplus carrying capacity of neritic-feeding fish (△) generated from the 1979 outmigration is also included for comparison. The shaded area indicates the naturally-spawned juvenile chum salmon.

The majority of the epibenthic-feeding juvenile chums which entered Hood Canal early in the 1978 outmigration were naturally-spawned "early run" fish as hatchery-propagated juveniles were not introduced into Hood Canal until late March. By our results, the small fish (40-49 mm FL) released from the hatcheries in early- to mid-April would also consume epibenthic organisms. It is at this time, though, that the epibenthic carrying capacity begins to decline dramatically, suggesting that up to 2 x 10^6 fish (per week) abundance may have been encountering declining prey resources at this time. From the existing information, we cannot determine whether they were the predators which were inducing the decline in epibenthic prey or whether it was due to 1) other predators, 2) a natural decline in epibenthic production or 3) the latent results of the foraging by the native fish during earlier months. We suggest, however, that introductions of juveniles 30-45 mm FL in size at this time in the outmigration would be exceeding the capacity of the shallow sublittoral epibenthos to support them. Releases of such small fish in early February, however, might be productive considering the high surplus of epibenthic prey apparently available at that time, although the fish should be of a size range which can effectively utilize gammarid amphipods, the dominant epibenthic prey at that time. Excessive overlap with native juveniles, however, may not be desirable and further research into the abundances of native outmigrants and their migration rates would be necessary before such a strategy is seriously implemented.

It could be inferred, however, that introduction of small, epibenthic-feeding juvenile chums and pinks after early May would not be productive from the standpoint of the depressed densities of preferred prey after that time. This would suggest that releases from egg box incubators, which allow the volitional emigration of the juveniles into estuarine and marine waters, should not be designed around stocks naturally migrating at a time when the epibenthic prey populations are low or naturally-spawned juvenile chums and pinks were abundant. At least, the potential decreased survival rates suggested to result from such releases should be taken into consideration when assessing the cost-benefit ratios of egg box incubator systems.

Furthermore, the manipulations of conventional hatchery releases should be considered in the context of the costs of the various options (e.g. x days feeding before release, volitional or nocturnal releases) versus the estimated costs or gains in survival which could be predicted to occur as a function of the projected carrying capacity at that time. This may be especially important in the case of neritic-feeding juveniles, whose migration behavior may be closely linked to unique prey resources such as Calanus and Epilabidocera, hyperiid amphipods, and larvaceans.

The most direct way to implement such an evaluation of hatchery release strategies is, of course, to conduct full scale production releases in the framework of an experimental design which incorporates the monitoring of growth, behavior and survival of outmigrating juvenile chum and pink salmon and the structure and standing stock of their prey resources. All these release strategies and experiments are predicated upon the relatively precise measurement of estuarine and marine survival rates, something that is seldom documented, diffucult to assess, and even less frequently incorporated in hatchery management policies at this time for these reasons. We are at a stage in the science of salmonid propagation where, if we are to implement effective enhancement programs, we must reach the point where we can implement production-scaled, structured experiments based upon testable hypotheses concerning predicted survival rates of alternate hatchery release strategies.

In addition to adjusting total release timing and density to the relative availability of preferred prey, spreading the individual releases out over an extended time period might reduce the mean size of the migrating schools, thus reducing the potential for short-term prey depletion. It might also be argued that a diverse size distribution of the released fry would minimize overexploitation of a single size or taxa of prey. Precise monitoring of preferred prey populations, although expensive, would allow even more control of the foraging pressure such that releasing fry during periods of reproductive intensity or high densities of egg-bearing female prey organisms may be avoided in order to ensure sufficient generations of prey for subsequent releases.

5.0 RECOMMENDATIONS

As ever, descriptive research of the type described in this report usually results in many more questions and hypotheses than were raised initially. The following recommendations address further research necessary to illucidate the mechanisms affecting the foraging and migration behavior of juvenile chum and pink salmon, the dynamics of their zooplankton prey communities and the interactions between these predators and their prey. Subsequent postulation and testing of alternative hypotheses, as a consequence of the limited carrying capacity hypothesis presented here, are imperative to the formulation of hatchery release strategies based upon optimum conditions for growth and survival during the early marine residency of salmon. The following are recommended:

1. While we now have a picture, though unclear in many areas, of the prey taxa utilized by outmigrating juvenile chum and pink salmon, our knowledge of the population dynamics and life history of the organisms is extremely limited. Proper interpretation of the predator-prey interactions between these organisms and the foraging salmon requires detailed ecological studies of the principal prey communities (harpacticoid and calanoid copepods and gammarid amphipods) and manipulation experiments to differentiate the effects of predation upon their population structure.

2. Although we have examined the foraging and migration behavior in shallow sublittoral habitats, we have no detailed data on the distribution and movement of juvenile salmon in neritic waters. This is an especially critical gap in terms of the location and feeding chronology in this habitat. A series of diel, depth-stratified collections should be conducted at several periods during the outmigration and be coordinated with similarly structured sampling of the neritic zooplankton community.

3. Considering the magnitude and expense involved in mark and recapture studies and the apparent feasibility of enumerating daily growth rings on otoliths, an experiment should be conducted to test the applicability of using otolith microstructure as an indicator of growth and residence time of juvenile salmon in estuarine and nearshore environs. Marking of the otolith with oxytetracycline or alazarin red organic dyes prior to release of juvenile salmon should also be investigated as a method of permanently fingerprinting the juveniles at various stages in their freshwater rearing.

4. Our hypotheses of low survival for juvenile chum salmon which have short residence times in Hood Canal is based upon a meager

data set from Big Beef Creek. This information requires analyses of the scales from returning adults for age composition. Scales from subsequent years of the Big Beef Creek chum salmon runs should be analyzed, if available, comparable data generated for the Hoodsport and Quilcene hatchery populations.

5. In addition to the basic biological and ecological studies still required for the prey communities, there is a definite need to investigate the basic environmental parameters (light, temperature, nutrients, detritus decomposition and microbial colonization, chlorophyll _a_ production) which might be directly involved in the timing of zooplankton population expansion and, as such, could be used as predictors of the availability and perhaps standing stock of preferred prey organisms.

6.0 LITERATURE CITED

Bajkov, A. D. 1935. How to estimate the daily food consumption of fish under natural conditions. Trans. Amer. Fish. Soc. 65:288-289.

Bakkala, R. G. 1970. Synopsis of biological data on the chum salmon (Oncorhynchus keta). FAO Fisheries Synopsis No. 41. U.S. Fish Wildl. Serv. Circ. 315. 89 pp.

Bax, N. J., E. O. Salo, B. P. Snyder, C. A. Simenstad, and W. J. Kinney. 1978. Salmonid outmigration studies in Hood Canal. Univ. Washington, Fish. Res. Inst., Final Report, Phase III, FRI-UW-7921. 128 pp.

Brett, J. R., and D. A. Higgs. 1970. Effect of temperature on the rate of gastric digestion in fingerling sockeye salmon, Oncorhynchus nerka. J. Fish. Res. Board Can. 27:1767-1779.

Brooks, J. L., and S. I. Dodson. 1965. Predation, body size, and composition of plankton. Science 150:28-35.

Cailliet, G. M., J. P. Barry. 1979. Composition of food array overlap measures useful in fish feeding habit analysis. Pages 67-79 in S. J. Lipovsky and C. A. Simenstad, eds. Workshop fish food habit studies. Proc. Sec. Pac. Tech., Sea Grant Publ., Univ. Washington, Seattle. WSG-SO-79-1.

Cardwell, R. D. 1978. Hood Canal studies (1 October 1977 to 30 September 1978). Washington State Dep. Fish., Annual Report. Olympia, WA. 15 pp.

Confer, J. L., and P. I. Blades. 1975. Omnivorous zooplankton and planktivorous fish. Limnol. Oceanogr. 20:571-579.

Cooney, R. T. 1971. Zooplankton and micronekton associated with a diffuse sound-scattering layer in Puget Sound, Washington. Ph.D. Dissertation, Dep. Oceanogr., Univ. Washington, Seattle. 208 pp.

Damkaer, D. M. 1964. Vertical distributions of Copepoda in Dabob Bay, December 1960. M.S. Thesis, Univ. Washington, Seattle. 84 pp.

Eggers, D. M. 1975. A synthesis of the feeding behavior and growth of juvenile sockeye salmon in the limnetic environment. Ph.D. Dissertation, Coll. Fish., Univ. Washington, Seattle. 217 pp.

Eggers, D. M. 1977. Factors in interpreting data obtained by diel sampling of fish stomachs. J. Fish. Res. Board Can. 34:290-294.

Eggers, D. M. 1979. Comments on some recent methods for estimating food consumption by fish. J. Fish. Res. Board Can. 36:1018-1019.

Eggers, D. M. (In review.) Planktivore preference by prey size. Ecology.

Fange, R., and D. Grove. 1979. Digestion. Pages 162-260 (Chapter 4) in W. S. Hoar, D. J. Randall, and J. R. Brett, eds. Fish physiology, Vol. VIII, Bioenergetics and growth. Acad. Press, New York.

Feller, R. J., and V. W. Kaczynski. 1975. Size selective predation by juvenile chum salmon (Oncorhynchus keta) on epibenthic prey in Puget Sound. J. Fish. Res. Board Can. 32:1419-1429.

Foskett, D. R. 1951. Young salmon in the Nanaimo area. Fish. Res. Board Can. Pac. Prog. Rep. 86:18-19.

Fresh, K. L., D. Rabin, C. Simenstad, E. O. Salo, K. Garrison, and L. Matheson. 1979. Fish ecology studies in the Nisqually Reach area of southern Puget Sound. Final Rep., March 1977-August 1978, to Weyerhaeuser Company. Fish. Res. Inst., Coll. Fish., Univ. Washington, Seattle, WA. FRI-UW-7904. 229 pp.

Fresh, K. L., R. D. Cardwell, B. P. Snyder, and E. O. Salo. In press. Some hatchery strategies for reducing predation upon juvenile chum salmon (Oncorhynchus keta) in freshwater. In Proc. North Pacific Aquaculture Symp., Anchorage, AK, Aug. 18-21, 1980 and Newport, OR, Aug. 25-27, 1980. Univ. Alaska, Fairbanks, AK.

Galbraith, M. G. 1967. Size-selective predation of Daphnia by rainbow trout and yellow perch. Trans. Amer. Fish. Soc. 96:1-10.

Gallagher, A. F. 1980. An analysis of factors affecting brood year returns in the wild stocks of Puget Sound chum (Oncorhynchus keta) and pink salmon (Oncorhynchus gorbuscha). M.S. Thesis, Coll. Fish., Univ. Washington, Seattle. 152 pp.

Gilhousen, P. 1962. Marine factors affecting survival of Fraser River pink salmon. Pages 105-109 in Symposium on pink salmon. Inst. Fish., Univ. British Columbia, Vancouver, B.C., Canada.

Gonsolus, R. T. 1978. The status of Oregon coho and recommendations for managing the production, harvest, and escapement of wild and hatchery-reared stocks. Unpubl. Report. Oregon Dep. Fish Wildl., Columbia Region. 59 pp.

Healey, M. C., R. J. LeBrasseur, J. R. Sibert, W. E. Barraclough, and J. C. Mason. 1976. Ecology of young salmon in Georgia Strait. Pages 201-207 in G. R. Gunstrom, ed. Proc. 1976 N.E. Pacific pink and chum salmon workshop. Alaska Dep. Fish Game, Juneau.

Healey, M. C. 1979. Detritus and juvenile salmon production in the Nanaimo Estuary: I. Production and feeding rates of juvenile chum salmon (Oncorhynchus keta). J. Fish. Res. Board Can. 36:488-496.

Hrbácek, J. 1963. Species composition and the amount of zooplankton in relation to the fish stock. Roxpr. Cesk. Akad. Ved. 72:1-116.

Hunter, J. G. 1959. Survival and production of pink and chum salmon in a coastal stream. J. Fish. Res. Board Can. 16(6):835-886.

Hyatt, K. D. 1979. Feeding strategy. Page 71-119 in W. S. Hoar, D. J. Randall and J. R. Brett, eds. Fish physiology, Vol. VIII, Bioenergetics and growth. Acad. Press, New York.

Kaczynski, V. W., R. J. Feller, And J. Clayton. 1973. Trophic analysis of juvenile pink and chum salmon (Oncorhynchus gorbuscha and O. keta) in Puget Sound. J. Fish. Res. Board Can. 30:1003-1008.

Kikuchi, T. 1974. Japanese contributions on consumer ecology in eelgrass (Zostera marina L.) beds, with special reference to trophic relationships and resources in inshore fisheries. Aquaculture 4:145-160.

Koeller, P., and T. R. Parsons. 1977. The growth of young salmonids (Oncorhynchus keta): Controlled ecosystem pollution experiment. Bull. Mar. Sci. 27(1):114-118.

Koski, K. V. 1975. The survival and fitness of two stocks of chum salmon (Oncorhynchus keta) from egg deposition to emergence in a controlled-stream environment at Big Beef Creek. Ph.D. Dissertation, Univ. Washington, Seattle. 212 pp.

LeBrasseur, R. J. 1969. Growth of juvenile chum salmon (Oncorhynchus keta) under different feeding regimes. J. Fish. Res. Board Can. 26:1631-1645.

LeBrasseur, R. J., W. E. Barraclough, O. D. Kennedy, and T. R. Parsons. 1969. Production studies in the Strait of Georgia. Part III. Observations on the food of larval and juvenile fish in the Fraser River plume, February to May 1967. J. Exp. Mar. Biol. Ecol. 3:51-61.

Levanidov, V. Y., and J. M. Levanidova. 1957. Pitanie pokatnoi molodi etnei kety i gorbushi v tritokakh amura [Food of downstream migrant young summer chum salmon and pink salmon in Amur tributaries]. Izvestiya Tikhookeanskogo Nauchno-Issledovatel′ Skogo Instituta Rybnogo Khozyaistva I Okeanografii, Vol 45:3-16. [In Pacific Salmon, IPST Trans. 341, S. Monson, ed. Jerusalem].

Levy, D. A., T. G. Northcote, and G. J. Birch. 1979. Juvenile salmon utilization of tidal channels in the Fraser River estuary, British Columbia. Univ. British Columbia, Westwater Res. Ctr. Tech. Rep. No. 23. 70 pp.

Marshall, S. M., and A. P. Orr. 1955. The biology of a marine copepod Calanus finmarchicus. Oliver and Boyd, Edinburgh. 189 pp.

Marshall, S. L., and S. S. Parker. 1979. Chignik sockeye studies: Daily growth patterns of sockeye salmon otoliths. Univ. Washington, Fish. Res. Inst. Final Report (Supplement) FRI-UW-7902. 18 pp.

Mason, J. C. 1974. Behavioral ecology of chum salmon fry (Oncorhynchus keta) in a small estuary. J. Fish. Res. Board Can. 31:83-92.

McDonald, J. 1960. The behavior of Pacific salmon fry during their downstream migration to freshwater and salt water nursery areas. J. Fish. Res. Board Can. 17:655-676.

Miller, B. S., C. A. Simenstad, K. L. Fresh, F. C. Funk, W. A. Karp, S. T. Borton, and L. L. Moulton. 1977. Puget Sound baseline program: Nearshore fish survey. Univ. Washington, Fish Res. Inst. Final Report FRI-UW-7710. 220 pp.

Miller, B. S., C. A. Simenstad, J. N. Cross, K. L. Fresh, and S. N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of the common nearshore fish: Final report of three years' sampling, 1976-1979. Rep. to MESA Puget Sound Project, Seattle, WA. Fish. Res. Inst., Coll. Fish. Univ. Wash., Seattle, WA. FRI-UW-8001. 213 pp.

Neave, F. 1955. Notes on the the seaward migration of pink and chum salmon fry. J. Fish. Res. Board Can. 12:369-374.

Okada, S., and A. Taniguchi. 1971. Size relationship between salmon juveniles in shore waters and their prey animals. Bull. Far. Fish., Hokkaido Univ. 22(1):30-36.

Parker, R. R. 1968. Marine mortality schedules of pink salmon of the Bella Coola River, Central British Columbia. J. Fish. Res. Board Can. 25(4):757-794.

Parker, R. R. 1971. Size selective predation among juvenile salmonid fishes in a British Columbia inlet. J. Fish. Res. Board Can. 28:1503-1510.

Pielou, E. C. 1977. Mathematical ecology. John Wiley & Sons, New York. 385 pp.

Pinkas, L., M. S. Oliphant, and I. L. K. Iverson. 1971. Food habits of albacore, bluefin, tuna, and bonito in California waters. Calif. Fish Game, Fish. Bull. 151:1-105.

Prinslow, T. E., E. O. Salo, and B. P. Snyder. 1979. Studies of behavioral effects of a lighted and an unlighted wharf on outmigrating salmonids, March-April 1978. Univ. Washington, Fish. Res. Inst. Final Report FRI-UW-7920. 35 pp.

Salo, E. O., N. J. Bax, T. E. Prinslow, C. J. Whitmus, B. P. Snyder, and C. A. Simenstad. 1980. The effects of construction of naval facilities on the outmigration of juvenile salmonids from Hood Canal, Washington. Univ. Washington, Fish. Res. Inst. Final Report (March 1, 1975 through July 31, 1979, to U.S. Navy) FRI-UW-8006. 159 pp.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr. 5(2):138-153.

Schreiner, J. U., A. Didier, E. O. Salo, and B. P. Snyder. 1975. Salmonid outmigration studies in Hood Canal. Univ. Washington, Fish. Res. Inst. Prog. Report. 26 pp.

Schreiner, J. U., E. O. Salo, B. P. Snyder, and C. A. Simenstad. 1977. Salmonid outmigration studies in Hood Canal. Univ. Washington, Fish. Res. Inst. Final Report, Phase II, FRI-UW-7715. 64 pp.

Schroder, S. L. 1977. Assessment of production of chum salmon fry from the Big Beef Creek spawning channel. Univ. Washington, Fish. Res. Inst., Acad. Fish. Project, NO. AFC-67. Completion Report FRI-UW-7718. 77 pp.

Sibert, J., T. J. Brown, M. C. Healey, B. A. Kask, and R. J. Naiman. 1977. Detritus based food webs: Exploitation by juvenile chum salmon (*Oncorhynchus keta*). Science 196:649-650.

Sibert, J. R. 1979. Detritus and juvenile salmon production in the Nanaimo estuary: II. Meiofauna available as food to juvenile chum salmon (*Oncorhynchus keta*). J. Fish. Res. Board Can. 36(5):497-503.

Simenstad, C. A. 1977. Prey organisms an prey community composition of juvenile salmonids in Hood Canal, Washington. Pages 163-176 *in* C. A. Simenstad and S. Lipovsky, eds. Proc. First Pac. Northwest Tech. Workshop, Fish Food Habits Studies, October 13-15, 1976, Astoria, Oregon. Univ. Washington, Washington Sea Grant, WSG-WO 77-2.

Simenstad, C. A. and W. J. Kinney. 1978. Trophic relationships of outmigrating chum salmon in Hood Canal, 1977. Univ. Washington, Fish. Res. Inst. Final Report FRI-UW-7810. 75 pp.

Simenstad, C. A., and W. J. Kinney. 1979. Selection of epibenthic plankton by outmigrating chum salmon in Hood Canal, Washington. Pages 243-289 in J. Mason, ed. Proc. 1978. Pink and chum salmon workshop, March 1978, Parksville, B.C., Canada. Pac. Biol. Sta., Nanaimo, B.C.

Simenstad, C. A., W. J. Kinney, and B. S. Miller. 1980. Epibenthic zooplankton assemblages at selected sites along the Strait of Juan de Fuca. NOAA Tech. Memo. ERL MESA-46, Mar. Ecosyst. Anal. Boulder, CO. 73 pp.

Sparrow, R. A. H. 1968. A first report of chum salmon fry feeding in fresh water of British Columbia. J. Fish. Res. Board Can. 25:599-602.

Stober, Q. J., and E. O. Salo. 1973. Ecological studies of the proposed Kiket Island Nuclear Power site. Univ. Washington, Fish. Res. Inst., Final Report FRI-UW-7304. 537 pp.

Taylor, S. G. 1980. Marine survival of pink salmon fry from early and late spawners. Trans. Amer. Fish. Soc. 109:79-82.

Tyler, R. W. 1964. Distribution and migration of young salmon in Bellingham Bay, Washington. Fish. Res. Inst., Coll. Fish., Univ. Washington, Circ. No. 212. 26 pp.

Tyler, R. W. 1972. Study of fingerling pink salmon at Kodiak Island with an evaluation of the method of forecasting based on townetting. Pages 40-49 in J. E. Bailey, ed. Proc. 1972 N.E. Pac. Pink Salmon workshop.

Werner, E. E., and D. J. Hall. 1974. Optimal foraging and the size selection of prey by the bluegill sunfish (Lepomis macrochirus). Ecology 55:1042-1052.

Wickett, W. P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. J. Fish. Res. Board Can. 15:1103-1126.

APPENDICES

APPENDIX A

The following definitions apply to terms and abbreviations used in this report:

Carrying capacity:	The maximum number of chum fry which can successfully rear in estuarine and nearshore marine habitats, sustaining growth and minimizing density-dependent losses due to predation, bioenergetic stress, parasitism, and disease.
Detritus:	Finely divided sinkable material of organic or inorganic origin which is suspended in the water.
Epibenthic:	Associated with interface between the surface of the bottom and the water column directly above the bottom.
Estuarine:	Related to estuaries, semi-enclosed bodies of water wherein the water is measurably diluted below the salinity of open ocean water by freshwater associated with land runoff.
Habitat:	The total of environmental conditions of a specific place that is occupied by an organism, a population, or a community.
IRI:	Index of Relative Importance (*see* Section 2.9).
Meiofauna:	Organisms $\leq$ 0.5 mm in size.
Nearshore:	The region of oceanic waters immediately adjacent to the foreshore, usually including the littoral, shallow sublittoral, and neritic zones where water depth is $\leq$ 20 mm.
Neritic:	Associated with the shallow surface water zone extending from the high-tide mark to the edge of the continental shelf.
Pelagic:	Inhabiting the water column.
Sublittoral:	Associated with the benthic zone extending from mean low water to 200 mm, or the edge of the continental shelf usually defined as being 200 mm deep.
Trophic:	Related to food and nutrition.

Appendix B

Appendix Table B-1. Prey taxa composition, based on percent total index of relative importance, of outmigrating chum fry in northern Hood Canal, according to three shallow sublittoral sites, 1977-1979.

Carlson Point	1977	1978	1979
	April 26 (3: lengths unavail)	April 26 (5; 49.2 ± 11.9 mm)	April 25 (5; 52.0 ± 6.6 mm)
Harpacticoid copepods	79.16	13.46	3.65
Insects	11.86	0.05	0.14
Gammarid amphipods	2.73	1.10	9.29
Hyperiid amphipods	3.04	24.82	
Barnacle larvae	3.20	0.05	0.66
Euphausiids		24.00	37.82
Calanoid copepods		14.93	12.39
Fish larvae		18.60	
Cyclopoid copepods		0.69	
Larvaceans		0.13	33.56
Copepod larvae			0.55
Mesogastropods			0.49
Decapod larvae			0.64
Polychaete annelids			0.74
Nematocera			0.09
		May 15 (35; 51.5 ± 9.4 mm)	
Calanoid copepods		76.87	
Copepod larvae		8.41	
Hyperiid amphipods		9.18	
Decapod larvae		3.33	
Harpacticoid copepods		0.72	
Gammarid amphipods		0.19	
Chaetognaths		0.76	
Fish larvae		0.76	
Larvaceans		0.09	
Insects		0.11	
Nematocera		0.01	
Barnacle larvae		0.01	
Unidentified eggs		0.01	
Algae		0.01	

Appendix Table B-1. (continued)

Carlson Point (cont.)	1977	1978	1979
	June 1 (5; lengths unavail)		June 5 (5; 53.6 ± 3.2 mm)*
Harpacticoid copepods	64.44		0.13
Mesogastropods	13.04		
Gammarid amphipods	8.40		
Unidentified eggs	6.08		
Hyperiid amphipods	2.32		0.01
Calanoid copepods	2.13		7.27
Euphausiids	2.11		6.40
Cumaceans	0.50		
Insects	0.50		9.11
Decapod larvae	0.50		
Larvaceans			73.57
Cyclopoid copepods			0.35
Polychaete annelids			1.26
Copepod larvae			0.88
Nematocera			0.07
Caprellid amphipods			0.01
Fish larvae			0.21
Debris			0.62
Barnacle larvae			0.01
Devils Hole Delta	1977	1978	1979
	April 19 (3; lengths unavail)	April 26 (5; 47.2 ± 6.1 mm)	April 25 (5; 49.8 ± 6.4 mm)
Decapod larvae	35.07		
Harpacticoid copepods	22.87	31.53	15.08
Unidentified eggs	19.62		
Gammarid amphipods	10.13	0.73	3.31
Fish larvae	9.86	37.85	0.12
Insects	2.46	0.12	2.18
Calanoid copepods		16.78	1.94
Euphausiids		9.23	11.25
Larvaceans		3.31	65.15

Appendix Table B-1. (continued)

Devils Hole Delta (cont.)	1977	1978	1979
	April 19 (3; lengths unavail)	April 26 (5; 47.2 ± 6.1 mm)	April 25 (5; 49.8 ± 6.4 mm)
Cyclopoid copepods		0.32	
Chaetognaths		0.12	0.54
Copepod larvae			0.25
Cumaceans			0.12
	May 16 (4; lengths unavail)		
Euphausiids	79.50		
Calanoid copepods	10.29		
Harpacticoid copepods	4.51		
Hyperiid amphipods	1.12		
Cumaceans	1.12		
Decapod larvae	1.12		
Insects	1.12		
Fish eggs and larvae	1.20		
			June 5 (6; 55.2 ± 4.9 mm)
Larvaceans			89.21
Insects			10.20
Copepod larvae			0.12
Calanoid copepods			0.06
Unidentified eggs			0.06
Gammarid amphipods			0.08
Harpacticoid copepods			0.03
Fish larvae			0.09
Hyperiid amphipods			0.02
Nematocera			0.04
Decapod larvae			0.02
Mesogastropods			0.01

Appendix Table B-1 (continued)

Brown Point	1977	1978	1979
	April 26 (5; lengths unavail)		April 25 (5; 46.6 7.3
Harpacticoid copepods	79.72		48.81
Barnacle larvae	14.98		0.27
Insects	1.89		0.14
Cumaceans	1.82		
Gammarid amphipods	1.59		31.34
Copepod larvae			15.43
Euphausiids			3.64
Cyclopoid copepods			0.22
Calanoid copepods			0.16
	May 16 (5; lengths unavail)		
Euphausiids	69.13		
Calanoid copepods	10.91		
Harpacticoid copepods	8.71		
Gammarid amphipods	6.22		
Barnacle larvae	1.66		
Decapod larvae	0.72		
Mesogastropods	0.70		
Hyperiid amphipods	0.65		
Insects	0.65		
Fish eggs and larvae	0.65		

Appendix Table B-1. (continued)

Brown Point	1977	1978	1979
			June 5 (10; 51.2 ± 5.7 mm)
Larvaceans			83.38
Cyclopoid copepods			8.89
Insects			2.23
Copepod larvae			2.87
Calanoid copepods			0.98
Euphausiacea			0.69
Decapod larvae			0.29
Barnacle larvae			0.09
Hyperiid amphipods			0.07
Polychaete annelids			0.09
Mesogastropods			0.01
Unidentified eggs			0.01
Nematocera			0.01
Fish larvae			0.01

Appendix Table B-2. Prey taxa composition, based on percent total Index of Relative Importance, of outmigrating chum fry in northern Hood Canal according to marked and unmarked fish and fish size interval, 1979.

February 6, 1979	30-39 mm unmarked (5)	40-49 mm marked (2)	50-59 mm marked (3)
Harpacticoid copepods	77.88	7.37	10.47
Calanoid copepods	7.00	1.38	13.46
Decapod larvae	6.42	4.02	2.77
Chaetognaths	5.44		
Gammarid amphipods	2.13	65.46	56.91
Cyclopoid copepods	0.82		
Hyperiid amphipods	0.16	0.69	11.54
Insects	0.16		0.58
Barnacle larvae		20.38	1.97
Cumaceans		0.69	2.30

April 25, 1979	40-49 mm unmarked (7)	50-59 mm unmarked (7)	60-69 mm unmarked (1)
Harpacticoid copepods	58.06	7.36	
Gammarid amphipods	25.08	5.95	
Copepod larvae	9.28	0.88	1.64
Larvaceans	5.84	46.44	61.37
Calanoid copepods	0.91	5.33	3.37
Insects	0.49	0.50	
Euphausiids	0.11	32.36	11.26
Barnacle larvae	0.06	0.35	
Cyclopoid copepods	0.04	0.02	
Polychaete annelids		0.21	8.67
Decapod larvae		0.13	12.04
Chaetognaths		0.21	
Mesogastropods		0.06	1.64
Fish larvae		0.05	

Appendix Table B-2. (continued)

June 5, 1979	40-49 mm marked (4)	50-59 mm marked (14)	50-59 mm unmarked (3)	60-69 mm marked (3)	60-69 mm unmarked (11)	70-79 mm marked (1)
Larvaceans	84.16	89.01	58.86	83.35	82.31	90.40
Copepod larvae	5.97	0.47	36.50	2.85	4.84	0.18
Insects	9.04	3.69		1.39	0.61	
Cyclopoid copepods	1.69	3.12	2.75	9.74	0.16	0.18
Calanoid copepods	0.93	0.96	1.01	0.61	6.68	0.18
Hyperiid amphipods	0.35	0.02	0.01	0.16	< 0.01	
Euphausiids	0.52	1.96	0.46	0.17	3.45	0.65
Polychaete annelids	0.86	0.45	0.02	0.35	0.35	
Fish larvae	0.32	0.01		0.15	1.27	8.18
Debris	0.31	0.01				
Mesogastropods	0.03	< 0.01	0.05		< 0.01	
Caprellid amphipods	0.02					
Cumaceans	0.02					
Unidentified eggs		0.03	0.17		0.08	
Barnacle larvae		0.02	0.02	0.26	0.07	
Decapod larvae		0.04	0.06	0.49	0.07	0.10
Harpacticoid copepods			0.09	0.45	0.06	
Cladocerans					< 0.00	
Chaetognaths					0.01	0.10
Gammarid amphipods					0.01	

Appendix Table B-3. IRI prey spectra of co-occurring juvenile chum and pink salmon in Hood Canal, Washington, April 25-26, May 1, May 15, and May 31, 1978.

Carlson Point — April 26, 1978

	% Total IRI	
	O. keta (n=5) 49.2 ± 11.9 mm FL	*O. gorbuscha* (n=6) 34.8 ± 0.8 mm FL
Hyperiid amphipods	24.82	
Euphausiids	24.00	15.48
Fish larvae	18.60	4.78
Calanoid copepods	14.93	8.32
Harpacticoid copepods	13.46	12.94
Gammarid amphipods	1.10	1.27
Cyclopoid copepods	0.69	7.32
Larvaceans	0.13	0.04
Insects	0.05	
Barnacle larvae	0.05	0.23
Copepod larvae		49.52
Decapod larvae		0.04
Thecosomata		0.05

Devils Hole Delta — April 25/26, 1978

	O. keta (n=5) 47.2 ± 6.1 mm FL	*O. gorbuscha* (n=4) 33.0 ± 0.8 mm FL
Fish larvae	37.85	6.18
Harpacticoid copepods	31.53	59.99
Calanoid copepods	16.78	13.15
Euphausiids	9.23	8.10
Larvaceans	3.31	
Gammarid amphipods	0.73	0.82
Cyclopoid copepods	0.32	0.13
Insects	0.12	
Chaetognaths	0.12	
Copepod larvae		10.97
Decapod larvae		0.66

Appendix Table B-3. (continued)

Carlson Point — May 1, 1978

	% Total IRI	
	O. keta (n=6) 56.5 ± 5.2 mm FL	*O. gorbuscha* (n=) 54.6 ± 4.4 mm FL
Larvaceans	83.22	57.52
Calanoid copepods	12.72	20.71
Euphausiids	2.25	2.57
Harpacticoid copepods	1.10	1.18
Gymnolaemata(cyphonautes larvae)	0.27	15.15
Hyperiid amphipods	0.18	
Insects	0.08	0.87
Fish eggs and larvae	0.07	0.90
Cyclopoid copepods	0.05	
Decapod larvae	0.03	
Barnacle larvae	0.01	0.20
Gammarid amphipods	0.01	0.29
Mesogastropods		0.38
Decapod larvae		0.13
Copepod larvae		0.07
Polychaete annelids		0.02

Carlson Point — May 15, 1978

	O. keta (n=13) 54.4 ± 3.8 mm FL	*O. gorbuscha* (n=5) 54.6 ± 4.4 mm FL
Calanoid copepods	71.10	20.71
Hyperiid amphipods	22.94	
Fish eggs and larvae	1.50	0.90
Decapod larvae	1.31	0.13
Harpacticoid copepods	1.19	1.18
Chaetognaths	0.86	
Copepod larvae	0.64	0.07
Larvaceans	0.15	57.52
Insects	0.13	0.87
Gammarid amphipods	0.08	0.29
Gymnolaemata(cyphonautes larvae)	0.06	15.15
Cyclopoid copepods	0.02	
Barnacle larvae	0.02	0.20
Mesogastropods	0.01	0.38
Caligoid copepods	0.01	
Unidentified eggs	0.01	
Polychaete annelids		0.02
Euphausiids		2.57

Appendix Table B-3. (continued)

Carlson Point — May 31, 1978

	% Total IRI	
	O. keta (n=) 48.2 ± 4.9 mm FL	*O. gorbuscha* (n=5) 50.4 ± 2.9 mm FL
Calanoid copepods	79.39	77.90
Gammarid amphipods	10.16	2.54
Chaetognaths	2.39	
Euphausiids	2.15	0.59
Hyperiid amphipods	1.74	0.61
Harpacticoid copepods	1.43	10.73
Insects	2.20	1.16
Valviferan isopods	0.26	
Larvaceans	0.19	
Cumaceans	0.10	
Decapod larvae		1.40
Fish eggs and larvae		0.08
Cyclopoid copepods		0.40
Mesogastropods		0.40
Polychaete annelids		0.27

Appendix Table B-4. Species and life history composition, abundance and biomass of epibenthic zooplankton sampled during diel feeding chronology experiment, 15 May, 1978, Carlson Pt., Hood Canal, Washington.

ORGANISM	ALL SAMPLES COMBINED LIFE HISTORY	ABUNDANCE X̄	ABUNDANCE S.D.	ABUNDANCE %	BIOMASS X̄	BIOMASS SD	BIOMASS %	F.C.1 03:40 LIFE HIST.	F.C.1 ABUNDANCE X̄	F.C.1 ABUNDANCE %	F.C.2 05:30 LIFE HIST.	F.C.2 ABUNDANCE X̄	F.C.2 ABUNDANCE %	F.C. 3 08:45 LIFE HIST.	F.C. 3 ABUNDANCE X̄	F.C. 3 ABUNDANCE %	F.C.4 11:35 LIFE HIST.	F.C.4 ABUNDANCE X̄	F.C.4 ABUNDANCE %	F.C. 5 14:40 LIFE HIST.	F.C. 5 ABUNDANCE X̄	F.C. 5 ABUNDANCE %	F.C. 6 18:00 LIFE HIST.	F.C. 6 ABUNDANCE X̄	F.C. 6 ABUNDANCE %	F.C. 7 20:15 LIFE HIST.	F.C. 7 ABUNDANCE X̄	F.C. 7 ABUNDANCE %
Coryne sp.	Polyp	0.3±	1.1	0.00	.000±	.0	0.01										Polyp	1.7	0.01									
Nemertea-Enopla	Jv or Ad	0.3±	1.1	0.00	.000±	.0	0.11													Jv or Ad	1.7	0.01						
Nematoda	Ad (Jv)	417.1±	629.6	2.24	.008±	.0	1.83	Adult	305.0	0.81	Adult (Jv)	66.7	0.64	Adult (Jv)	238.3	1.33	Adult (Jv)	368.3	1.50	Adult (Jv)	566.7	2.43	Adult	66.7	0.47	Adult(Jv)	1233.3	8.27
Polychaeta	Jv (Ad)	16.3±	51.1	0.09	.001±	.0	0.24	Jv (Ad)	205.0	0.54										Jv (Adult)	1.7	0.01				Juvenile	33.3	0.22
Polynoidae	Jv or Ad	0.5±	1.6	0.00	.001±	.0	0.11	Jv or Ad	5.0	0.01	Jv or Ad	1.7	0.02															
Harmothoe sp.	Jv or Ad	0.3±	1.1	0.00	.001±	.0	0.11				Jv or Ad	1.7	0.02															
Harmothoe imbricata	Ad (Jv)	2.1±	4.2	0.01	.004±	.01	0.91				Jv or Ad	1.7	0.02	Adult	1.7	0.01	Adult (Jv)	8.3	0.03				Adult	1.7	0.01			
Anaitides sp.	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01										Jv or Adult	1.7	0.01									
Micropodarke dubia	Adult	1.1±	3.6	0.01	.003±	.01	0.74				Adult	5.0	0.05				Adult	1.7	0.01									
Syllidae	Jv or Ad	0.5±	1.6	0.00	.001±	.00	0.12				Jv or Ad	1.7	0.02				Jv or Adult	1.7	0.01									
Exogone lourei	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01							Jv or Adult	1.7	0.01												
Sphaerosyllis sp.	Adult	5.3±	22.9	0.03	.001±	.00	0.11													Adult	33.3	0.14						
Sphaerosyllis brandhorsti	Adult	0.8±	1.9	0.00	.000±	.00	0.02				Adult	1.7	0.02	Adult	1.7	0.01				Adult	1.7	0.01						
Brania brevipharyngea	Adult	0.3±	1.1	0.00	.000±	.00	0.01													Adult	1.7	0.01						
Braniella sp.	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01													Jv or Adult	1.7	0.01						
Nereis sp.	Juvenile	0.3±	1.1	0.00	.000±	.00	0.01													Juvenile	1.7	0.01						
Platynereis bicanaliculata	Juvenile	5.3±	22.9	0.03	.016±	.07	3.40							Juvenile	33.3	0.19												
Sphaerodoropsis minuta	Adult	0.3±	1.1	0.00	.000±	.00	0.06													Adult	1.7	0.01						
Sphaerodorum biserialis	Adult	0.3±	1.1	0.00	.000±	.00	0.06										Adult	1.7	0.01									
Spionidae	Jv or Ad	0.5±	2.3	0.00	.000±	.00	0.01	Jv or Ad	10.0	0.03																		
Aproprionospio sp.	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01				Jv or Ad	1.7	0.02															
Archiannelida	Adult	0.3±	1.1	0.00	.000±	.00	0.01										Adult	1.7	0.01									
Oligochaeta	Ad and Jv	11.6±	31.3	0.06	.001±	.00	0.24	Ad or Jv	10.0	0.03																Adult or Jv	70.0	0.47
Gastropoda	Egg	55.0±	84.3	0.30	.005±	.01	0.98				Egg	35.0	0.34	Egg	168.3	0.94	Egg	36.7	0.15	Egg	36.7	0.16	Egg	38.3	0.27	Egg	33.3	0.22
Acmaeidae	Juvenile	0.3±	1.1	0.00	.000±	.00	0.01							Juvenile	1.7	0.01												
Margarites sp.	Juvenile	0.5±	1.6	0.00	.000±	.00	0.01				Juvenile	1.7	0.02							Juvenile	1.7	0.01						
Mesogastropoda	Egg	0.8±	2.5	0.00	.000±	.00	0.01										Egg	1.7	0.01	Egg	3.3	0.01						
Mesogastropoda	Juvenile	107.4±	125.3	0.58	.006±	.01	1.25	Juvenile	400.0	1.06	Juvenile	66.7	0.64	Juvenile	66.7	0.37	Juvenile	233.3	0.95	Juvenile	133.3	0.57	Juvenile	33.3	0.23	Juvenile	13.3	0.09
Lacuna sp.	Jv or Ad	151.6±	126.2	0.81	.025±	.02	5.35	Juvenile	115.0	0.30	Juvenile	81.7	0.79	Juvenile	210.0	1.17	Jv and Ad	263.3	1.07	Juvenile	231.7	0.99	Juvenile	121.7	0.85	Juvenile	13.3	0.09
Alvinia sp.	Jv or Ad	7.9±	23.9	0.04	.005±	.01	0.97				Jv and Ad	11.7	0.11				Jv and Ad	36.7	0.15				Adult	1.7	0.01			
Neogastropoda	Juvenile	0.3±	1.1	0.00	.000±	.00	0.01																			Juvenile	1.7	0.01
Turbonilla sp.	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01	Jv or Ad	5.0	0.01																		
Nudibranchia	Jv (Adult)	3.2±	5.6	0.02	.007±	.02	1.59							Jv (Adult)	10.0	0.06	Jv (Adult)	6.7	0.03				Jv (Adult)	3.3	0.02			
Opisthobranchia	Juvenile	1.1±	3.6	0.01	.002±	.01	0.46	Juvenile	15.0	0.04	Juvenile	1.7	0.02															
Bivalvia	Juvenile	10.5±	31.5	0.06	.001±	.00	0.23										Juvenile	33.3	0.14	Juvenile	33.3	0.14						
Araneae	Jv or Ad	0.3±	1.1	0.00	.000±	.00	0.01				Juvenile	1.7	0.02															
Halacaridae	Jv and Ad	63.2±	89.5	0.34	.004±	.01	0.91				Adult	66.7	0.64	Jv and Adult	166.7	0.93	Jv and Ad	66.7	0.27				Adult	33.3	0.23	Juvenile	66.7	0.45
Crustacea	Egg	247.4±	400.7	1.33	.006±	.00	1.38	Egg	725.0	1.92	Egg	88.3	0.85	Egg	270.0	1.50	Egg	166.7	0.68	Egg	633.3	2.72	Egg	100.0	0.70	Egg	66.7	0.45
Myodocopa	Adult	0.3±	1.1	0.00	.000±	.00	0.01										Adult	1.7	0.01									
Podocopa	Jv and Ad	931.1±	1168.9	5.00	.010±	.00	2.19	Ad and Jv	4850.0	12.84	Jv and Ad	435.0	4.18	Jv or Ad	800.0	4.45	Jv and Ad	1541.7	6.29	Jv and Ad	968.3	4.15	Jv and Ad	168.3	1.18	Jv and Ad	366.7	2.46
Copepoda	Egg	768.4±	525.0	4.13	.009±	.00	1.93				Egg	400.0	3.84	Egg	1333.3	7.42	Egg	366.7	1.50	Egg	966.7	4.15	Egg	866.7	6.07	Egg	933.3	6.26
Copepoda	Naup and Cp	210.5±	284.6	1.13	.006±	.00	1.36	Naup	800.0	2.12	Naup	566.7	5.45	Naup	100.0	0.56	Naup, Cp	233.3	0.95	Cpodid	33.3	0.14	Cpodid	66.7	0.47	Naup	66.7	0.45
Calanoida	Adult, Np,Cp	258.2±	516.7	1.39	.005±	.01	1.14	Jv or Ad	2205.0	5.84	Jv or Ad	33.3	0.32	Naup, Cp	366.7	2.04	Jv or Ad, Cp	166.7	0.68	Cpodid	33.3	0.14	Ad, Cpodid	266.7	1.87	Jv or Adult	33.3	0.22
Paracalanus parvus	Adult	31.8±	100.2	0.17	.001±	.00	0.23																Adult	133.3	0.93	Adult	68.3	0.46
Pseudocalanus minutus	Adult	306.6±	552.0	1.65	.004±	.01	0.81										Adult	601.7	2.46	Adult	66.7	0.29	Adult	1138.3	7.97	Adult	135.0	0.90
Centropages sp.	Adult	0.3±	1.1	0.00	.000±	.00	0.01										Adult	1.7	0.01									
Eurytemora americana	Adult	15.8±	68.8	0.08	.001±	.00	0.11																			Adult	100.0	0.67
Eurytemora hirundoides	Adult	26.3±	80.6	0.14	.001±	.00	0.23																			Adult	166.7	1.12
Harpacticoida	Egg	244.7±	458.9	1.31	.004±	.00	0.81	Egg	1300.0	3.44	Egg	33.3	0.32				Egg	940.0	3.84	Egg	10.0	0.04				Egg	133.3	0.89
Harpacticoida	MP, Cp, Ad, ϕ	10459.7±	6185.1	56.15	.030±	.09	6.57	Ad, ϕ	15770.0	41.75	Ad(Jv)MPϕ	4878.3	46.89	ϕMP,Np,Cp,Ad	9568.3	53.25	Ad,MP,ϕ	15070.0	61.50	Ad,MP,Cp,ϕ	12470.0	53.48	Ad,MP,ϕ	9350.0	65.49	Ad,MP,Cp,ϕ	9651.7	64.69
Tegastidae	Adult	36.8±	95.5	0.20	.002±	.00	0.34	Adult	300.0	0.79							Adult	33.3	0.14	Adult	100.0	0.43						
Porcellidiidae	Adult, ϕ	63.9±	205.9	0.34	.002±	.00	0.47	Ad, ϕ	900.0	2.38	Adult	33.3	0.32				Adult	33.3	0.14	Adult	38.3	0.16						
Cyclopoida	Adult, ϕ	1764.2±	1575.1	9.47	.010±	.00	2.18	Adult	6105.0	16.16	Adult, ϕ	1266.7	12.18	Ad, ϕ	2200.0	12.24	Ad, ϕ	1668.3	6.81	Ad, ϕ	2901.7	12.45	Adult	300.0	2.10	Ad, ϕ	801.7	5.37
Corycaeus sp.	Adult	10.5±	31.5	0.06	.001±	.00	0.23										Adult	33.3	0.14	Adult	33.3	0.14						
Oithona sp.	Adult	463.2±	693.0	2.49	.007±	.00	1.48				Adult	1566.7	12.18	Adult	266.7	1.48	Adult	300.0	1.22	Adult	266.7	1.14	Adult	466.7	3.27	Adult	66.7	0.45
Nebalia pugettensis	Adult	0.3±	1.1	0.00	.000±	.00	0.06	Adult	5.0	0.01																		
Mysidae	Juvenile	0.3±	1.1	0.00	.000±	.00	0.01																Juvenile	1.7	0.01			
Lampropidae	Jv and Adult	116.3±	159.4	0.62	.007±	.01	1.50							Juvenile	133.3	0.74	Jv and Ad	180.0	0.73	Jv and Ad	198.3	0.85	Juvenile	151.7	1.06	Juvenile	73.3	0.49
Lamprops sp.	Jv and Adult	37.1±	83.3	0.20	.002±	.00	0.46	Jv & Ad	105.0	0.28							Juvenile	66.7	0.27				Juvenile	133.3	0.93			
Hemilamprops sp.	Jv and Adult	7.6±	16.0	0.04	.002±	.01	0.51							Jv and Ad	41.7	0.23	Jv and Ad	6.7	0.03									
______ sp.	Jv and Adult	62.6±	78.9	0.34	.006±	.01	1.20	Jv & Ad	175.0	0.46	Jv & Ad	78.3	0.75	Adult	13.3	0.07	Jv and Ad	51.7	0.21	Jv and Ad	135.0	0.58	Jv and Ad	35.0	0.25	Adult	25.0	0.17
Bodotriidae	Adult	0.3±	1.1	0.00	.000±	.00	0.01																Adult	1.7	0.01			
Tanaidae	Juvenile	10.5±	45.9	0.06	.001±	.00	0.11																			Juvenile	66.7	0.45
Leptochelia dubia	Jv and Adult	47.1±	61.4	0.25	.006±	.01	1.40	Adult	10.0	0.03	Jv or Ad	8.3	0.08	Jv or Adult	136.7	0.76	Jv and Ad	40.0	0.16	Adult	1.7	0.01	Juvenile	35.0	0.25	Jv or Ad	73.3	0.49
Exosphaeroma media	Jv (Adult)	0.8±	2.5	0.00	.000±	.00	0.01				Jv (Ad)	5.0	0.05															
Munna sp.	Juvenile	10.5±	31.5	0.06	.001±	.00	0.23													Juvenile	33.3	0.14	Juvenile	33.0	0.23			
Munna ubiquita	Jv, Ad, ϕ	130.5±	167.0	0.70	.006±	.01	1.21	Jv, Ad, ϕ	325.0	0.86	Jv, Ad, ϕ	191.7	1.84	Jv, Ad, ϕ	56.7	0.32	Jv, Ad, ϕ	338.3	1.38	Jv, Ad, ϕ	130.0	0.56	Jv (Adult)	1.7	0.01			
Bopyridae	Adult	42.1±	83.8	0.23	.003±	.00	0.57	Adult	300.0	0.79	Adult	33.3	0.32							Adult	66.7	0.29				Adult	66.7	0.45
Gammaridea	Jv (Adult)	96.3±	322.0	0.52	.003±	.00	0.58	Juvenile	1415.0	3.75	Jv or Ad	3.3	0.03	Juvenile	35.0	0.19	Juvenile	66.7	0.27	Juvenile	33.3	0.14						
Amphithoe sp.	Jv (Adult)	4.5±	6.4	0.02	.003±	.00	0.58							Jv (Adult)	3.3	0.02	Juvenile	1.7	0.01	Juvenile	8.3	0.04	Juvenile	13.3	0.09	Juvenile	1.7	0.01
Amphithoe simulans	Adult	0.3±	1.1	0.00	.005±	.02	1.13																			Adult	1.7	0.01
Amphithoe lacertosa	Juvenile	6.1±	26.4	0.03	.006±	.03	1.36										Juvenile	38.3	0.16									
Aoroides columbiae	Jv and Adult	33.2±	44.0	0.18	.006±	.01	1.33	Jv and Ad	30.0	0.08	Jv and Ad	1.7	0.02	Jv and Ad	51.7	0.29	Jv and Ad	65.0	0.27	Jv and Ad	81.7	0.35						
Aytlus tridens	Juvenile	0.8±	2.5	0.00	.000±	.00	0.01							Juvenile	5.0	0.03												
Calliopius sp.	Jv or Adult	0.3±	1.1	0.00	.001±	.00	0.11	Jv or Ad	5.0	0.01																		
Calliopius laeviusculus	Adult	0.3±	1.1	0.00	.001±	.00	0.23													Adult	1.7	0.01						
Calliopiella pratti	Jv, Ad, ϕ	52.4±	76.0	0.28	.006±	.01	1.40	Juvenile	5.0	0.01							Jv, Ad, ϕ	40.0	0.16	Jv, Ad, ϕ	130.0	0.56	Juvenile	75.0	0.53	Jv and Adult	85.0	0.57
Dexaminidae	Jv or Adult	0.5±	2.3	0.00	.000±	.00	0.01	Jv or Ad	10.0	0.03																		
Pontogeneia sp.	Jv and Adult	354.2±	686.9	1.90	.074±	.11	15.89	Jv or Ad	85.0	0.23	Jv or Ad	83.3	0.80	Jv and Adult	141.7	0.79	Jv and Adult	210.0	0.86	Jv and Ad	1415.0	6.07	Jv and Ad	158.3	1.11	Juvenile	206.7	1.39
Pontogeneia rostrata	Jv or Adult	1.1±	4.6	0.01	.000±	.00	0.06				Jv or Ad	6.7	0.06															
Melita sp.	Juvenile	0.8±	1.9	0.00	.000±	.00	0.02				Juvenile	3.3	0.03							Juvenile	1.7	0.01						
Melita dentata	Juvenile	3.2±	13.8	0.02	.000±	.00	0.06										Juvenile	20.0	0.08									

Appendix Table B-4, (continued)

	- - - - ALL	SAMPLES ABUNDANCE		COMBINED	BIOMASS - - - - -		F.C.1	03:40 ABUNDANCE		F.C.2	05:30 ABUNDANCE	
ORGANISM	LIFE HISTORY	$\bar{X}$	S.D.	%	$\bar{X}$ SD	%	LIFE HIST.	$\bar{X}$	%	LIFE HIST.	$\bar{X}$	%
Photis sp.	Jv (Adult)	33.7±	60.0	0.18	.003±.01	0.65						
Photis brevipes	Juvenile	0.3±	1.1	0.00	.000±.00	0.01	Juvenile	5.0	0.01			
Podoceropsis sp.	Jv, Ad, ϕ	57.6±	109.5	0.31	.006±.01	1.20	Jv or Adult	40.0	0.11	Jv, Ad,ϕ	3.3	0.03
Ischyrocerus sp.	Jv and Adult	59.7±	132.3	0.32	.005±.01	0.99				Juvenile	33.3	0.32
Lysianassidae	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01						
Orchomene sp.	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01	Jv or Adult	5.0	0.01			
Synchelidium shoemakeri	Jv and Adult	79.5±	126.4	0.43	.008±.01	1.63	Jv and Ad	80.0	0.21	Adult	3.3	0.03
Westwoodilla caecula	Jv and Adult	10.5±	24.9	0.06	.003±.01	0.66	Jv and Ad	25.0	0.07	Jv and Ad	5.0	0.05
Phoxocephalidae	Juvenile	5.8±	22.9	0.03	.001±.00	0.12						
Paraphoxus sp.	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01						
Paraphoxus spinosus	Jv and Adult	6.3±	22.8	0.03	.001±.00	0.18	Jv (Adult)	10.0	0.03			
Pleustidae	Juvenile	0.5±	2.3	0.00	.000±.00	0.01						
Parapleustes nautilus	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01						
Pleustes depressa	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01						
Pleusirus secorrus	Jv or Adult	0.3±	1.1	0.00	.000±.00	0.01						
Amphipoda-Hyperiidea	Juvenile	0.3±	1.1	0.00	.000±.00	0.01						
Caprellidae	Juvenile	10.5±	31.5	0.06	.001±.00	0.23						
Caprella sp.	Jv, Ad, ϕ	272.0±	243.0	1.46	.032±.04	6.92	Juvenile	300.0	0.79	Juvenile	133.3	1.28
Caprella laeviuscula	Ad, ϕ	52.6±	79.1	0.28	.026±.03	5.56	Adult, ϕ	190.0	0.50	Jv, Ad,ϕ	48.3	0.46
Hippolytidae	Juvenile	0.3±	1.1	0.00	.000±.00	0.06						
Hippolyte clarki	Jv (Adult)	1.8±	4.2	0.01	.023±.05	4.88	Juvenile	5.0	0.01			
Heptacarpus sp.	Juvenile	0.3±	1.1	0.00	.001±.00	0.11						
Crangonidae	Juvenile	0.3±	1.1	0.00	.000±.00	0.06						
Crangon sp.	Juvenile	0.8±	1.9	0.00	.005±.02	1.08	Juvenile	5.9	0.01			
Sclerocrangon sp.	Juvenile	0.3±	1.1	0.00	.000±.00	0.06						
Pagurus sp.	Juvenile	1.3±	2.8	0.01	.001±.00	0.28						
Pinnotheridae	Zoea	0.5±	1.6	0.00	.000±.00	0.01	Zoea	5.0	0.01	Zoea	1.7	0.02
Diptera	larva, adult	8.2±	22.9	0.04	.001±.00	0.31				larva	41.7	0.40
Gymnolaemata	Cyphonautes	52.6±	77.2	0.28	.004±.01	0.91						
Gymnolaemata-cheilostomata	Colony	10.0±	16.9	0.05	.003±.01	0.66						
Ophiuroidea	Juvenile	6.3±	26.3	0.03	.001±.00	0.18						
Amphipholis squamata	Jv or Adult	0.3±	1.1	0.00	.001±.00	0.11				Jv or Adult	1.7	0.02
Ascidiacea	Larva	5.3±	22.9	0.03	.001±.00	0.11						
Teleostei	Egg	0.5±	1.6	0.00	.001±.00	0.12	Egg	5.0	0.01			
Unidentified egg	Egg	196.0±		1.05	.006±.00	1.14	Egg	600.0	1.59	Egg	66.6	0.64
Unidentified	indeterminable	26.3±	65.3	0.14	.002±.00	0.34						
TOTAL ABUNDANCE $\bar{X}$		18627.89						37770.00			10403.33	
TOTAL ABUNDANCE S.D.		10050.03						0.			1718.66	
TOTAL ABUNDANCE COEF. VAR.		.54						0.			.17	
SAMPLE WET WEIGHT $\bar{X}$		.583						.985			.352	
SAMPLE WET WEIGHT S.D.		.280						0.			.163	
SAMPLE WET WEIGHT COEF. VAR.		.479						0.			.462	
TOTAL NO. CATEGORIES		119.						43.			47.	
SHANNON-WEINER INDEX NO.S		2.94						2.98			2.81	
BIOMASS		5.24						4.59			4.51	
BRILLOUINS INDEX		2.93						2.98			2.80	

	F.C. 3 ↔	08:45 ABUNDANCE		F.C.4 ↔	11:35 ABUNDANCE		F.C. 5 ↔	14:40 ABUNDANCE		F.C. 6 ↔	18:00 ABUNDANCE		F.C. 7 ↔	20:15 ABUNDANCE	
ORGANISM	LIFE HIST.	$\bar{X}$	%	LIFE HIST.	$\bar{X}$	%	LIFE HIST.	$\bar{X}$	%	LIFE HIST.	$\bar{X}$	%	LIFE HIST.	$\bar{X}$	%
Photis sp.	Juvenile	108.3	0.60	Juvenile	1.7	0.01	Jv (Adult)	36.7	0.16	Juvenile	33.3	0.23	Juvenile	33.3	0.22
Photis brevipes															
Podoceropsis sp.	Jv, Adult, ϕ	91.7	0.51	Ad, Jv, ϕ	193.3	0.79	Jv or Ad	63.3	0.27						
Ischyrocerus sp.	Juvenile	100.0	0.56	Jv and Ad	6.7	0.03	Jv and Ad	236.7	1.02				Adult	1.7	0.01
Lysianassidae	Jv or Ad	1.7	0.01												
Orchomene sp.															
Synchelidium shoemakeri	Jv (Adult)	226.7	1.26	Jv and Ad	85.0	0.35	Jv and Ad	153.3	0.66	Juvenile	1.7	0.01	Jv or Adult	6.7	0.04
Westwoodilla caecula	Jv (Adult)	38.3	0.21	Juvenile	3.3	0.01	Juvenile	1.7	0.01	Juvenile	3.3	0.02	Jv and Adult	6.7	0.04
Phoxocephalidae				Juvenile	3.3	0.01	Juvenile	33.3	0.14						
Paraphoxus sp.							Jv or Ad	1.7	0.01						
Paraphoxus spinosus				Jv (Adult)	35.0	0.14	Adult	1.7	0.01						
Pleustidae	Juvenile	3.3	0.02												
Parapleustes nautilus										Jv or Adult	1.7	0.01			
Pleustes depressa				Jv or Adult	1.7	0.01									
Pleusirus secorrus				Jv or Adult	1.7	0.01									
Amphipoda-Hyperiidea													Juvenile	1.7	0.01
Caprellidae				Juvenile	33.3	0.14	Juvenile	33.3	0.14						
Caprella sp.	Juvenile	233.3	1.30	Jv and Ad	243.3	0.99	Jv, Ad, ϕ	475.0	2.04	Jv, Ad, ϕ	398.3	2.79	Juvenile	140.0	0.94
Caprella laeviuscula	Jv and Adult	110.0	0.61	Ad, ϕ	111.7	0.46									
Hippolytidae										Juvenile	1.7	0.01			
Hippolyte clarki	Jv (Adult)	5.0	0.03				Juvenile	5.0	0.02						
Heptacarpus sp.	Juvenile	1.7	0.01												
Crangonidae				Juvenile	1.7	0.01									
Crangon sp.				Juvenile	1.7	0.01	Juvenile	1.7	0.01						
Sclerocrangon sp.	Juvenile	1.7	0.01												
Pagurus sp.	Juvenile	1.7	0.01							Juvenile	3.3	0.02	Juvenile	3.3	0.02
Pinnotheridae															
Diptera	Larva	3.3	0.02	Larva	1.7	0.01							Adult, Lrv	5.0	0.03
Gymnolaemata	Cyphonautes	100.0	0.56	Cyphonautes	66.7	0.27	Cyphonautes	100.0	0.43				Cyphonautes	66.7	0.45
Gymnolaemata-cheilostomata	Colony	16.7	0.09	Colony	23.3	0.10	Colony	20.0	0.09	Colony	3.3	0.02			
Ophiuroidea				Juvenile	40.0	0.16									
Amphipholis squamata															
Ascidiacea	Larva	33.3	0.19												
Teleostei	Egg	1.7	0.01												
Unidentified egg	Egg	366.7	2.04	Egg	233.3	0.95	Egg	341.6	1.47	Egg	33.3	0.23			
Unidentified	Unident.	100.0	0.56	Unident.	66.7	0.27									
TOTAL ABUNDANCE $\bar{X}$		17968.33			24503.33			23315.00			14276.67			14920.00	
TOTAL ABUNDANCE S.D.		5918.49			16587.29			11955.60			2810.38			5097.88	
TOTAL ABUNDANCE COEF. VAR.		.33			.68			.51			.20			.34	
SAMPLE WET WEIGHT $\bar{X}$		.675			.705			.793			.432			.410	
SAMPLE WET WEIGHT S.D.		.387			.312			.284			.030			.084	
SAMPLE WET WEIGHT COEF. VAR.		.574			.442			.358			.070			.205	
TOTAL NO. CATEGORIES		50.			64.			57.			38.			39.	
SHANNON-WEINER INDEX NO.S		2.88			2.63			2.81			2.23			2.27	
BIOMASS		4.66			4.60			4.01			4.12			4.36	
BRILLOUINS INDEX		2.87			2.63			2.81			2.23			2.27	

LIFE HISTORY STAGE ABBREVIATIONS: Jv = Juvenile, Ad = Adult, Np = Nauplius, Cp = Copepodid, MP = Mating Pair, ϕ = Egg bearing Female, () = suspected

Appendix C

Appendix Table C-1. Estimate* of mean length of chum fry at time of release from hatcheries; based on fish/lb data (From Salo et al. 1980).

Sampling Week	Final Day In Week	Size of Release	Mean Length* Estimate (mm)	Hatchery/s.
13	April 1	1,324,075	49	Hood Canal
14	April 8	99,953	44	Hood Canal
15	April 15	1,226,900	43	Hood Canal
16	April 22	1,333,067	49	Hood Canal
17	April 29	725,506	56	Hood Canal
18	May 6	346,953	61	Skokomish
19	May 13	2,287,030	59	Hood Canal; Quilcene
20	May 20	1,298,245	63	Hood Canal; Skokomish
21	May 27	540,416	63	Hood Canal
22	June 3	890,359	55	Skokomish
23	June 10	1,156,200	?	Hood Canal
24	June 17	3,490,450	68	Quilcene

* This is a rough estimate calculated from fish/lb data only assuming that condition factor = 0.75 in all cases.