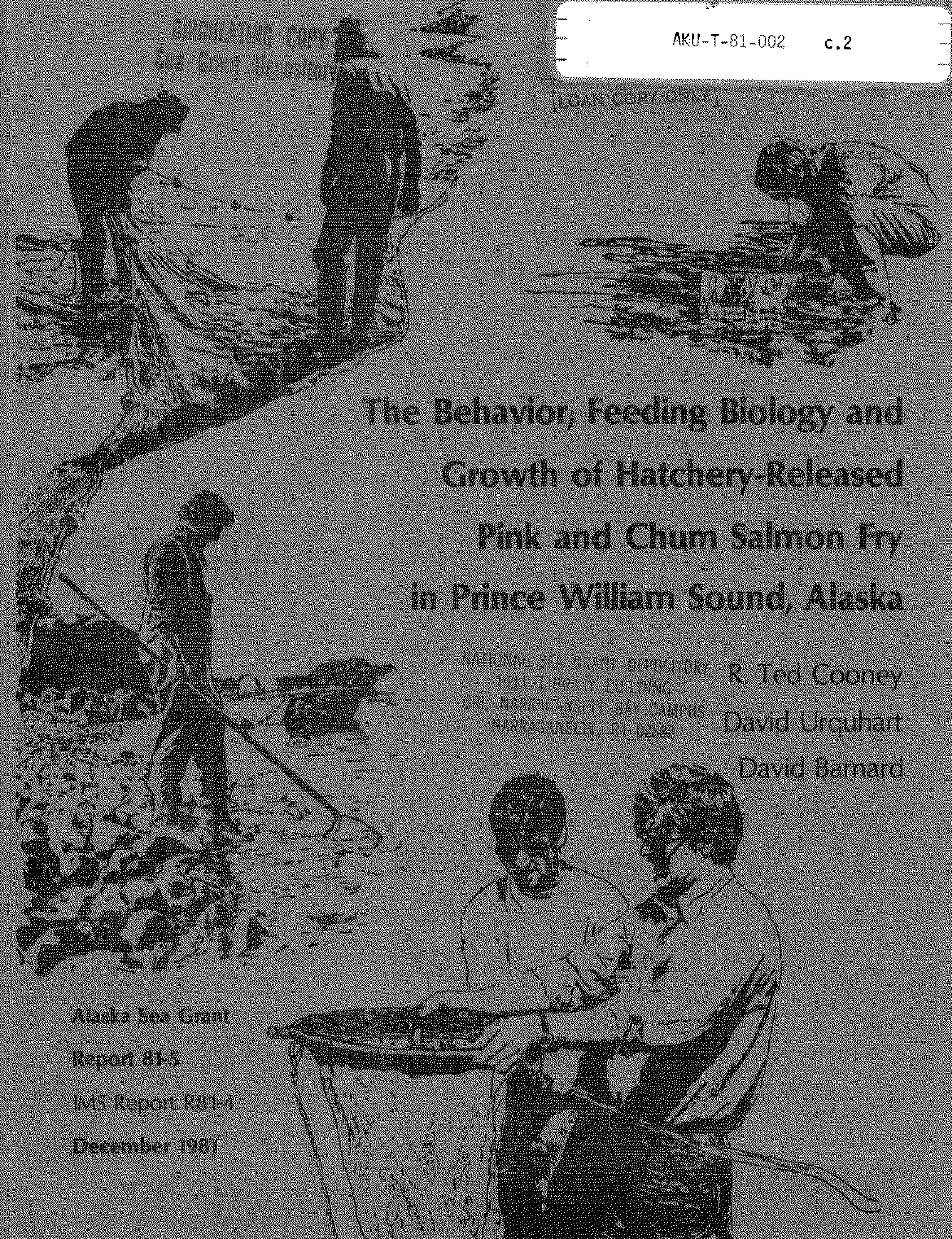

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Alaska Sea Grant
Report 81-5
IMS Report R81-4
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ALASKA SEA GRANT COLLEGE PROGRAM
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

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ACKNOWLEDGEMENTS

This research was sponsored by the Alaska Sea Grant Program cooperatively supported by NOAA, U.S. Department of Commerce under Grant Number 04-8-M01-49, Project Number R/02-01 and by the University of Alaska with funds appropriated by the State of Alaska and by the Institute of Marine Science, Fairbanks. The project was made possible through cooperation with the Prince William Sound Aquaculture Corporation, Cordova, Alaska. Mr. Armin Koernig, Mr. Wallace Noerenberg, and the employees of the Port San Juan hatchery are particularly thanked for their assistance in all aspects of the field study.

Additional thanks go to Mr. Bob Clasby, Mr. William Gallanger, Mr. John Hilsinger, Mr. Michael Travis, Mr. Al Adams, Mr. Ken Coyle, and Ms. Patricia Wagner for their help in the field and laboratory.

We particularly acknowledge Mr. Donald Rosenberg, Director of the Alaska Sea Grant Program, and Mr. Ray Hadley, Assistant Director, for their support of the research and education represented by this work.

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ABSTRACT

Hatchery-reared pink and chum salmon fry released into southwestern Prince William Sound, Alaska, exhibit most of the behavior patterns and feeding preferences previously described for these species at other locations along the Pacific coast of North America. The young pinks quickly adopt a dependency on pelagic copepods and other organisms typical of the "plankton" community. Chum salmon fry in contrast select insects, harpacticoid copepods, and larvaceans. The diets of both species are quite consistently different on a mass basis, suggesting a sharing rather than competition for food resources.

Large numbers of pink salmon fry released in 1977 took up residence in numerous sheltered coves some distance from the hatchery. These locations, later termed "nursery areas", were bordered by strong tidal currents which apparently provided consistently high fluxes of food even during periods of low zooplankton abundance (mid-May of each year). In 1978, the use of these nursery areas was less noticeable.

Growth of pink salmon fry sampled in the nursery areas is similar to that noted for populations of this species in British Columbia. The average increase in size for 1977 was 4.6 percent of the body weight per day and in 1978, 3.2 percent of body weight.

We are unable to detect any irregularities in growth or behavior that would suggest the hatchery fry use the estuary differently than do wild stocks. Food limitation does not appear to be a problem except perhaps for releases very early in the season, February or March, when local stocks of small copepods are approaching their seasonal lows.

We recommend that future studies include investigations of both intra- and interspecific competition as well as surveys of fry predators. We also recommend that for Prince William Sound, the role of salmon fry as consumers be evaluated in the context of the system as a whole.

INTRODUCTION

In late November 1975, the University of Alaska, Institute of Marine Science, supported by the Alaska Sea Grant Program, initiated studies of the carrying capacity of waters adjacent to eastern Evans Island in Prince William Sound, Alaska. This endeavor came at the request of the Prince William Sound Aquaculture Corporation, Cordova, Alaska, which had received a permit to develop and operate a nonprofit hatchery for pink and chum salmon at Sawmill Bay. The survival of millions of fry introduced each spring from Port San Juan was posed as a legitimate research problem both from the economics aspect of the hatchery and common property fishery, and the fact that little was known about the specific habitat requirements of fry using this estuary. It was expected that the results of the study would be used by hatchery personnel to minimize losses to natural mortality associated with food and predation during the many weeks the young salmon remained near the facility prior to their migration to the open Gulf of Alaska. It was also hoped that following the study, certain environmental "signals" would be identified as critical to fry survival and hence subject to long-term, low-level monitoring. The coordination of fry releases with optimal environmental conditions for survival was a goal which seemed reasonable at the time and which directed the research toward the descriptions of environmental parameters known or thought to be important to fry survival and growth.

The specific research goals of this project were to carefully examine the behavior and feeding biology of both pink and chum salmon fry released into the estuary at Port San Juan. A pilot study conducted in the summer of 1976 suggested that an on-site approach to the research would be both feasible and practical. In fact, the strength of the subsequent information base was directly related to how frequently the research team surveyed the waters adjacent to the hatchery. The weekly, sometimes daily, observations proved extremely important in determining the initial responses of fry to the system and their subsequent patterns of movement and paths of migration.

The preliminary findings of this work appear as an interim report, "Some aspects of the carrying capacity of Prince William Sound, Alaska, for hatchery released pink and chum salmon fry" (Cooney *et al.*, 1978). The results reported here represent major portions of two masters theses (Urquhart, 1979; Barnard, 1981) completed with funds obtained through the Alaska Sea Grant Program and State of Alaska. The work was greatly facilitated by substantial in-kind contributions of space and field assistance from the Prince William Sound Aquaculture Corporation, Cordova, Alaska.

THE STUDY AREA

Prince William Sound is a fjord-type estuary of glacial origin on Alaska's southcentral coast bordering the northern Gulf of Alaska. Evans Island is one of four major islands in the southwest corner of the Sound. Average air temperature in the region ranges between -1°C and 13°C annually. Total precipitation is high; nearly 500 cm of rain and 380 cm of snowfall each year (Muench and Schmidt, 1975).

Port San Juan is located at the southern end of Sawmill Bay on the east coast of Evans Island, approximately 145 km southwest of Cordova and 80 km east of Seward (Figure 1). Sawmill Bay is 5 km long and ringed by steep terrain. Two major streams enter the Bay; one is Larsen Creek, adjacent to Port San Juan, while O'Brien Creek enters Crab Bay. These streams and other seeps occasionally support small spawning runs of pink salmon, but overfishing, and uplift caused by the 1964 earthquake, combined to eliminate commercially important runs in the area.

Sawmill Bay opens to the northeast into Latouche Passage and is bordered on the east by a narrow peninsula and a group of islands. These islands, known collectively as the Bettles Island group, are situated at the north end of Elrington Passage where they are exposed to the powerful semi-diurnal tidal currents flowing into and out of Latouche Passage. The tidal range is between 1.8 and 4.3 m for this district.

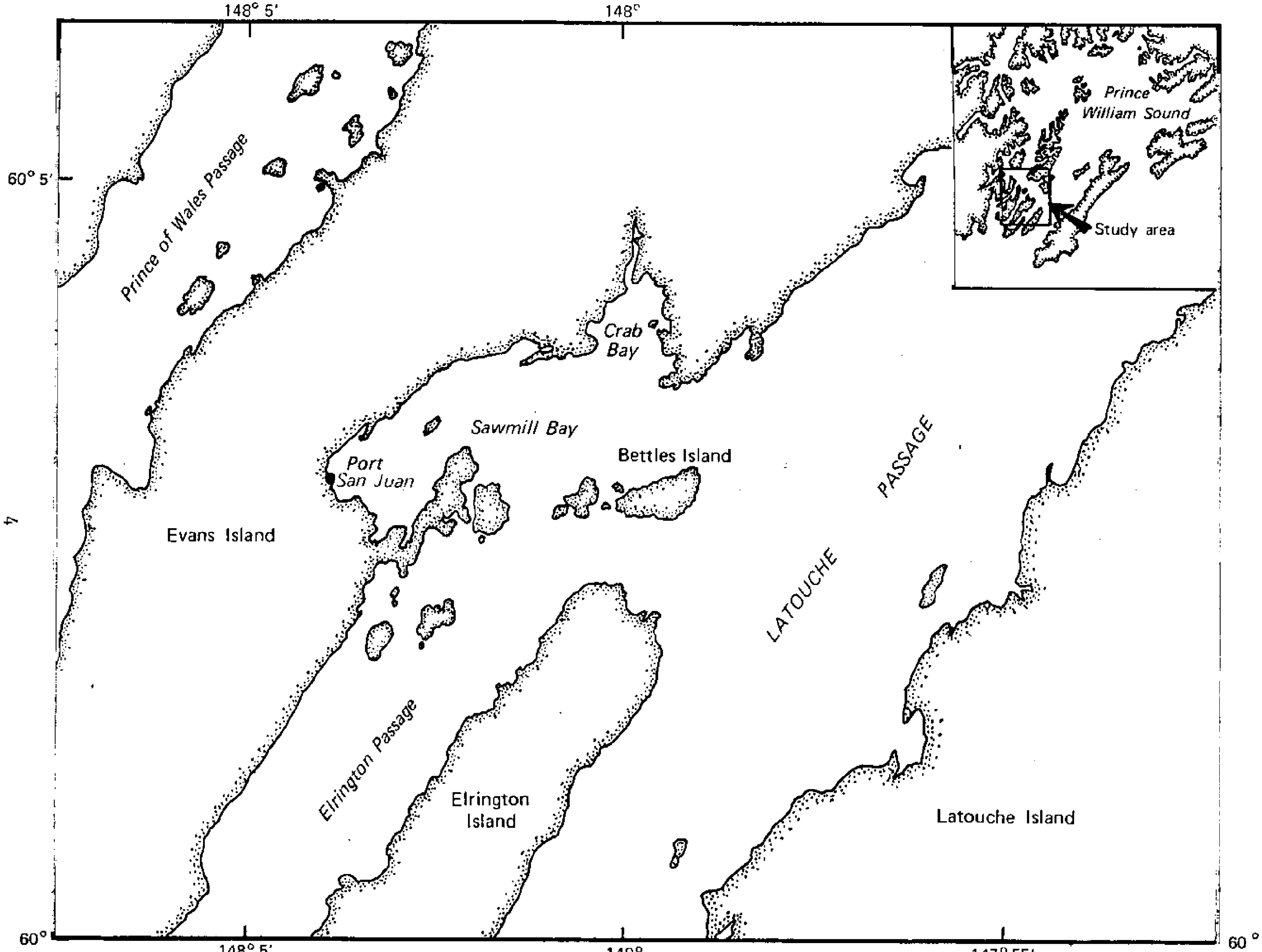

Figure 1. Study area and location of Port San Juan, site of the Prince William Sound Aquaculture Corporation pink and chum salmon hatchery.

METHODS AND MATERIALS

The Field Study

Early in the spring of 1977 and again in 1978, equipment and supplies were placed in a cabin on Evans Island at Port San Juan. The cabin provided both laboratory and living space for personnel who stayed on the island and collected samples of fry and zooplankton beginning April 1, 1977, and March 20, 1978. This timing was dictated by the initiation of the outmigration of pink salmon from the hatchery. In 1977 the fry outmigration began in March, peaking on April 22. In 1978 the peak outmigration occurred on April 8 (Figure 2). Roughly 10 million pink fry were released by the hatchery in 1977, and 16.9 million the following year.

Dissecting and compound microscopes were set up in the laboratory to sort and identify zooplankton. Microscopic examination of the stomach contents of fry was also performed on the island. In 1977 a 5 m (17 ft) Boston Whaler provided transportation. The Whaler was used again in 1978 as well as a 7 m (24 ft) Cordova cabin skiff.

The sampling season for pink salmon fry ended in both years during the last few days of June. At this time, all hatchery-reared pink salmon fry had been in the estuary at least a month and had grown to a size which made them difficult to collect.

Zooplankton Sampling

Zooplankton was sampled during daylight hours in the waters adjacent to Evans Island to document the number and variety of organisms available as forage to the young salmon. One sampling location was established inside Sawmill Bay, another at the north end of Elrington Passage (Figure 3). There, zooplankton was sampled at least once a week beginning late in April in 1977 and early April in 1978. Horizontal surface tows were taken both years. In 1977 a winch and boom mounted in the Boston Whaler were used to make vertical zooplankton tows at these stations.

Zooplankton was usually sampled at the surface wherever fry were sampled in order to census prey. However, if the pink fry had recently been released from the hatchery, they were often caught in Sawmill Bay within centimeters of the shore and bottom. In these cases tows for food organisms were not attempted.

Particular attention was paid to obtaining a time series of zooplankton samples from a location frequented by the fry. One area, labeled M-cove, was a preferred habitat in 1977 and frequently contained schools of fry in 1978 (Figure 3). Nearshore horizontal tows for zooplankton were taken at this location once a week beginning late in April 1977 and again beginning April 1 in 1978.

Zooplankton was collected with a 2.5 m long, 0.5 m diameter, 0.216 mm mesh, cone-shaped plankton net connected to a PVC cod end with 0.216 mm mesh windows. Tows were made by securing a single line or cable to the

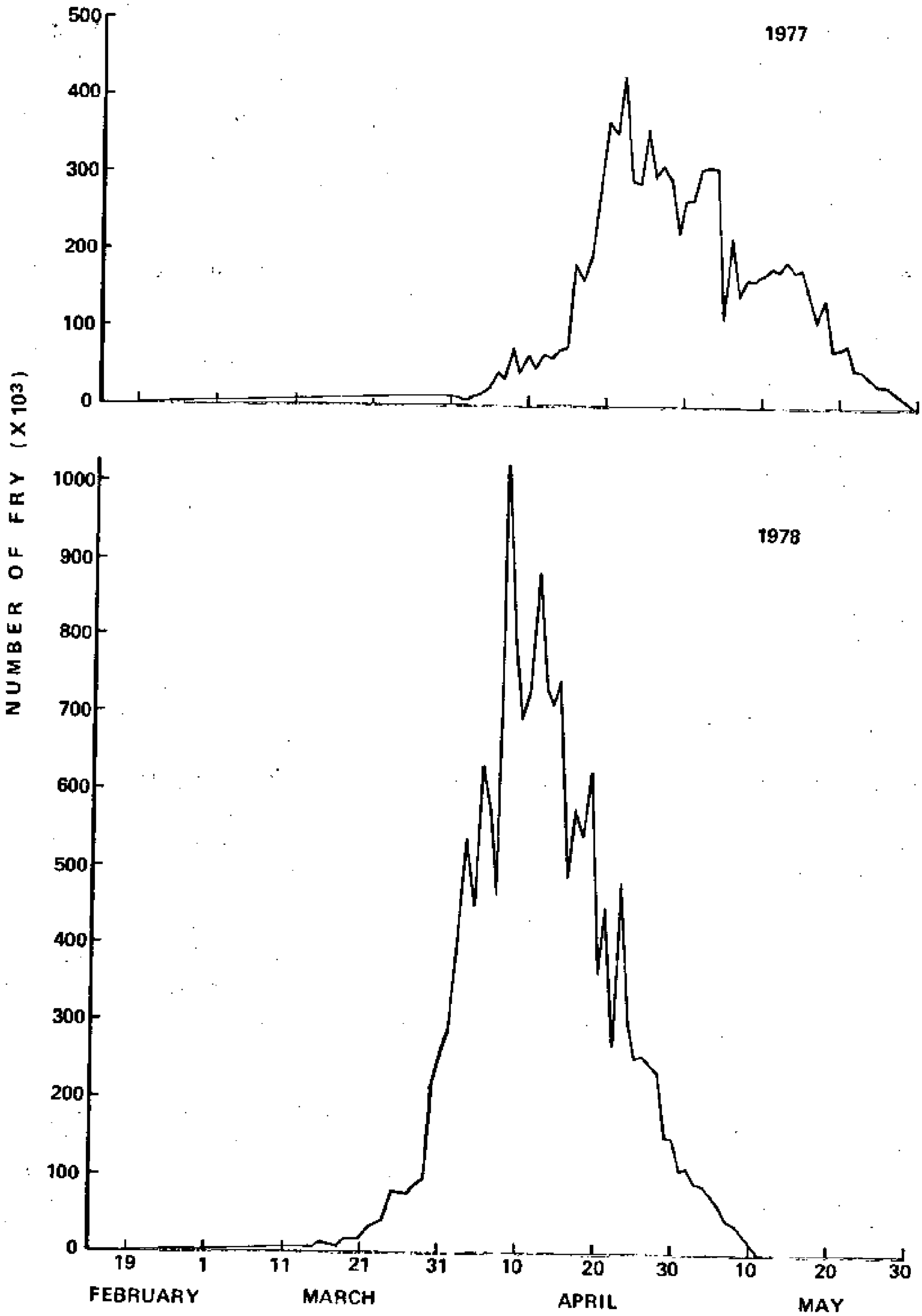

Figure 2. Daily outmigration curves for pink salmon fry leaving the Port San Juan hatchery in 1977 and 1978.

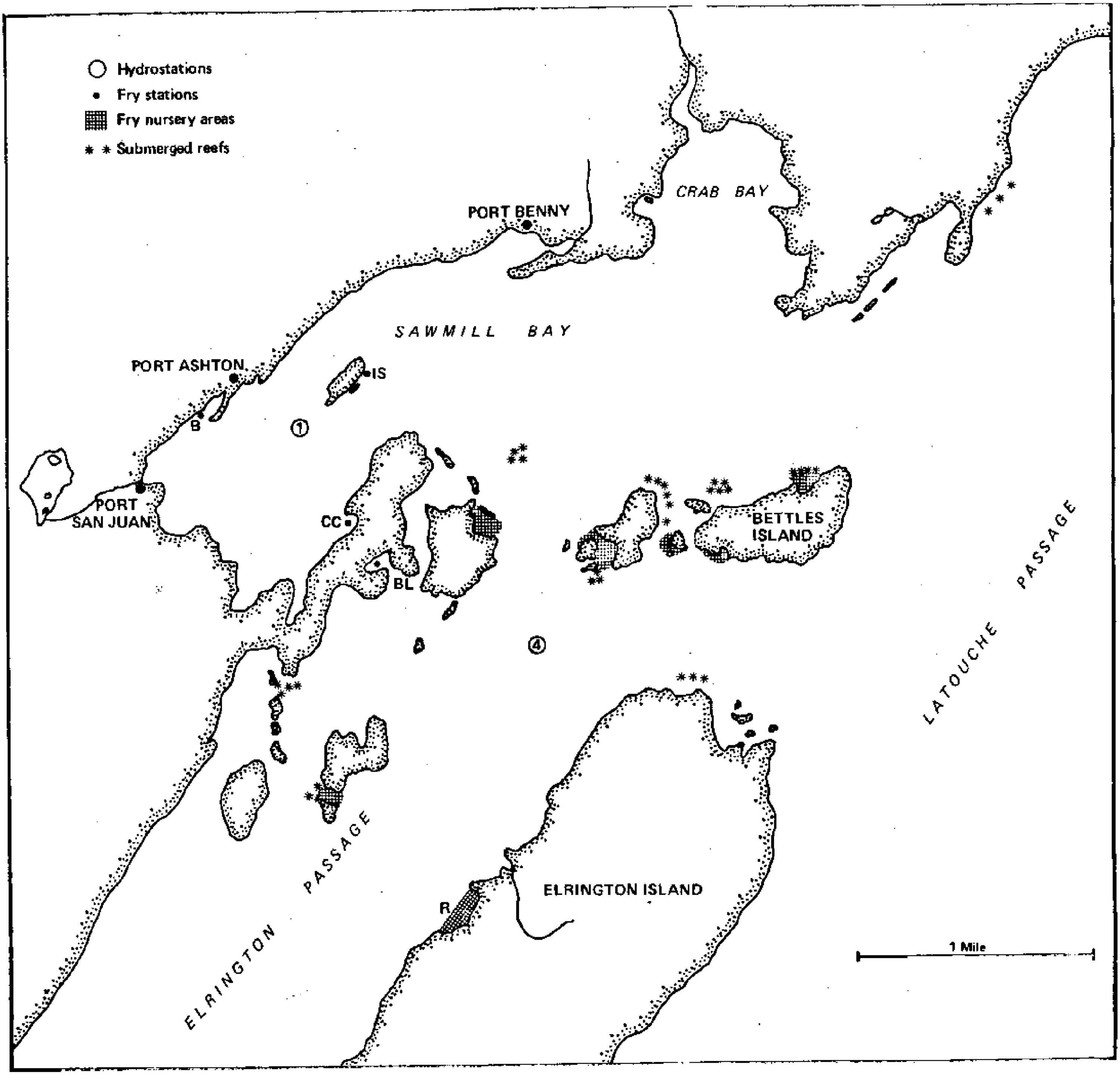

Figure 3. Pink salmon fry and zooplankton sampling stations in waters adjacent to Port San Juan, 1977 and 1978.

net's three arm bridle and by either towing it at the surface 5 to 10 m behind the boat or by lowering it vertically to a known depth and then retrieving it with the winch. Volumes filtered were determined for all samples by attaching a flow meter[1] to each net. At both zooplankton stations and in M-cove, replicate tows were frequently made to determine sample representativeness.

In June of 1978 attempts were made in M-cove to sample epibenthic prey organisms used by the fry. Small weights were attached to the 0.5 m net to keep it 2 to 3 m below the surface while "deep" horizontal tows were made across the cove. The net was also held by hand at the surface from the bow of the Boston Whaler while the boat was backed along the shore of the cove. When backing, submerged obstacles could be avoided, and the net was passed close to nearshore substrates (these were designated "off the bow" tows).

A 12 volt self-priming bilge pump[2] was also used in June of 1978 to sample nearshore epibenthic organisms. The pump was attached to 10 m of garden hose marked off in meters and wired into the electrical system of the cabin skiff. A weight was attached to the nozzle end of the hose so it would hang normally to the surface of the water when lowered. Calibration revealed the device pumped 19.1 liters/min. Water from the pump was passed through a 0.216 mm plankton net, and the zooplankton retained was later identified and counted.

Using this device, samples were pumped from fixed points at varying distances from bottom and nearshore substrates. Pumping positions were maintained by mooring the skiff with several anchors. Samples were taken horizontally over a range of 7 m and vertically to 10 m.

Zooplankton Sample Analysis

Zooplankton samples were preserved with a 4 percent formaldehyde and seawater solution and returned to the laboratory in 500 ml (16 oz) jars. Prior to examination these samples were rinsed in fresh water and diluted to known volumes. Subsamples representing a known portion of the complete sample were then taken with a calibrated pipet, washed into a petri dish, and placed under a binocular dissection microscope. That portion of the sample not prepared for examination was returned for storage in 4 percent formaldehyde and fresh water buffered with hexamethylenetetramine.

All organisms were counted and identified to the lowest convenient taxonomic level. Total counts were used to calculate the number of zooplankton m^{-3} for the sampling station at the time the sample was collected. Count variability and representativeness of samples were evaluated through duplication of this procedure on replicate samples.

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[1] flow meter - Model 2030, General Oceanics Inc., Miami, Florida.

[2] bilge pump - Water Puppy, Jabsco Products ITT., Costa Mesa, California.

Large pink salmon fry feeding outside Sawmill Bay in M-cove preyed on zooplankton that varied considerably in size. Thus, the food these fish obtained from a particular taxon was not necessarily indicated by the frequency with which the item was taken in net tows. In addition, the size and oil content of many prey organisms increased as the season progressed. Accordingly, the dry-weights of selected prey organisms were obtained for M-cove zooplankton to provide some indication of their size and ability to contribute to fry diet each week. Zooplankton samples were rinsed in fresh water and then, depending on size, a few to several hundred specific prey organisms were picked out and placed in a weighing tray and dried in a chemical dessicator at room temperature until constant weight was reached (usually 24 hours). Total dry-weight was measured on a laboratory balance and individual dry-weights calculated. The tables listing these prey organism dry-weights for both 1977 and 1978 are presented in Appendix I.

Fry Sampling and Observation

Small, recently released pink salmon fry were collected from shore and from boats with long handled 3 mm (1/8 in.) mesh dip nets. Later, as the fry grew larger and increased in wariness, a 46 m (150 ft) beach seine was used. The seine had tapered wings of 13 mm (1/2 in.) mesh nylon and a center bag of 3 mm mesh. Depending on the variability in the length of fry being sampled, between 100 and 300 individuals were included in a sample to assure representativeness in size frequency. Samples were routinely collected at the hatchery to monitor the size of fry leaving the facility at any time.

Visual surveys of the nearshore environment were made to describe pink fry habitat preference and to gain an understanding of the pathways the fry used in reaching Prince William Sound and the open Gulf of Alaska. In this latter regard, frequent surveys were made of the many tens of kilometers of coastline near the Port San Juan hatchery. In 1977, pink fry and zooplankton were initially sampled at random. Later, as patterns in fry behavior became apparent, nearshore surveying continued, but regular sampling stations were established and visited at least weekly. In the absence of a fry marking program, only the large numbers of pink fry swimming in the waters adjacent to Port San Juan, an area producing relatively few wild fry, provided an indication that the behavior patterns observed were those of the hatchery-reared fishes.

In order to make reasonable comparisons in feeding behavior between the even and odd year salmon released from the hatchery, attempts were made in 1978 to sample fry regularly at stations established the year before. Many pink salmon fry samples were obtained both years inside Sawmill Bay and outside, in M-cove in the Bettles Island group (Figure 3).

Fry Measurement and Stomach Analysis

To prevent regurgitation of food items, fry were allowed to suffocate in air before being preserved (4 percent formaldehyde solution buffered with hexamethylenetetramine). Fork-lengths were measured to the nearest millimeter after the fish spent at least 24 hours in the preservative. The average wet-weight of fry in each sample was obtained following length measurements.

Between 10 and 20 fry were selected from each sample for stomach analysis. Each fish was rinsed, measured, and placed on a petri dish under the dissecting microscope. Stomachs were removed with forceps by breaking them free from their junction with the pyloric caeca, swimbladder, and gill arches. The contents were suspended in water for counting and identification. Clumps of prey organisms were teased apart until identifiable. Identification was made to the lowest convenient taxonomic level possible depending on the state of digestion.

The results obtained from the stomach analysis of each subsample of fry were pooled and listed (Appendix II and III). These tables present the number of individual prey organisms counted and identified to species or the lowest convenient taxon. The count for each prey item is also given as a percentage of the total prey count for the entire group of fish. The frequency of occurrence of prey organisms in the stomachs of the fry within each group is expressed as a percentage.

The tables listing the stomach contents of fry from M-cove present total calculated dry-weights for selected numerically important or large prey organisms as one indication of the relative amount of food each contributed. These values are given in Appendix III in milligrams (mg) and are obtained by multiplying the individual dry-weight value of the selected prey organism from Appendix I, by the total count N, which is the number of times the organism was taken by the fish in that group.

Electivity coefficients were calculated using Ivlev's (1961) formula:

$$E = (\%N - P\%N)/(\%N + P\%N).$$

The value %N is the percent contribution of prey organisms in the pooled stomach contents of a subsample, and P%N is the percent contribution of that prey organism in the surface zooplankton community at the time of fry capture. The coefficients are used to gain an understanding of prey selection by the pink and chum salmon fry. The coefficient E theoretically ranges from -1.0 to +1.0; positive values indicate the degree of selection, and negative values indicate the degree of avoidance or rejection. A coefficient equal to zero indicates prey organisms were taken in proportion to their abundance as observed by net catches of the zooplankton community.

An index of niche overlap was used to compare the similarity or difference between the diets of the pink and chum fry. The index is that devised by Morisita (1959) and modified by Horn (1966). Its formula is as follows:

$$C\lambda = \frac{2 \sum_{j=1}^{s} X_j Y_j}{\sum_{j=1}^{s} X^2_j + \sum_{j=1}^{s} Y^2_j}$$

where $C\lambda$ is the coefficient of overlap, S is the total number of food categories, X_j is that proportion of the total diet of species X taken from a given prey category j, and Y_j is that proportion of the total diet of species Y taken from a given prey category j. The coefficient $C\lambda$ varies from zero when there is no diet overlap (no food categories in common) to 1.0 when the diets are identical.

RESULTS

The Near Surface Zooplankton Community

Eighty-five zooplankton samples were collected at Stations 1, 4, and M-cove in 1977 and 1978 (Table 1). The majority of these were from horizontal tows taken at the surface where the young pink salmon fry appeared to be feeding. Fourteen were vertical tows taken in 1977, and seven were deep horizontal and nearshore samples collected in M-cove in 1978.

Zooplankton was patchy, and total abundance varied considerably within samples and between stations. A one-way analysis of variance performed on 37 pairs of replicate samples indicates total zooplankton abundance estimates routinely vary by as much as a factor of 2.0 as a result of patchiness, sampling error, and subsampling and counting error in the laboratory. Despite this, zooplankton concentration apparently changes with time at each station in a consistent way within and between years (Figures 4 and 5).

Following a bloom composed of large centric and smaller chain-forming diatoms (*Coscinodiscus* spp., *Thalassiosira* spp., *Chaetoceros* spp., *Stephanopyxis* spp.) and dinoflagellates (*Ceratium* spp.), which formed in early April, near surface concentrations of zooplankton increased. Populations peaked at 3.0 to 5.0×10^3 animals per m^{-3} during late April and early May. Thereafter, zooplankton concentrations fell consistently each year to a low which occurred around May 20. This low in abundance of zooplankton occurred in the waters adjacent to Port San Juan at the same time in 1976 (Cooney *et al.*, 1978). Zooplankton concentrations increased again to higher values during late May and June, presumably in association with a secondary bloom of primary producers.

The succession of organisms that dominated the near surface zooplankton community during April, May, and June near Port San Juan was similar in 1977 and 1978 (Tables 2 and 3). Barnacle nauplii and the copepods *Acartia longiremis*, *Oithona similis*, and *Pseudocalanus* spp. were abundant throughout the period and exhibited fluctuations that characterized the entire community. Large copepods in the genus *Calanus* (*Calanus plumchrus*, *C. marshallae*) appeared in abundance at the surface toward the end of April and disappeared again toward the end of May. Following the period of low zooplankton abundance, the cladoceran, *Evadne* spp.; the larvacean, *Oikopleura* spp.; and the dinoflagellate, *Noctiluca* spp. became numerically important at the surface. A summation of the concentrations of these numerically dominant species indicates that near surface zooplankters in the local estuary were generally more abundant in 1977 than they were the following years (Tables 2 and 3).

Between stations there were differences in the near surface zooplankton community (Table 4). In both 1977 and 1978 fewer taxa were in the surface waters of Sawmill Bay than occurred outside at Station 4 and M-cove. The calanoid copepods *Calanus* spp. and *Metridia* spp. were rare or absent inside Sawmill Bay and along with the epibenthic harpacticoid copepods appear to have been more abundant within M-cove than they were in the waters of Elrington Passage. Table 4 also suggests that the waters adjacent to Port San Juan possessed a greater diversity of zooplankters in 1977 than it did in 1978.

Table 1. The number and type of zooplankton samples collected at stations 1, 4, and M-cove in 1977 and 1978

1977

Station	Total Number	Replicates	Vertical tows	Surface tows	Other	Collected
1	12	6	7	5	0	April 27 - June 13
4	13	8	7	6	0	April 30 - June 13
M-cove	10	0	0	10	0	April 28 - June 28

1978

Station	Total Number	Replicates	Vertical tows	Surface tows	Other	Collected
1	15	10	0	15	0	April 8 - July 1
4	17	10	0	17	0	April 2 - July 1
M-cove	18	3	0	11	7	April 1 - June 23

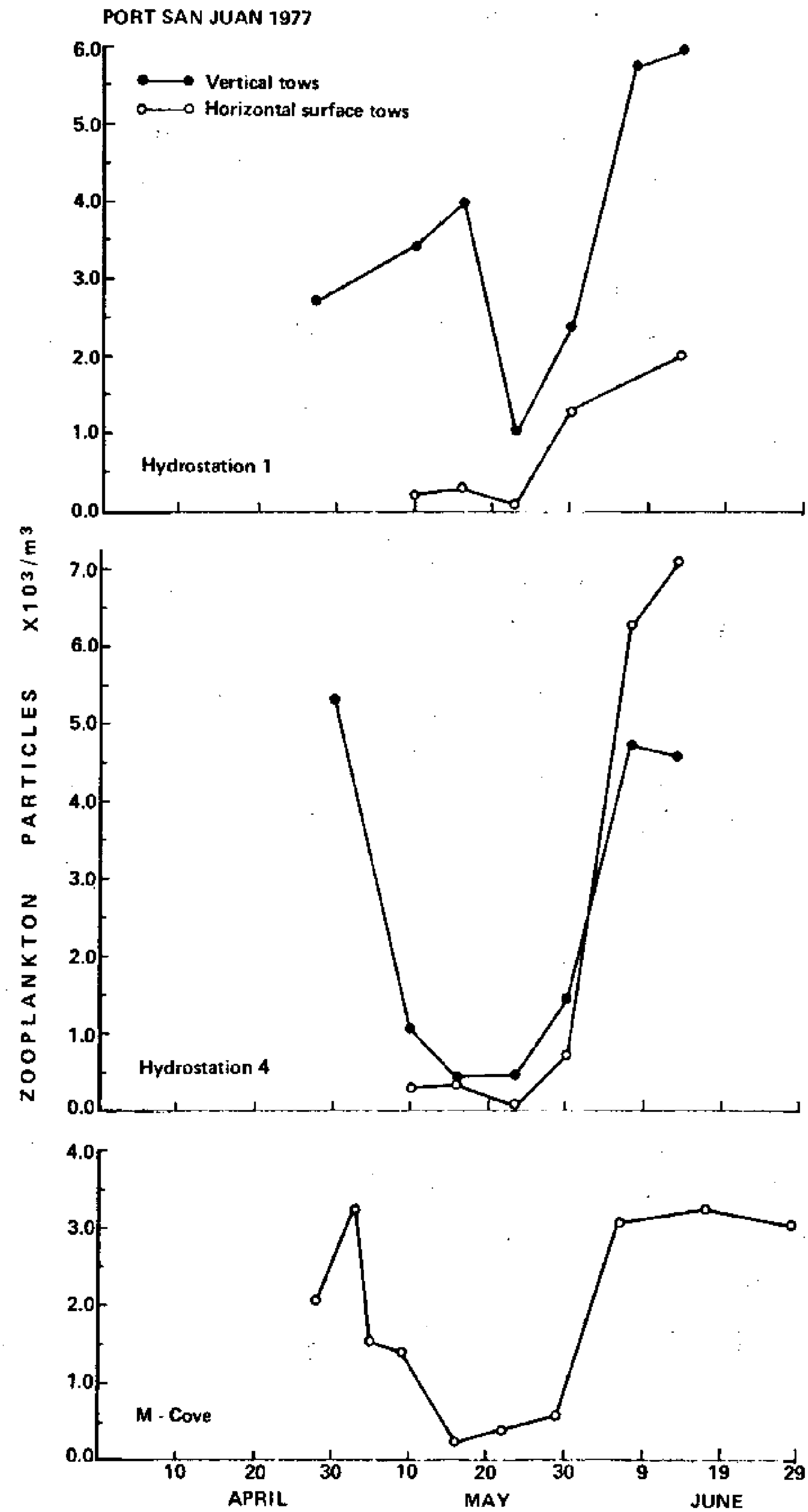


Figure 4. Zooplankton concentrations at three locations near Port San Juan, 1977.

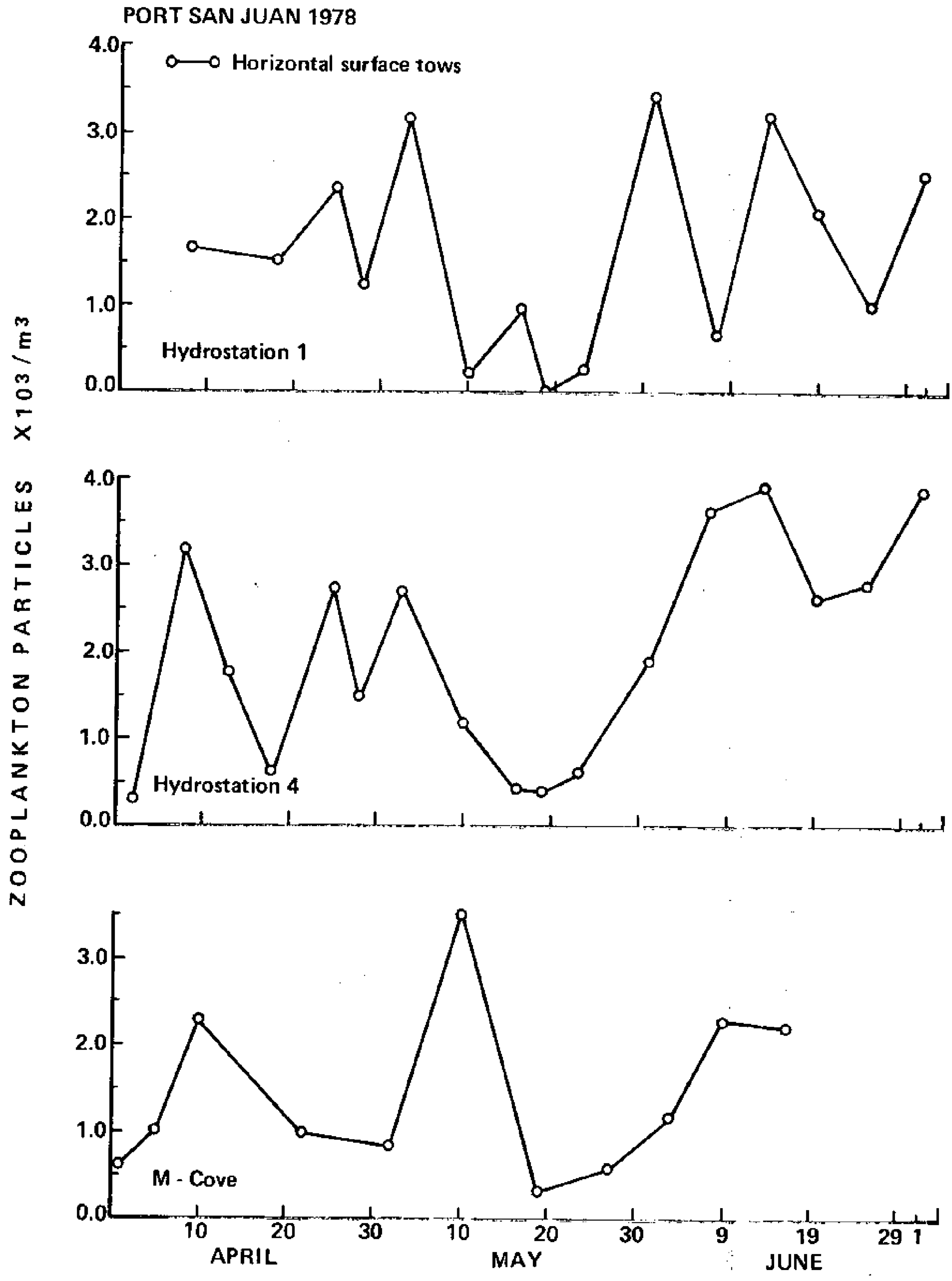


Figure 5. Zooplankton concentrations at three locations near Port San Juan, 1978.

Table 2. Abundance of selected zooplankters at stations 1, 4, and M-cove by week in 1977

	Individuals m^{-3}									
Taxon	4/22	4/29	5/6	5/13	5/20	5/27	6/3	6/10	6/17	6/24
Noctiluca spp.	0	0	3	0	1	0	60	1075	1041	2795
Evadne spp.	0	0	0	0	0	0	52	206	286	21
Acartia longiremis	128	90	252	292	100	218	191	697	124	0
Calanus spp.	52	8	26	7	1	2	0	0	0	0
Oithona similis	418	482	326	262	110	278	981	886	980	144
Pseudocalanus spp.	421	1727	348	117	68	221	374	462	124	3
Barnacle nauplii	117	29	58	29	16	122	360	261	244	3
Oikopleura spp.	158	152	14	14	1	101	1258	740	775	37
Total	1294	2488	1024	721	297	942	3276	4327	3574	3003

Table 3. Abundance of selected zooplankters at stations 1, 4, and M-cove by week in 1978

	Individuals m^{-3}						
Taxon	4/1	4/8	4/15	4/22	4/29	5/6	5/13
Noctiluca spp.	0	0	0	0	0	0	0
Evadne spp.	0	0	0	0	0	0	0
Acartia longiremis	30	14	91	166	398	349	78
Calanus spp.	0	0	0	3	81	600	6
Oithona similis	91	411	63	351	936	139	65
Pseudocalanus spp.	24	62	1	216	50	271	69
Barnacle nauplii	168	277	5	28	120	10	2
Oikopleura spp.	6	14	0	9	0	14	3
Total	319	778	160	773	1585	1383	223

Table 3. Continued

	Individuals m^{-3}						
Taxon	5/20	5/27	6/3	6/10	6/17	6/24	7/1
Noctiluca spp.	0	0	58	270	460	0	0
Evadne spp.	0	2	39	179	62	242	126
Acartia longiremis	35	565	890	232	138	239	136
Calanus spp.	1	1	0	0	0	0	0
Oithona similis	18	160	292	735	234	283	1031
Pseudocalanus spp.	19	331	19	12	27	69	103
Barnacle nauplii	5	55	90	483	130	27	152
Oikopleura spp.	5	66	319	299	911	343	452
Total	83	1180	1707	2210	1962	1203	2000

Table 4. The relative abundance of taxonomic groups in near surface zooplankton sampled at three stations near Port San Juan during April, May, and June of 1977 and 1978 (+: < $1/m^3$, *: $1\text{-}10/m^3$, **: $10\text{-}100/m^3$, ***: > $100/m^3$).

	Relative Abundance					
	1977			1978		
Taxonomic Group	1	4	M-cove	1	4	M-cove
Protozoa						
Phytomastigophorea						
Dinoflagellida						
Noctiluca spp.	*	***	***	**	**	**
Rhizopodea						
Foraminiferida						
(unidentified spp.)		+	+			
Cnidaria						
(medusae)	+	+	*	+	+	
Hydrozoa						
(hydromedusae)	*	+	*	*	*	+
Hydroidea						
Bougainvillia spp.		+				
Coryne princeps	+					
Obelia longissima	*	*				
Trachylina						
(Aeginidae narcomedusae)		+				
Phoronida						
(larvae)						+
Bryozoa						
(cyphonautes larvae)	**	**	**	**	**	**
Mollusca						
(egg cases)	+		*	*	+	*
Bivalvia						
(veligers)		+				
(juveniles)	**	*	*	*	**	*
Gastropoda						
(veligers)		+		+		
(juveniles)	**	*	**			**
Thecosomata						
(pteropods)			**	*	**	*
Clione limacina		+	*			
Limacina helicina		**	*	*	*	*
Nemotoda						
(unidentified spp.)				+	*	**

Table 4. Continued

Taxonomic Group	1977			1978		
	Relative Abundance					
	1	4	M-cove	1	4	M-cove
Annelida						
Polychaeta						
(trochophores)	+	*	*		+	*
(mitraria larvae)			+		+	+
(juveniles)	**	*	*	*	**	*
(unidentified spp.)	**	+	*	*	+	*
Arthropoda						
Arachnida						
Acarina						
(unidentified mites)	+	+	+	*	+	+
Crustacea						
Branchiopoda						
Diplostraca						
Evadne spp.	**	**	**	**	**	**
Podon spp.	*	*	*	+	*	+
Ostracoda						
(unidentified spp.)	+		*		+	
Mydocopa						
Conchoecia sp.		*				
Copepoda						
(nauplii)	**	**	**	***	***	***
Calanoida						
Acartia clausi	+	+		**	*	
A. longiremis	***	***	**	***	***	***
A. tumida	+		+	**	+	
Calanus cristatus		+				
C. marshallae		*	*	+		*
C. plumchrus		*	**	*	**	***
Centropages spp.	**	**	*	**	*	*
Epilabidocera amphitrites				+		
Eucalanus bungii bungii	+					
Eurytemora herdmani		*				
E. pacifica		*				
Heterorhabdus spp.						+
Metridia spp.		*	**	+	*	*
Microcalanus spp.	*	*	*	+	*	+
Pseudocalanus spp.	***	***	***	***	**	***
Tortanus discaudatus	+					
(unidentified copepodids)	***	***	**	***	***	***

Table 4. Continued

Taxonomic Group	1977: 1	1977: 4	1977: M-cove	1978: 1	1978: 4	1978: M-cove
Cyclopoida						
Oithona similis	***	***	***	***	***	***
O. spinirostris	*	*	+	*	**	**
Oncaea spp.	*	*	*	*	+	+
(unidentified spp.)			*	*	*	+
Harpacticoida						
Microsetella spp.		+				+
(unidentified spp.)	*	*	**	*	*	**
Cirripedia						
(nauplii)	***	**	**	***	***	***
(cyprids)	*	+	*	**	**	*
Malacostraca						
Leptostraca						
Nebalia spp.		+				
Amphipoda						
Parathemisto libellula	+	+				
(unidentified spp.)	*		*	+	+	+
Euphausiacea						
(eggs)	*		+			
(nauplii)	*	**	*	*	**	*
(calyptopis)	*		*	+	*	
(furcilia)	+	*	*	+	+	+
Thysanoessa spp.						+
Decapoda						
(Cancridae zoeae)		*				*
(Oregoniinae zoeae)			*			
(Oxyrhyncha zoeae)			*			
(Paguridae zoeae)	+					
(unidentified zoeae)	*		*	+	*	+
Isopoda						
(unidentified spp.)		+				+
Insecta						
(unidentified spp.)		+	+	+	+	
Chaetognatha						
(juveniles)		*	*			
(unidentified spp.)		+	*	+	*	*
Sagitta elegans	+	+	*		+	

Relative Abundance

Table 4. Continued

Taxonomic Group	1977: 1	1977: 4	1977: M-cove	1978: 1	1978: 4	1978: M-cove
Echinodermata						
(larvae)	*		*		*	
(plutei)			*	*	*	*
Stelleroidea						
(bipinnaria)				+	*	*
(brachiolaria)		+				
(ophioplutei)		*	+			*
Echinoidea						
(echinoplutei)	*	+	*	+		+
Chordata						
Larvacea						
Fritillaria spp.		**	**	*	*	**
Oikopleura spp.	***	***	***	***	***	**
Osteichthyes						
(fish eggs)	+	*	**	*		*
(fish larvae)		+	*		+	*
Gadiformes						
(gadid larvae)	+	*	**			
Unidentified						
(larvae)		*	+	+	*	*
(eggs)	*	***	**	**	**	**
Total of Taxonomic groups	48	61	60	49	50	55
Number of samples	12	13	10	13	15	11

Relative Abundance

Spatial Distribution of Harpacticoid Copepods

Seven samples of zooplankton were taken in M-cove in June of 1978 to examine the distribution of the epibenthic harpacticoid copepods used there as forage by the fry. Five of these samples were from horizontal tows taken either close to shore and the bottom, or at a depth 2 to 3 m below the surface across the middle of the cove. Two were samples taken with the bilge pump just above the sediment water interface (Table 5).

The pump was used at three other sites in June of 1978 to determine the abundance of harpacticoid copepods relative to vertical and horizontal distances from the bottom and nearshore substrates. The sites were Black Lagoon (BL), S-cove, and Sawmill Bay Island (IS) (Figure 3). They were selected because fry frequented these sites and because each shore presented a sheer rock face that dropped vertically into the estuary to a depth of 3 to 5 m (Tables 6, 7, and 8).

The four tables show epibenthic harpacticoid copepods were available to the fry in the water column, several meters from shore or the bottom. Moreover, the concentrations of these organisms in the nearshore region increased as the shore or as the bottom was approached.

Fry Migration, 1977

In 1977 hatchery released pink fry demonstrated three separate patterns of behavior before they grew too large to be effectively sampled with a beach seine. These three patterns were: (1) behavior observed in Sawmill Bay immediately following release of fry from the hatchery; (2) behavior observed in coves (nursery areas) formed by the islands and shoreline at the north end of Elrington Passage; and (3) behavior adopted suddenly in June after the fry abandoned these nursery areas and moved offshore.

Hatchery fry released from incubation boxes or saltwater holding pens quickly formed schools and moved across Sawmill Bay a few centimeters below the surface. Fish released in the morning often appeared to orient into the sun and within a few hours would gain the east shore of south Sawmill Bay. Thereafter, the fry were observed moving along a few meters from the shore. Within 24 hours from the time of release, most fry would leave the bay. On days when the hatchery held all fry in pens, few from previous releases were found in Sawmill Bay. During June occasional schools of smolt size pink salmon were seen offshore inside Sawmill Bay. Otherwise, the only pink salmon fry captured at various sampling stations inside Sawmill Bay (Figure 3) were recent releases (indicated by their size, between 30 and 34 mm in fork-length) with few, or more frequently no, prey items in their stomachs.

In late April 1977, the search for pink fry was extended to the waters of Elrington Passage outside Sawmill Bay, and millions of pinks were observed. The fish were found in discrete schools in shallow coves or protected areas among the Bettles Island group and along the shore of the Passage. The schools varied in size, sometimes including what appeared to be more than several hundred thousand fishes within an area less than 25 m across.

Table 5. The number of epibenthic harpacticoid copepods per m^3 in seven zooplankton and two epibenthic pump samples taken from M-cove in June 1978[1]

Sample	Depth (m)	Harpacticoids (No./m^3)	Date
surf.	0–0.5	23	6/9
deep horiz.	2.0–3.0	264	6/9
otb.	0–0.5	287	6/9
pump #1	0.5	367	6/9
pump #2	0.5	1,627	6/9
surf.	0–0.5	11	6/16
deep horiz.	2.0–3.0	1,866	6/16
otb.	0–0.5	753	6/16
deep horiz.	0.5–1.0	11	6/23

[1] The zooplankton samples were either surface, deep horizontal, or near-shore "off-the-bow" (otb) tows. The epibenthic pump samples were taken in the intertidal zone.

Table 6. Pump samples showing the number of harpacticoid copepods per m^3 in the Black Lagoon with vertical and horizontal distance from the surface and shore, June 15, 1978

No./m^3

Distance from shore, m

		0.0	0.5	1.0	2.0	3.0	4.0	5.0	6.0
distance from surface, m	0.5	---	2199	131	53	131	157	---	---
	1.0	---	---	---	---	---	---	53	---
	2.0	---	---	---	---	---	---	79	---
	3.0	---	---	---	---	---	---	288	---
	4.0	---	---	---	---	---	---	3665	---
water depth, m		1.0	---	---	2.0	---	---	4.5	

Table 7. Pump samples showing the number of harpacticoid copepods per m^3 in S-cove with vertical and horizontal distance from the surface and shore, June 20, 1978

		No./m^3							
		Distance from shore, m							
		0.0	1.0	2.0	3.0	4.0	5.0	...	30.0
distance from surface, m	0.0	---	---	---	---	---	---		---
	0.3	---	---	814	367	656	184		0
	1.0	---	---	---	---	---	---		---
water depth, m		0.0	---	---	---	---	3.0	...	10.0

Table 8. Pump samples showing the number of harpacticoid copepods per m^3 at Sawmill Bay Island with vertical and horizontal distance from the surface and shore, June 21, 1978

		No./m^3								
		Distance from shore, m								
		0.0	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0
distance from surface, m	0.5	---	103	---	---	---	---	---	---	---
	1.0	---	---	---	34	---	17	---	0	---
	2.0	---	---	---	120	---	0	---	17	---
	3.0	---	---	---	1359	---	86	---	0	---
water depth, m		3.0	---	---	---	---	---	---	4.0	

Some of these large schools of fry persisted in time in the same cove for up to six weeks. Other coves would contain fry for a few days, be left vacant, and then later fill again with fish. The coves were designated as nursery areas because of their apparent importance to the young salmon. Nine coves, some of which are shown in Figure 3, were visited every few days. Table 9 lists the periods during which pink fry schools appeared to continuously occupy each monitored cove. M-cove was selected as a fry and zooplankton sampling station because of the large number of fry it consistently supported.

In early April of 1977 the fry in the nursery areas were small and formed tight, swirling, circular schools at the surface. Dip nets could be used to capture them. Later, as the fish in these coves grew larger, the schools they formed grew more diffuse, covered a larger area, and the beach seine was needed to collect samples. When the fry did depart from the nursery coves, it was sudden and *en masse*. At most coves the departure behavior occurred in the month of June. Apparently, once the pink fry reached 50 to 70 mm in fork-length, the shallow nearshore zones of the Bettles Island group and Elrington Passage no longer satisfied their needs.

After the fry left the nursery areas in 1977, they could be seen throughout Elrington Passage and Sawmill Bay over deep water, moving in schools at the surface. Fry were frequently seen holding position in strong currents just beyond rocky promontories and the rocks and reefs that helped form the protected nursery coves. At this third stage in their behavior, the young salmon were often seen jumping clear of the water. By the end of June many of the pinks exceeded 100 mm in length and usually were so far offshore that direct sampling was discontinued. The relative numbers of pink salmon fry in Elrington Passage and the waters south of Evans Island, compared to Latouche and Prince of Wales Passage during the spring of 1977, gave the distinct impression the hatchery fry were using Elrington Passage to reach the open ocean (Figure 6).

Fry Migration, 1978

The coves designated as nursery areas in 1977 were again important fry habitat the following year; samples of fry were frequently taken from them. However, in 1978, pink fry outside Sawmill Bay spent much of their time elsewhere. Early outmigrants were held by the hatchery in saltwater pens, and none were released until March 30. As mentioned previously, the peak in outmigration in 1978 came early (Figure 2), and by the end of April nearly 17 million pink salmon had been observed swimming out at the surface of Sawmill Bay just as they had the year before.

However, once the 1978 pink fry left Sawmill Bay, few were seen again until early May. The previous year, large schools of pink fry were not observed in Elrington Passage until the end of April when the field team began routine daily surveys outside Sawmill Bay. Yet, even though millions of fry left the hatchery in April of 1978, only occasional groups of a few thousand could be found anywhere that month in the waters around Bettles Island or in Elrington Passage. Early in May of 1978 some larger groups

Table 9. Fry nursery areas monitored in 1977 and the periods during which they appeared to be continuously occupied by pink fry (see Figure 3)

Nursery Area	Distance from PSJ (km)	Occupied continuously from - to	Total days
L	3.7	4/28 - 5/6	9
M	3.2	4/28 - 6/10	44
O	3.4	4/27 - 6/9	44
P	2.5	5/5 - 6/5	32
Q	5.3	5/7 - 5/19	13
R	5.5	5/7 - 6/6	31
S	4.4	5/11 - 6/24	45
V	12.6	5/13 - 6/14	33
W	17.0	5/13 - 6/28	47

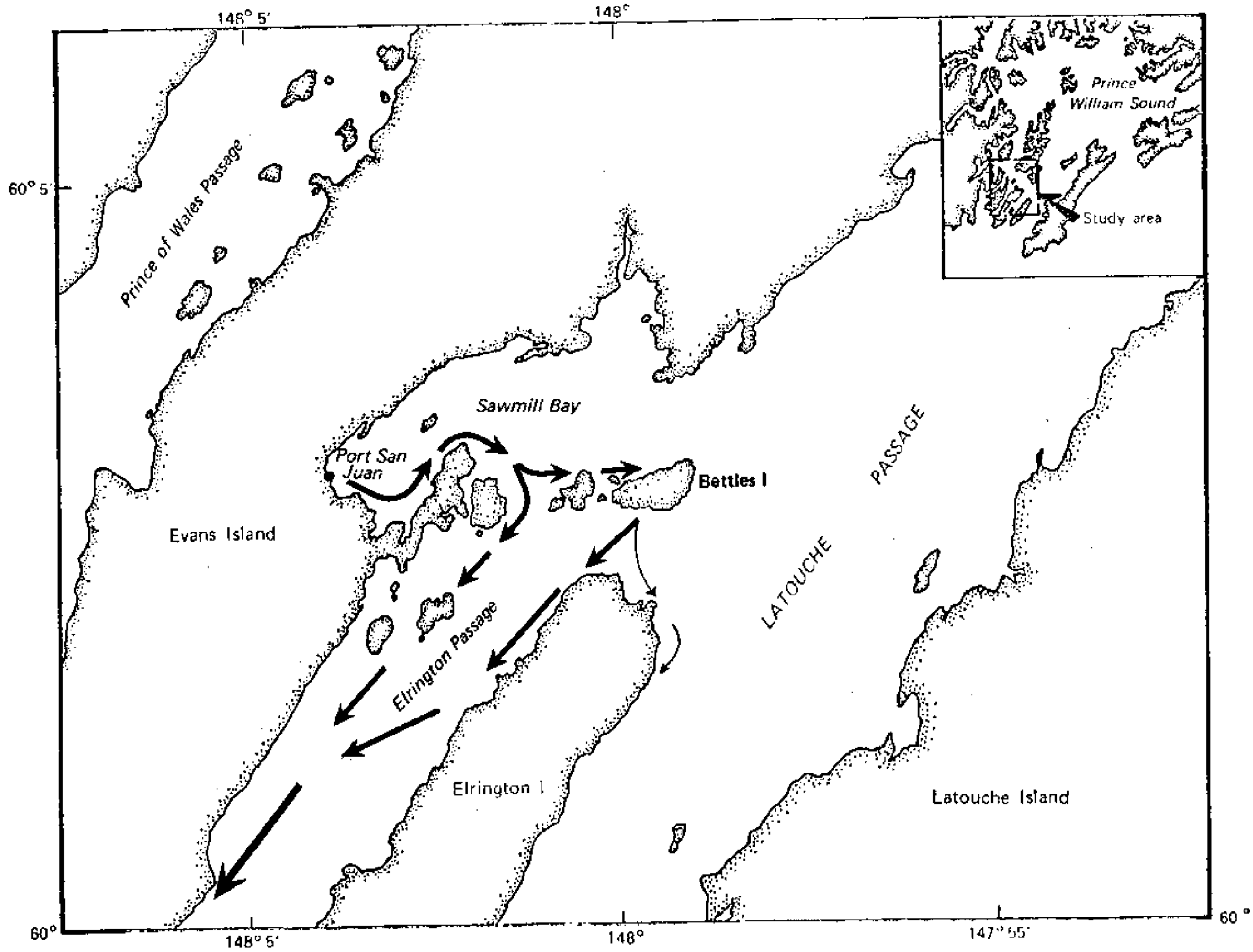


Figure 6. Major migration paths for pink salmon fry leaving the Port San Juan hatchery in 1977 and 1978.

of fry were seen, often within coves previously designated as nursery areas. Yet, these fish did not establish the resident behavior patterns observed the year before.

Migration paths in 1978 appeared in general to be the same as those described for 1977 (Figure 6). This statement is based on the frequency with which concentrations of fry were observed within a 10 to 15 km radius of the hatchery. Even during April and early May, pink fry were seen most frequently near Bettles Island and in Elrington Passage. In the latter half of May and during June, surveys of these areas revealed the presence of millions of fry, while few were observed in adjacent Latouche Passage or Prince of Wales Passage.

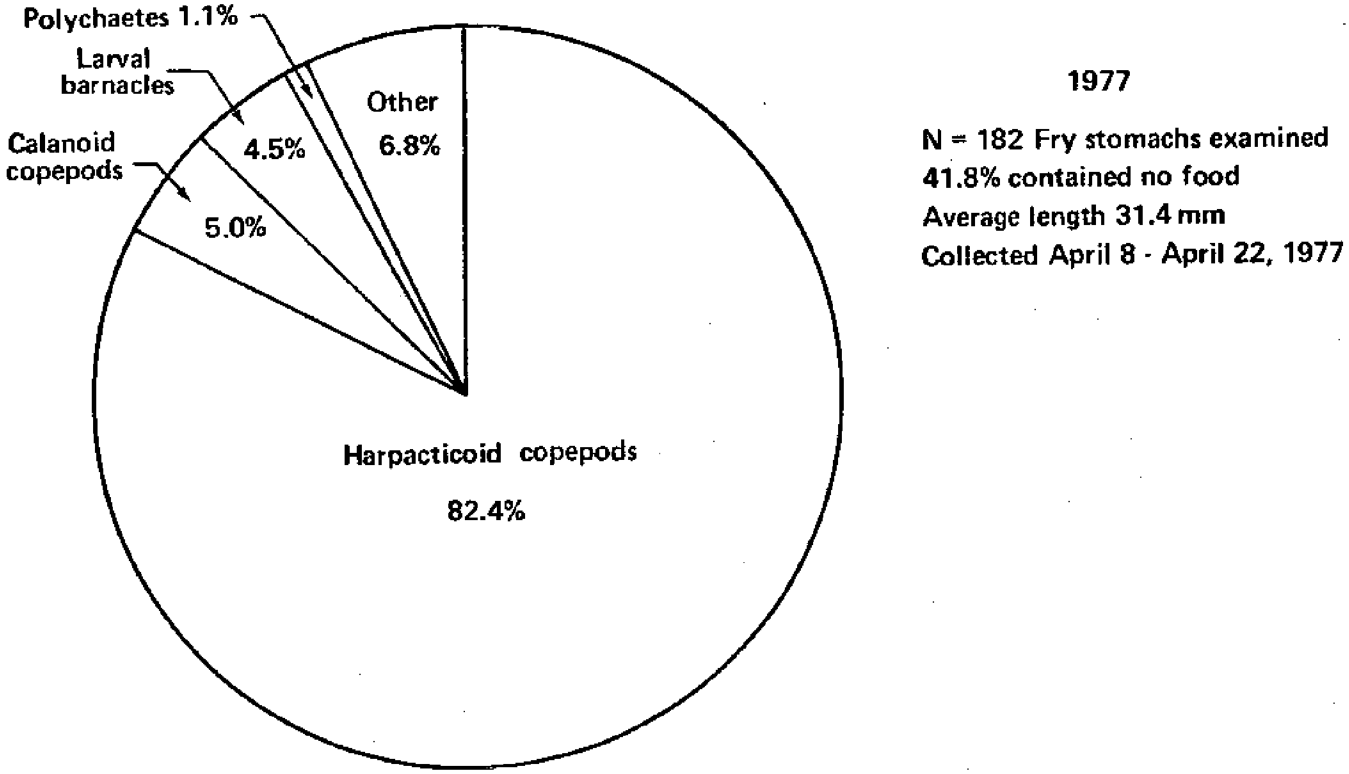
Frequent checks were made of the nine coves designated as nursery areas in 1977. Though these coves were empty in April, during May and June they were the places where large numbers of pink salmon fry concentrated. Schools of pink fry containing several hundred thousand fry would appear within one of these areas, spend a few days, and then swim away. M-cove was again a favored location, and samples of fry and zooplankton were collected to compare with those taken there the year before.

Because the pink fry schools did not establish residency in any coves in 1978, no obvious post nursery area behavior was observed. However, toward the end of June, the movements and apparent abundance of fry in the waters adjacent to Evans Island mimicked what had been observed the year before. Fry schools occurred well offshore with individuals jumping at the surface and holding position in the tidal currents.

Fry Feeding in Sawmill Bay

Most pink salmon fry released from the Port San Juan hatchery consumed their first natural food items while migrating through Sawmill Bay. In 1977 nearly all fry were released as soon as they left the hatching incubation boxes. In 1978 the hatchery fed the fry before it released them. Thus, many of the fish captured in Sawmill Bay the second year of the study were advanced in the development of their digestive system and also in terms of the number of prey items they contained. In all, the stomach contents of 267 pink fry were examined (Appendix II) from 18 different samples collected in Sawmill Bay (Appendix IV).

Epibenthic harpacticoid copepods were the numerically and volumetrically dominant prey organism found in pink fry captured inside Sawmill Bay (Figure 7). *Harpacticus uniremis* was identified as the most frequently ingested harpacticoid copepod. The number of other species and taxa comprising the pink fry diet in Sawmill Bay was limited. Small calanoid copepods (*Acartia* spp., *Pseudocalanus* spp.), and barnacle and copepod nauplii also contributed as prey. Many fishes contained no prey organisms, especially in 1977 when fry were released immediately from the hatchery and still possessed large reserves of yolk. For this reason and because they had not been artificially fed, most fry in Sawmill Bay in 1977 contained fewer than 10 items per stomach (Table 1 in Appendix II). The number of prey items per stomach in 1978 was higher as was the length of the list of taxonomic groups contributing to the diet (Table 2 in Appendix II).



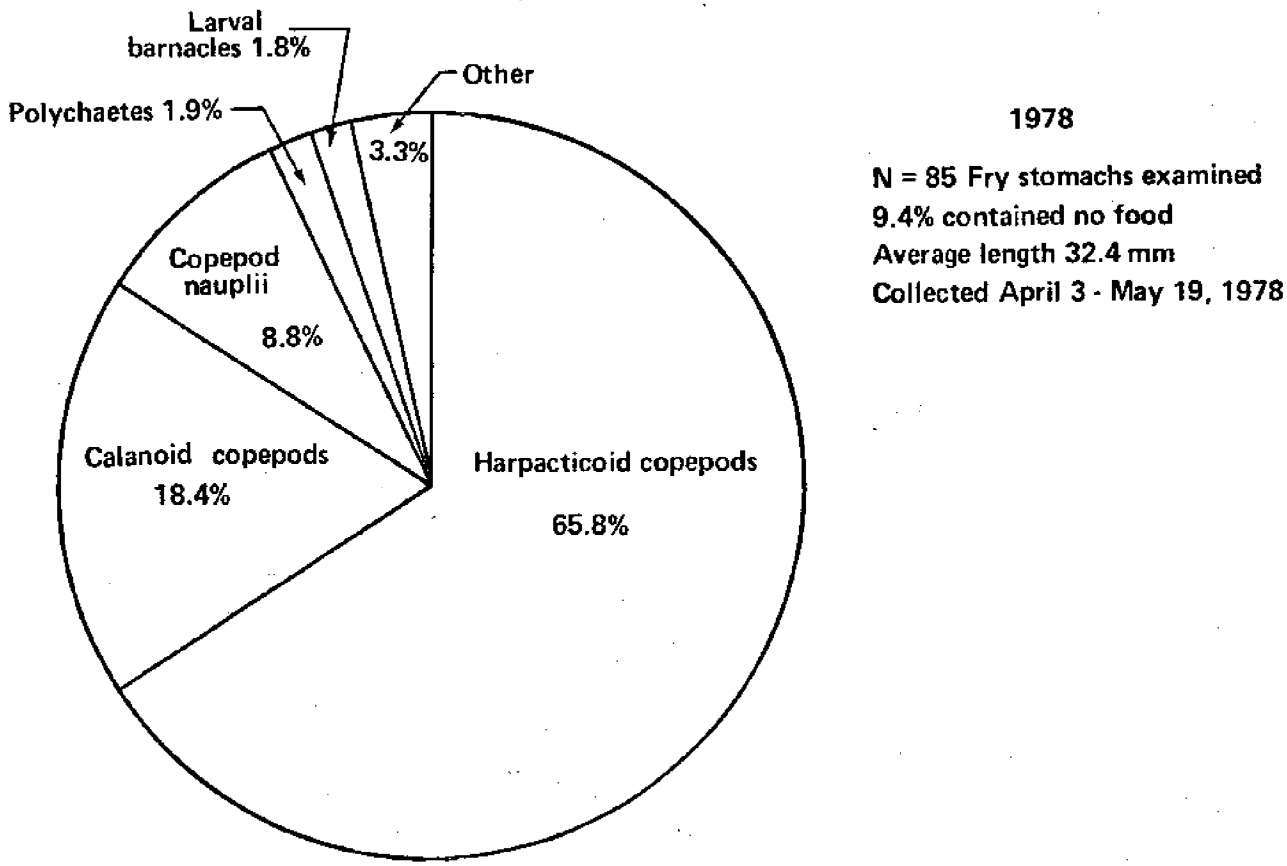


Figure 7. The percentage of prey organisms first taken by pink salmon fry migrating from the Port San Juan hatchery at Evans Island, Alaska.

Fry Feeding in M-cove

When the salmon fry left Sawmill Bay, they moved into slightly deeper water where they were exposed to strong tidal currents. Sixteen samples of fry taken from M-cove in 1977 and 1978 (Appendix V) show this change in habitat preference was associated with a change in diet (Appendix III). The stomach contents of 194 fry from these samples were examined.

Pink fry fed primarily on calanoid copepods while in M-cove with *Pseudocalanus* spp. most frequently dominating the diet (Figure 8). *Calanus cristatus, C. marshallae, C. plumchrus, Metridia lucens,* and *M. okhotensis* also contributed substantially to the nutrition of the fry.

M-cove also supplied the growing fry with *Harpacticus uniremis* and other epibenthic harpacticoid copepods. These organisms, though always a component of the diet, were usually of secondary importance. However, in late May and June of 1978, harpacticoids did numerically dominate the diet of M-cove fry (Table 2 in Appendix III). However, because harpacticoids are small, the copepods *Calanus* and *Metridia* remained more important in terms of biomass contribution (Appendix I and III).

As the season progressed and the fry in M-cove increased in size, the number of taxa comprising their diet also increased (Appendix III). The first fry collected both years failed to capture most large prey organisms. Later, when the fry were bigger, larger items were eaten. Yet, many smaller organisms continued to be taken by the larger fry, thereby accounting for the increase in prey diversity with increases in the size of the fish. There was no apparent correlation between the number of prey items in the stomachs of the fry and fry fork-length ($r = -0.20$; $df = 41$; $\alpha = 0.01$).

Ivlev electivity indices given in the tables in Appendix III, relating the abundance of near surface zooplankton to their abundance in the stomachs of pink fry collected at the same time, show the fry to have been selective. The fry avoided or failed to see the consistently abundant, small, and transparent copepods *Oithona similis* and *Acartia longiremis* (Table 6). These copepods were eaten when they carried egg sacs, apparently making them more visible to the fry.

Pseudocalanus seems to have been taken more nearly in proportion to its abundance. Larger, more visible calanoids like *Calanus* and *Metridia* were actively sought. The negative coefficient (Table 10) indicating M-cove fry partially avoided *Calanus* around May 10 of both years is most certainly an artifact of the index calculation. *Calanus plumchrus* was so abundant at that time in May it covered the surface in places. Late in the season of both years, M-cove fry fed heavily on *Metridia*, though none were to be found in any of the near surface plankton tows. Also, it was not clear where the fry were obtaining *Exogone* spp., a polychaete. These small worms appeared to be taken along with the harpacticoid copepods, thus making a significant contribution to the diet late in the 1978 season (Table 2 in Appendix III). Figures 9 and 10 depict the relative concentrations of some of these prey organisms as they change with time in both the surface waters of M-cove and in the stomachs of the eight groups of fry collected there each year.

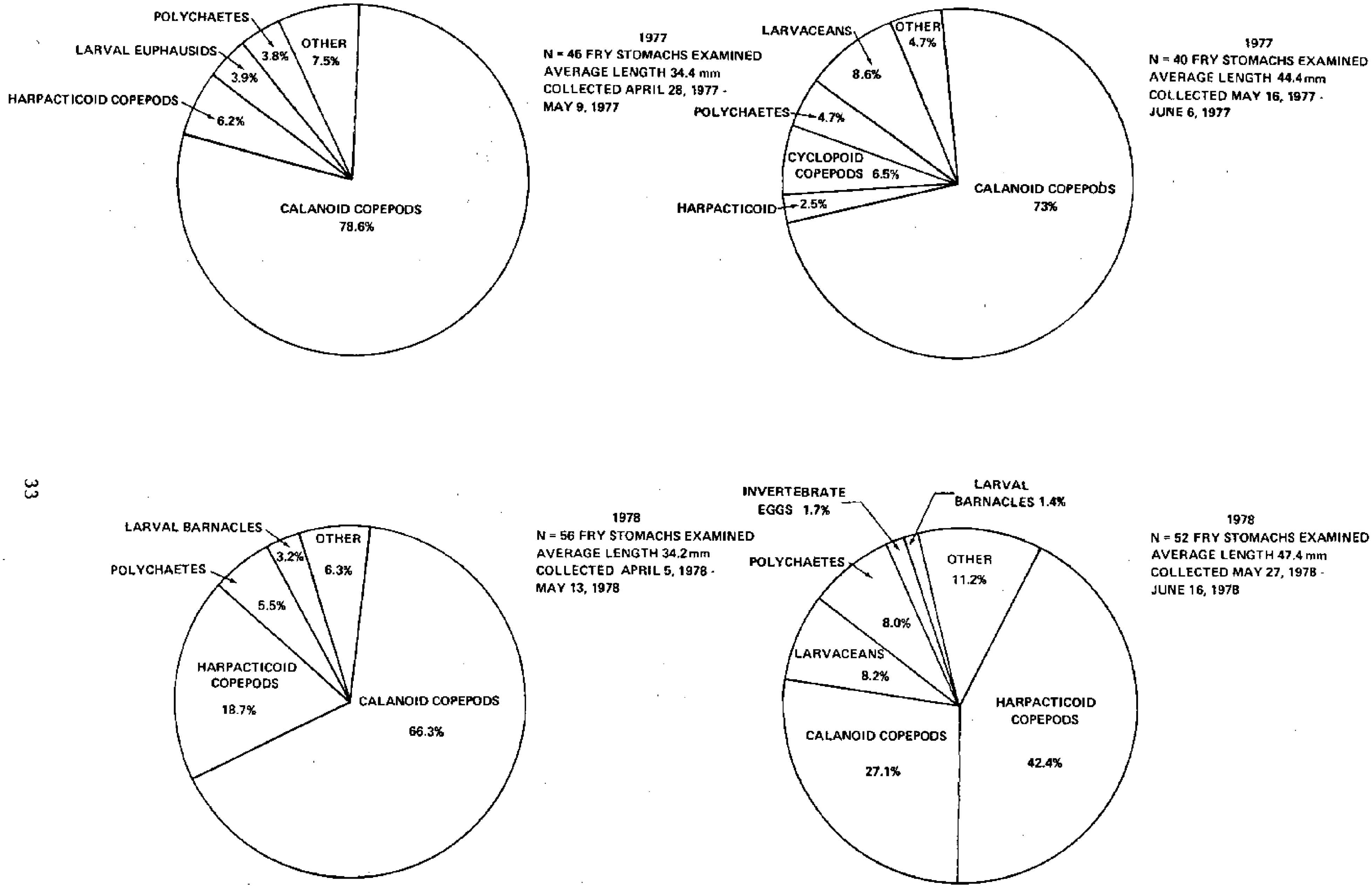


Figure 8. The percentage of prey organisms taken by M-cove pink salmon fry in April and early May, and during late May and June of 1977 and 1978.

Table 10. Ivlev electivity coefficients relating the stomach contents of M-cove pink fry to the near surface abundance of five copepods (from Appendix E). Size ranges are for Stage III copepodids to adults, in millimeters

1977

Date	Average fry fork-length, mm	*Oithona similis* 0.4-0.9 mm	*Acartia longiremis* 0.6-1.5 mm	*Pseudocalanus* spp. 0.7-1.7 mm	*Metridia* spp. 1.0-4.4 mm	*Calanus* spp. 1.8-8.7 mm
4/28	33.0	- .86	-1.00	+ .43	+ .08	- .15
5/3	34.6	- .83	-1.00	- .19	+ .54	+ .85
5/5	34.7	-1.00	-1.00	- .15	- .57	+1.00
5/9	36.1	- .82	- .96	+ .30	+ .81	- .43
5/16	37.4	- .97	-1.00	+ .91	+1.00	+ .33
5/22	41.5	- .92	-1.00	+ .01	+1.00	+ .70
5/29	42.5	- .31	-1.00	+ .56	+ .88	+ .79
6/6	56.2	- .98	-1.00	+ .63	+1.00	+1.00

1978

4/5	31.1	-1.00	-1.00	+ .93	+1.00	-1.00
5/2	33.7	-1.00	-1.00	+ .67	-0.00	+ .98
5/10	36.8	-1.00	-1.00	+ .28	+ .96	- .41
5/27	42.0	-1.00	- .94	- .03	- .14	+ .79
6/3	45.8	- .92	- .89	+ .96	+1.00	+1.00
6/9	50.3	-1.00	-1.00	- .60	+1.00	+1.00
6/16	51.4	- .92	- .95	+ .75	+1.00	+1.00

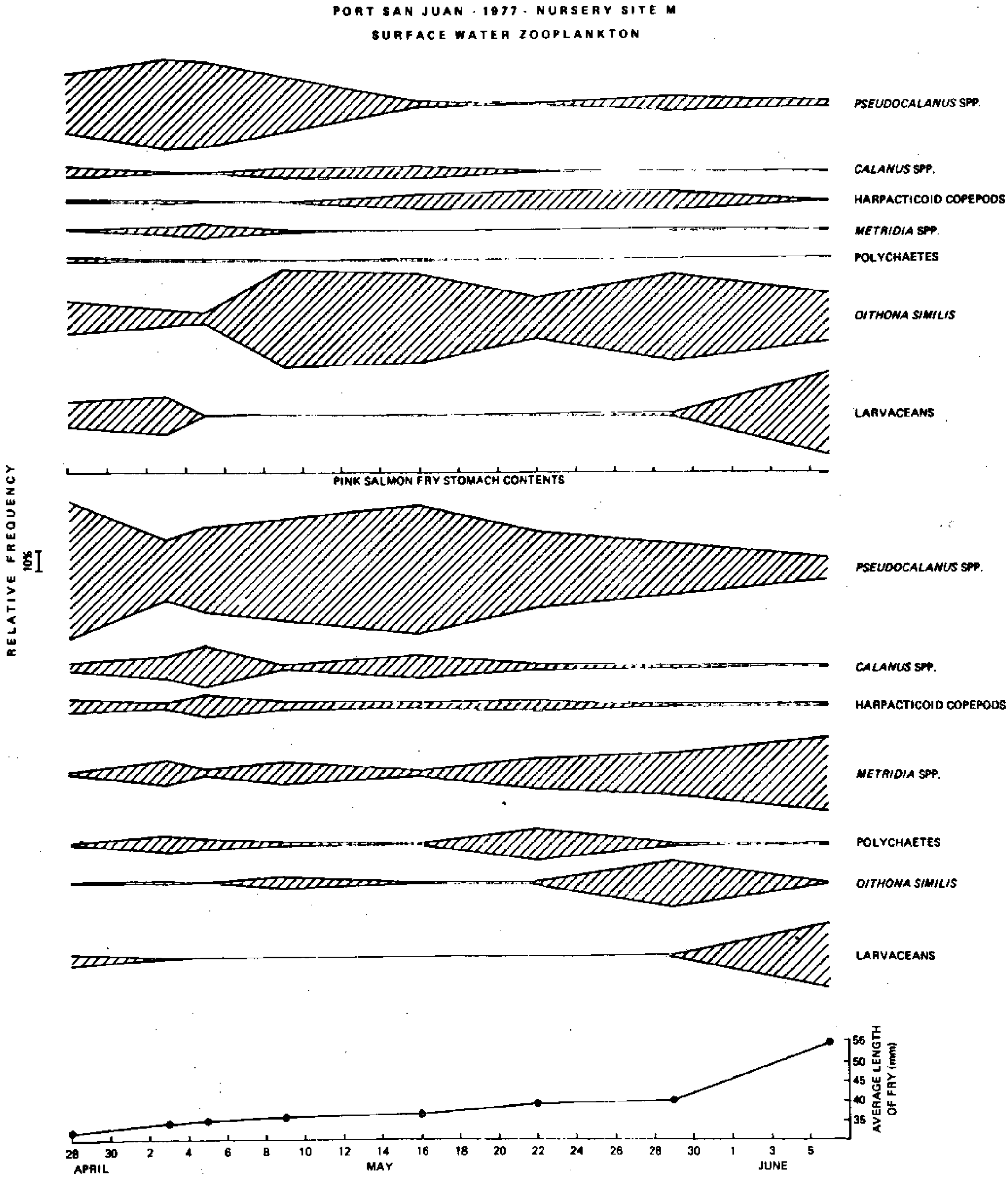


Figure 9. The relative abundance of zooplankton in the near surface waters of M-cove and in the stomachs of pink fry collected there during the spring of 1977. Vertical distance presents the relative frequency of the occurrence.

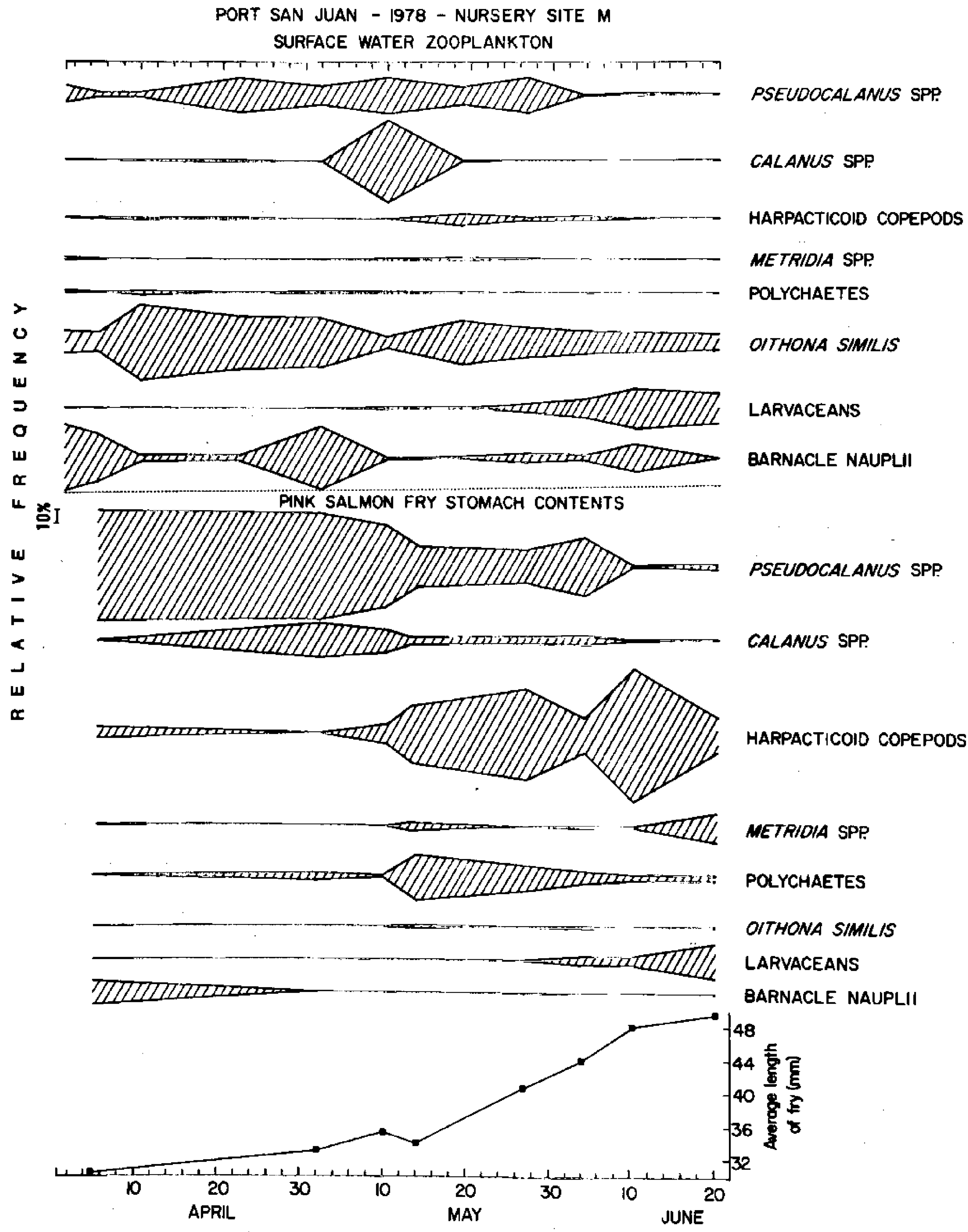


Figure 10. The relative abundance of zooplankton in the near surface waters of M-cove and in the stomachs of pink salmon fry taken there during the spring of 1978. Vertical distance presents the relative frequency of occurrence.

Pink and Chum Fry Feeding Interactions

From May 1 to June 27, 1978, a total of 16 samples of salmon fry were collected in the four study sites. Of these, 12 were selected for analysis (Appendix VI, Table 1). Since overall differences or similarities in the diets of the two salmon species were to be examined, the results of fry stomach analyses for some of the sample sites were combined. The result was a series of eight samples, one for each of the eight weeks the study was in progress. Collections of fry from different sites taken on the same date were treated as one sample in the stomach analysis summaries. Sampling was discontinued after June 27 because neither species of salmon fry were available in the nearshore area.

Forty-six taxa of prey organisms were identified from the stomachs of 140 chum fry (Table 11). Over the eight-week sampling period, larvacea were the numerically dominant prey taxa (Table 12). Following larvacea in order of numerical importance were harpacticoid copepods, insects, and cladocera.

The diet of chum fry was dominated by insects and harpacticoid copepods for the first three weeks of sampling (Table 13). Harpacticoids continued to be a major prey item in all but the eighth week. Larvacea first appeared in the diet during the fifth week and numerically accounted for more than 65 percent of the diet in weeks seven and eight. Cumaceans were a major contributor to the diet during the fourth week and declined in number in the following weeks. Calanoid and cyclopoid copepods, cirripedia juveniles, amphipods, polychaetes, and copepod nauplii, though present, made only minor contributions to the diet at any one time. Cladocera and cyphonautes larvae were important in the eighth and fifth weeks respectively.

Thirty-eight taxa of prey organisms were identified from 140 pink salmon fry stomachs (Table 11). For the eight-week sampling period as a whole, copepod nauplii were the numerically dominant prey taxa (Table 12). Other dominant prey, in order of importance, were harpacticoid copepods, calanoid copepods, and larvacea.

Harpacticoid copepods were numerically important prey for pink fry in all but the eighth week (Table 14). Calanoid copepods contributed substantially to the diet, also becoming less important in the eighth week. Larvacea were important during weeks six through eight. Copepod nauplii and cladocera were major prey only in the eighth week. Cyclopoid copepods, cirripedia juveniles, insects, amphipods, polychaetes, and cumaceans were present in the diet in low numbers during the eight weeks of sampling.

Diet Overlap

Ivlev electivity coefficients (Table 15) indicate that both species of fry feed selectively. Most of the prey taxa were consistently selected or avoided, but the degree of selection or avoidance differed slightly for the two salmon species. The most striking difference is seen within the calanoid copepod taxa. Chum fry consistently avoided calanoid copepods, while pink fry selected these copepods in six of the eight sampling periods. Larvaceas were selected more strongly by chum fry than pink fry in the last

Table 11. The percent frequency of occurrence of prey taxonomic groups in the stomachs of 140 chum and 140 pink fry

Taxonomic Group	Percent Frequency of Occurrence	
	Chum	Pink
Cnidaria		
Scyphozoa		
(larvae)	1	--
Bryozoa		
(Cyphonautes larvae)	3	1
Mollusca		
Bivalvia		
(juveniles)	2	--
Gastropoda		
(egg cases)	6	4
Thecostomata		
(pteropods)	11	3
Nematoda		
(Unidentified spp.)	2	1
Annelida		
Polychaeta		
(trochophore)	4	1
(juveniles)	14	8
(Unidentified spp.)	1	--
Arthropoda		
Arachnida		
Acarina	6	4
Araneae	1	--
Pseudoscorpiones	1	--
Crustacea		
Branchiopoda		
Diplostraca		
Evadne spp.	13	13
Podon spp.	1	1
Ostracoda		
Conchoecia spp.	2	4
(Unidentified spp.)	2	--
Copepoda		
(nauplii)	9	11

Table 11. Continued

Taxonomic Group	Percent Frequency of Occurrence	
	Chum	Pink
Calanoida		
Acartia spp.	2	4
Calanus spp.	14	40
Epilabidocera spp.	--	1
Eurytemora spp.	1	--
Metridia spp.	3	13
Pseudocalanus spp.	16	61
(Unidentified copepodids)	1	8
Cyclopoida		
Oithona spp.	6	7
Harpacticoida		
(Unidentified spp.)	74	77
Cirripedia		
(nauplii)	6	10
(cyprids)	27	26
Malocostraca		
Amphipoda		
Gammaridea	21	14
Hyperiida	8	11
Cumacea		
(Unidentified spp.)	14	6
Decapoda		
(crab zoea)	6	1
Euphausiacea		
(nauplii)	4	6
(calyptopis)	1	1
(furcillia)	6	16
(Unidentified spp.)	--	1
Isopoda		
(Unidentified spp.)	2	1
Insecta		
Coleoptera		
(Unidentifed spp.)	1	1
Diptera		
(larvae)	13	6
(Unidentified spp.)	67	18
Hemiptera		
(Unidentified spp.)	1	--
Trichoptera		
(larvae)	4	--

Table 11. Continued

Taxonomic Group	Percent Frequency of Occurrence	
	Chum	Pink
Chaetognatha		
(Unidentified spp.)	2	7
Echinodermata		
(plutei)	1	--
Chordata		
Larvacea	28	29
Osteichthyes		
fish (eggs)	7	4
fish (larvae)	4	9
Unidentified (eggs)	5	6

Table 12. Abundance of prey taxa in the stomachs of 140 chum fry and 140 pink fry collected between 1 May and 27 June 1978 (a + indicates a value less than 0.1)

	CHUM FRY			PINK FRY		
Prey Taxa	N	%N	%FO	N	%N	%FO
CALANOID COPEPODS	121	1.0	30	1838	19.7	74
CYCLOPOID COPEPODS	209	1.8	6	389	4.2	7
HARPACTICOID COPEPODS	3212	27.4	74	2091	22.4	76
CIRRIPEDIA JUVENILES	109	0.9	26	196	2.1	32
LARVACEA	5247	44.8	28	1311	14.0	29
COPEPOD NAUPLII	347	3.0	9	2483	26.5	11
INSECTS	894	7.6	71	56	0.6	22
AMPHIPODS	76	0.7	26	67	0.7	25
POLYCHAETES	93	0.8	17	35	0.4	10
CUMACEA	260	2.2	14	43	0.4	6
CLADOCERA	636	5.4	13	492	5.3	13
CYPHONAUTES LARVAE	210	1.8	3	1	+	1
OTHER	304	2.6	39	394	3.7	41
TOTAL	11718			9351		

Table 13. The percent number and percent frequency of occurrence (in parentheses) of prey taxa in chum fry stomachs for each weekly sample

	SAMPLE PERIOD (date)							
Prey Taxa	1 5/1	2 5/11	3 5/19	4 5/27	5 6/4	6 6/11	7 6/20	8 6/27
CALANOID COPEPODS	0.7 (20)	4.1 (50)	2.6 (40)	0.8 (20)	0.6 (15)	0.1 (10)	1.9 (50)	0.1 (30)
CYCLOPOID COPEPODS	--	--	--	--	--	--	--	5.5 (80)
HARPACTICOID COPEPODS	74.6 (85)	41.0 (60)	81.3 (90)	37.3 (80)	35.3 (85)	58.5 (80)	17.3 (60)	0.4 (40)
CIRRIPEDIA JUVENILES	0.8 (20)	1.5 (15)	1.1 (20)	1.2 (20)	5.5 (45)	1.1 (25)	0.6 (25)	0.2 (50)
LARVACEA	--	--	--	--	6.5 (25)	24.9 (55)	65.7 (65)	67.6 (100)
COPEPOD NAUPLII	--	--	--	--	0.5 (10)	--	0.1 (5)	9.0 (100)
INSECTS	21.6 (80)	52.2 (80)	10.8 (55)	26.3 (100)	6.3 (70)	7.1 (80)	5.4 (75)	0.1 (20)
AMPHIPODS	1.8 (35)	--	0.2 (5)	2.4 (30)	0.8 (10)	1.1 (50)	0.8 (65)	0.1 (10)

Table 13. Continued

	SAMPLE PERIOD (date)							
Prey Taxa	1 5/1	2 5/11	3 5/19	4 5/27	5 6/4	6 6/11	7 6/20	8 6/27
POLYCHAETES	0.5 (10)	1.2 (5)	3.7 (15)	--	0.1 (5)	1.2 (15)	0.9 (50)	0.2 (40)
CUMACEA	--	--	--	31.2 (40)	12.3 (25)	2.3 (30)	1.5 (20)	--
CLADOCERA	--	--	--	--	--	0.3 (15)	0.4 (25)	16.1 (100)
CYPHONAUTES LARVAE	--	--	--	--	27.4 (20)	--	--	--
TOTAL %	100.0	100.0	99.7	99.2	95.3	96.6	94.6	99.3

Table 14. The percent number and percent frequency (in parentheses) of prey taxa in pink fry stomachs for each weekly sample

Prey Taxa	SAMPLE PERIOD (date) 1 5/1	2 5/11	3 5/19	4 5/27	5 6/4	6 6/11	7 6/20	8 6/27
CALANOID COPEPODS	11.0 (65)	13.1 (55)	60.1 (90)	23.1 (80)	54.3 (90)	18.2 (60)	37.9 (80)	1.4 (70)
CYCLOPOID COPEPODS	--	--	--	--	0.2 (5)	--	0.1 (5)	8.5 (80)
HARPACTICOID COPEPODS	87.3 (80)	69.8 (65)	28.1 (95)	58.4 (90)	32.3 (75)	37.6 (75)	38.5 (80)	0.2 (40)
CIRRIPEDIA JUVENILES	0.2 (5)	1.0 (10)	7.4 (35)	7.8 (50)	3.5 (25)	4.2 (55)	3.1 (60)	0.1 (20)
LARVACEA	--	--	--	--	2.3 (35)	26.3 (65)	12.0 (50)	21.1 (100)
COPEPOD NAUPLII	--	--	0.7 (5)	0.5 (10)	0.2 (5)	--	0.3 (15)	53.9 (100)
INSECTS	0.8 (20)	3.6 (30)	0.4 (5)	--	1.9 (25)	3.1 (40)	0.9 (35)	--
AMPHIPODS	0.2 (5)	1.1 (10)	1.4 (25)	0.2 (10)	1.4 (35)	2.0 (20)	1.9 (75)	--

Table 14. Continued

Prey Taxa	SAMPLE PERIOD (date) 1 5/1	2 5/11	3 5/19	4 5/27	5 6/4	6 6/11	7 6/20	8 6/27
POLYCHAETES	0.4 (10)	9.9 (25)	0.5 (5)	0.2 (10)	0.4 (10)	--	0.3 (15)	--
CUMACEA	--	0.5 (5)	--	8.9 (30)	0.3 (10)	--	0.1 (5)	0.1 (10)
CLADOCERA	--	--	--	--	--	0.7 (10)	0.4 (30)	10.5 (100)
CYPHONAUTES LARVAE	--	--	--	--	0.2 (5)	--	--	--
TOTAL %	99.9	99.0	98.6	99.1	97.0	92.1	95.5	95.8

Table 15. The Ivlev's electivity coefficients relating the abundance of prey taxa in the stomachs of pink and chum fry to the abundance of prey taxa in the surrounding waters

		SAMPLE PERIOD (date)			
Prey Taxa	Fry Species	1 5/1	2 5/11	3 5/19	4 5/27
CALANOID COPEPODS	Chum	-0.95	-0.86	-0.81	-0.84
	Pink	-0.39	-0.62	+0.41	+0.43
CYCLOPOID COPEPODS	Chum	-1.00	-1.00	-1.00	-1.00
	Pink	-1.00	-1.00	-1.00	-1.00
HARPACTICOID COPEPODS	Chum	+0.67	+0.80	+0.59	+0.72
	Pink	+0.71	+0.88	+0.14	+0.71
CIRRIPEDIA JUVENILES	Chum	-0.94	-0.76	-0.78	-0.97
	Pink	-0.98	-0.83	-0.08	-0.80
LARVACEA	Chum	0.00	-1.00	0.00	-1.00
	Pink	0.00	-1.00	0.00	-1.00
COPEPOD NAUPLII	Chum	-1.00	-1.00	0.00	-1.00
	Pink	-1.00	-1.00	+1.00	-0.17
INSECTS	Chum	+0.97	+1.00	+1.00	+1.00
	Pink	+0.45	+1.00	+1.00	0.00
AMPHIPODS	Chum	+1.00	-1.00	+1.00	+1.00
	Pink	+1.00	-0.12	+1.00	+1.00
POLYCHAETES	Chum	-0.09	-0.14	+1.00	-1.00
	Pink	-0.20	+0.72	+1.00	-0.33
CUMACEA	Chum	-1.00	0.00	0.00	+1.00
	Pink	-1.00	+1.00	0.00	+1.00
CLADOCERA	Chum	0.00	0.00	0.00	0.00
	Pink	0.00	0.00	0.00	0.00
CYPHONAUTES LARVAE	Chum	0.00	-1.00	-1.00	-1.00
	Pink	0.00	-1.00	-1.00	-1.00

Table 15. Continued

Prey Taxa	Fry Species	SAMPLE PERIOD (date) 5 6/4	6 6/11	7 6/20	8 6/27
CALANOID COPEPODS	Chum	-0.90	-0.96	-0.60	-0.85
	Pink	+0.64	+0.60	+0.67	+0.08
CYCLOPOID COPEPODS	Chum	-1.00	-1.00	-0.99	-0.46
	Pink	-0.96	-1.00	-0.97	-0.27
HARPACTICOID COPEPODS	Chum	+0.77	+0.89	+0.89	+0.60
	Pink	+0.75	+0.84	+0.95	+0.33
CIRRIPEDIA JUVENILES	Chum	-0.53	-0.78	-0.84	-0.76
	Pink	-0.67	-0.35	-0.38	-0.88
LARVACEA	Chum	-0.34	+0.38	+0.89	+0.87
	Pink	-0.70	+0.41	+0.50	+0.64
COPEPOD NAUPLII	Chum	-0.82	-1.00	-0.83	+0.91
	Pink	-0.92	-1.00	-0.57	+0.99
INSECTS	Chum	+1.00	+1.00	+1.00	+1.00
	Pink	+1.00	+1.00	+1.00	0.00
AMPHIPODS	Chum	+1.00	+0.83	+0.78	+1.00
	Pink	+1.00	+0.90	+0.90	0.00
POLYCHAETES	Chum	-0.33	+0.71	+0.13	+0.33
	Pink	+0.33	-1.00	-0.40	-1.00
CUMACEA	Chum	+1.00	+1.00	+1.00	0.00
	Pink	+1.00	0.00	+1.00	+1.00
CLADOCERA	Chum	-1.00	-0.57	-0.38	+0.74
	Pink	-1.00	-0.22	-0.38	+0.63
CYPHONAUTES LARVAE	Chum	+0.77	-1.00	-1.00	-1.00
	Pink	-0.89	-1.00	-1.00	-1.00

two weeks of sampling. Insects, amphipods, and cumacea were rarely found in zooplankton samples, which accounts for the large number of +1.00 values for these categories. Cyclopoid copepods, cirripedia juveniles, and cyphonautes larvae were rarely as abundant proportionally in fry stomachs as they were in the surrounding water.

The coefficients of overlap are found in Table 16 and Figure 11. Two values of Morisita's $C\lambda$ were calculated. The first, $C\lambda_1$, was calculated using the percent number (%N) of the twelve prey taxa. The second, $C\lambda_2$, was calculated using the percent dry-weight (%DW) of the twelve prey taxa. A value of $C\lambda$ greater than or equal to 0.60 was considered to be a significant overlap (Zaret and Rand, 1971). This is an assumed value chosen as a means of comparing the calculated values.

The values of $C\lambda_1$ and $C\lambda_2$ were quite different, the values of $C\lambda_2$ being usually lower than $C\lambda_1$. Only in weeks three and eight is the value of $C\lambda_2$ greater than $C\lambda_1$. The value of $C\lambda_1$ for week one indicates nearly identical diets for the two salmon fry. Subsequent values of $C\lambda_1$ for the remaining weeks indicate a decreased similarity in diets with overlap values oscillating around the critical value of 0.60 (Figure 11).

All values of $C\lambda_2$ but one lie below the critical value. Only in week eight did $C\lambda_2$ exceed 0.60. These values reach a peak of 0.52 for week three, then decrease to a low of 0.08 for week five. At this point the diets of the two fry species are quite dissimilar. During the following weeks the overlap values of $C\lambda_2$ increase to an overall maximum of 0.75 during week eight.

Fry Growth in M-cove

Length-frequency data obtained from the fry samples collected within M-cove provided a way of estimating the initial growth rate of pink salmon fry released from the Port San Juan hatchery in 1977 and 1978. Instantaneous daily growth rates (g_ℓ) were calculated using the expression:

$$g_\ell = \frac{\text{Ln } \ell_t - \text{Ln } \ell_o}{t} ,$$

where ℓ_o is an initial measure of fry fork-length and ℓ_t the final fork-length achieved in t days. Instantaneous growth rates in weight (g_ω), were obtained by the relationship:

$$g_\omega = bg_\ell$$

where b is the slope of the regression equation relating fry length to weight. The instantaneous growth rate in weight (g_ω) was used to calculate the change in fry body weight per day (ΔW) where:

$$\Delta W = (e^{g_\omega} - 1) \text{ X } 100$$

Table 16. The coefficients of overlap indicating the similarity of chum and pink fry diets

Week	Date	COEFFICIENTS OF OVERLAP $C\lambda_1$*	$C\lambda_2$**
1	May 1	0.95	0.37
2	May 11	0.65	0.27
3	May 19	0.44	0.52
4	May 27	0.70	0.22
5	June 4	0.39	0.08
6	June 11	0.88	0.26
7	June 20	0.40	0.29
8	June 27	0.50	0.75
Eight-week Summary		0.59	0.25

* calculated using percent number (%N)

** calculated using percent dry weight (%DW)

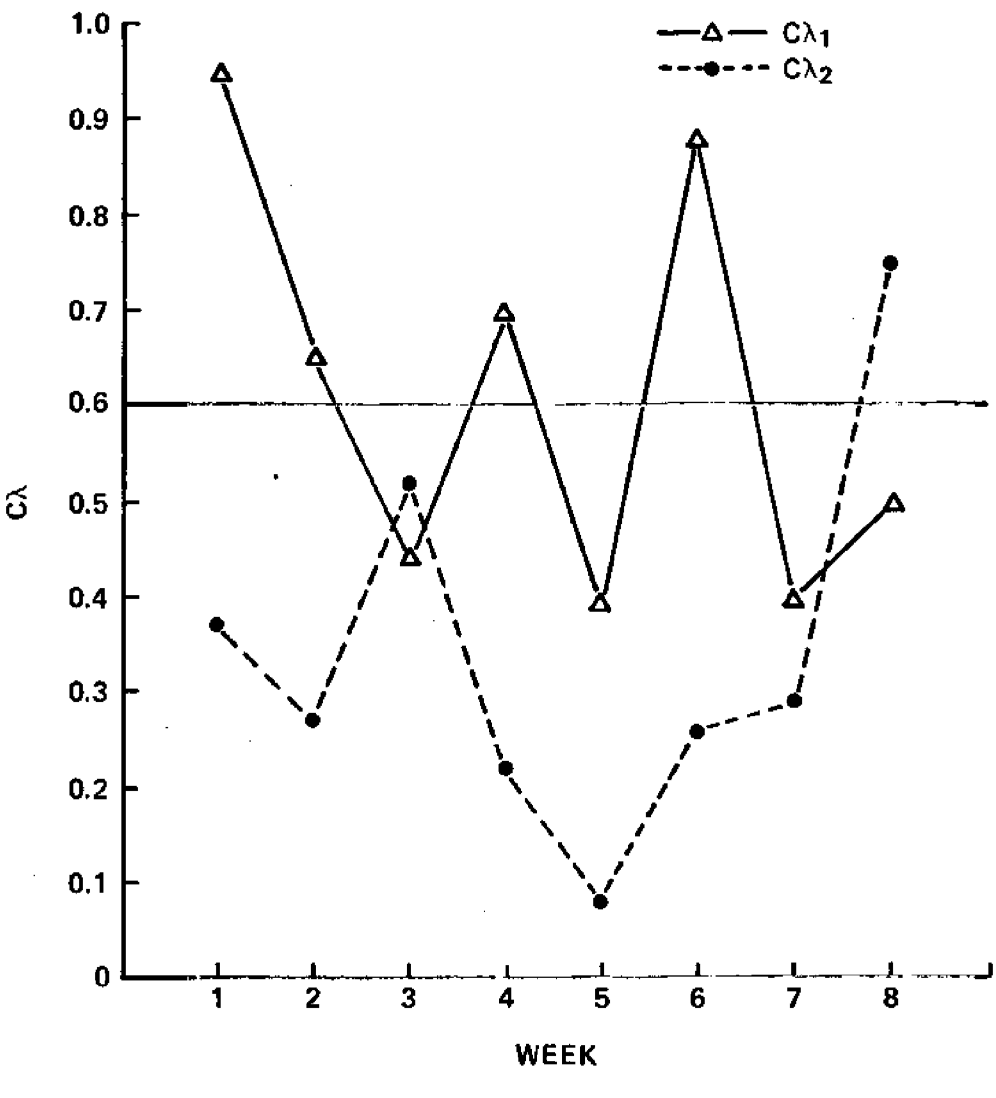


Figure 11. Coefficients of overlap indicating the similarity of pink and chum salmon diets; $C\lambda_1$ computed on a % number occurrence; $C\lambda_2$ computed on % dry-weight basis.

(Phillips and Barraclough, 1978). For juvenile pink salmon the coefficient b can be assumed to equal 3.25 (LeBrasseur and Parker, 1964).

To calculate instantaneous growth rates as the slope of a linear regression on length with respect to time, a natural logarithm transformation was applied to the length data from the M-cove fry samples (Tables 17 and 18). Samples were given equal weight in the regressions by converting numerical frequencies of occurrence to a percentage value.

An instantaneous growth rate in length (g_ℓ) of 0.0112 natural log units per day was calculated for fry collected from M-cove in 1977 ($r = +0.74$; $df = 798$; $\alpha = 0.01$) (Figure 12). The growth rate (slope) increased to 0.0137 when a fry cohort (indicated by cross-hatching), first appeared May 16 in sample M#5, was excluded from the calculations. The confidence interval ($P = 0.05$) for this estimate of the growth rate in length, which corresponds to a 4.6 percent increase in fry body weight per day (ΔW), is 0.0132 to 0.0142 natural log units per day.

The growth rate in 1978, as indicated by the fry samples collected in M-cove, was apparently lower. An instantaneous growth rate in length (g_ℓ) of only 0.0075 natural log units per day (Figure 12, dashed line) is obtained when regressing over all eight samples collected between April 5 and June 16, 1978 ($r = +0.78$; $df = 798$; $\alpha = 0.01$). Inspection of the 1978 length-frequency plots suggests an increase in the growth rate beginning May 1, 1978. When comparing the growth of fry between these two years, the sample M#1, collected on April 5, 1978, was omitted (Table 12, Appendix V). A growth rate of only 0.0031 natural log units per day is obtained when plotting a line between the first two samples collected in M-cove in 1978. An instantaneous daily growth rate in length (g_ℓ) of 0.0098 is obtained when regressing over the seven M-cove samples collected between May 2 and June 16, 1978 ($\Delta W = 3.2\%$/day). The 95 percent confidence interval for this estimate of M-cove fry growth during May and June of 1978 is 0.0093 to 0.0104 natural log units per day.

Table 17. Percentage length-frequency data for pink salmon fry taken from M-cove in 1977 (Millimeter fork-lengths have been transformed to natural logarithms (cm) in order to compute a simple linear regression.)

Group limits (cm)	Group mark (Ln 1)	Percent Fry in Sample M#1 4/28	M#2 5/3	M#3 5/5	M#4 5/9	M#5 5/16	M#6 5/22	M#7 5/29	M#8 6/6
2.8 - 3.0	1.05	17.4	4.1	-	-	0.9	4.2	-	-
3.1 - 3.3	1.15	71.2	35.6	28.1	11.8	19.5	20.9	10.2	-
3.4 - 3.6	1.25	11.4	42.5	47.5	54.9	34.6	9.8	32.1	-
3.7 - 4.0	1.35	-	17.8	23.7	28.4	31.0	21.1	18.6	3.6
4.1 - 4.4	1.45	-	-	0.7	4.9	9.1	20.3	14.2	8.1
4.5 - 4.9	1.55	-	-	-	-	4.5	19.3	13.0	7.2
5.0 - 5.4	1.65	-	-	-	-	0.4	4.0	10.2	18.9
5.5 - 6.0	1.75	-	-	-	-	-	0.4	1.7	44.2
6.1 - 6.6	1.85	-	-	-	-	-	-	-	12.6
6.7 - 7.3	1.95	-	-	-	-	-	-	-	5.4
7.4 - 8.1	2.05	-	-	-	-	-	-	-	-
Number of fry (N)		80	73	139	144	220	505	177	111
Totals (%)		100	100	100	100	100	100	100	100
Average fork-length (mm)		32.0	34.3	35.0	36.0	36.8	39.4	40.1	55.1

Table 18. Percentage length-frequency data for pink salmon fry taken from M-cove in 1978 (Millimeter fork-lengths have been transformed to natural logarithms (cm) in order to compute a simple linear regression.)

Group limits (cm)	Group mark (Ln 1)	Percent Fry in Sample M#1 4/5	M#2 5/2	M#3 5/10	M#4 5/13	M#5 5/27	M#6 6/3	M#7 6/9	M#8 6/16
2.8 - 3.0	1.05	46.3	3.4	2.1	1.6	-	0.4	-	-
3.1 - 3.3	1.15	53.7	62.7	32.1	50.9	11.0	1.5	2.8	0.8
3.4 - 3.6	1.25	-	30.5	33.7	34.1	13.4	8.9	4.6	4.0
3.7 - 4.0	1.35	-	3.4	24.8	11.9	27.1	29.1	9.8	7.6
4.1 - 4.4	1.45	-	-	7.3	1.5	23.8	21.2	15.4	13.8
4.5 - 4.9	1.55	-	-	-	-	20.0	18.9	32.1	24.0
5.0 - 5.4	1.65	-	-	-	-	4.3	10.2	14.0	23.5
5.5 - 6.0	1.75	-	-	-	-	0.4	7.5	12.0	19.1
6.1 - 6.6	1.85	-	-	-	-	-	2.3	8.3	5.2
6.7 - 7.3	1.95	-	-	-	-	-	-	1.0	2.0
7.4 - 8.1	2.05	-	-	-	-	-	-	-	-
Number of fry (N)		54	118	190	191	239	281	215	253
Totals (%)		100	100	100	100	100	100	100	100
Average fork-length (mm)		30.4	33.1	35.3	33.9	40.5	43.9	48.1	49.6

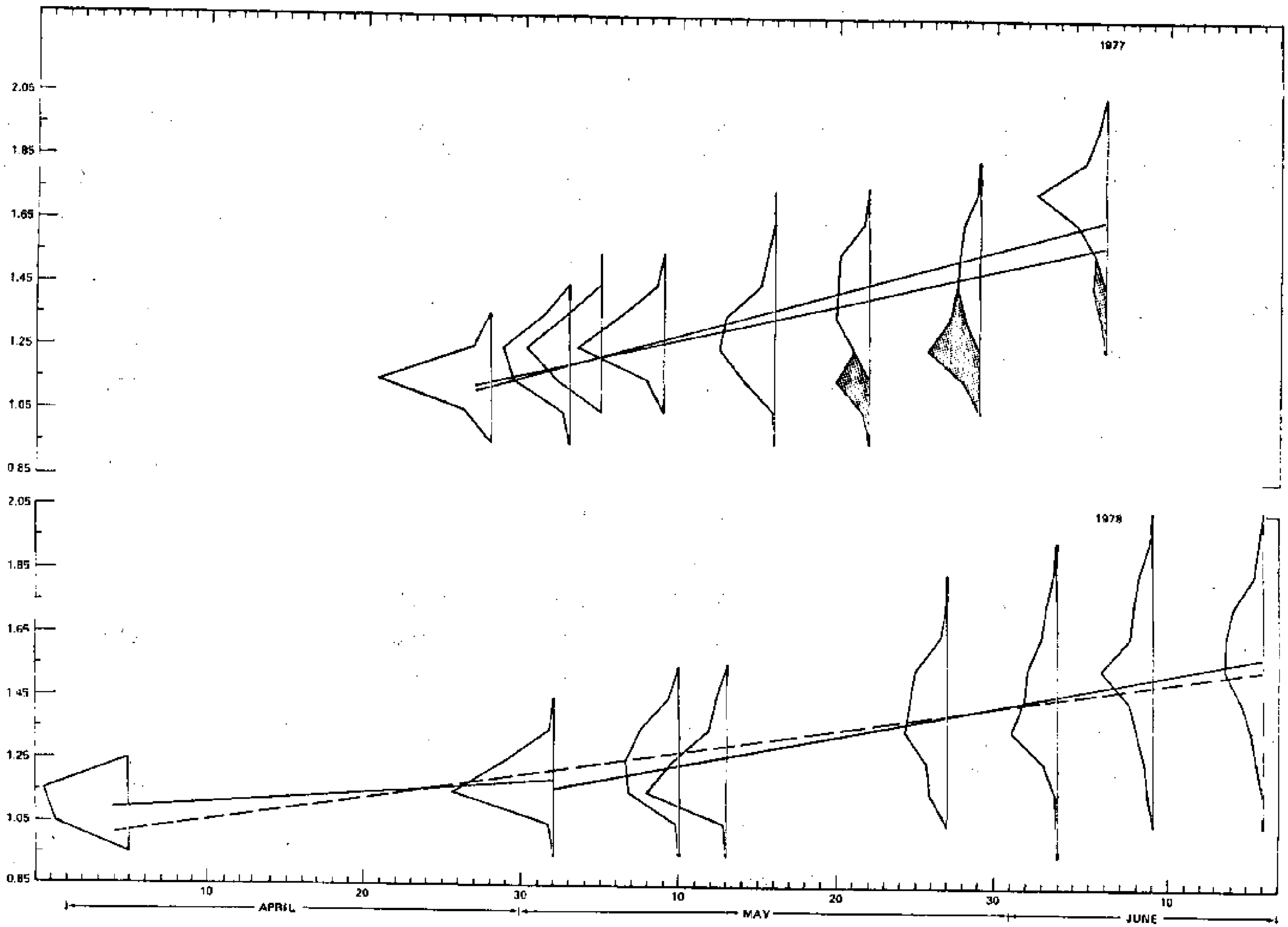


Figure 12. Logarithm transformed length-frequency curves for pink salmon fry captured in M-cove during April, May, and June of 1977 and 1978.

DISCUSSION

Fry Migration and Nursery Areas

Unlike other Pacific salmon, pink salmon bear no cryptic, camouflaging parr marks but begin life as a "silvery pelagic animal" (Hoar, 1958). Pinks go to sea earlier than other Pacific salmon (Hoar, 1958, 1976; Neave, 1958), and exhibit a marked preference for waters with a salinity near that of the open ocean (McInerney, 1964; Weisbart, 1968). Sawmill Bay may have failed to hold the pink fry that were outmigrating from the Port San Juan hatchery because the south end is frequently covered with a lens of fresh water. The Bay is well protected from strong currents that could break down this salinity stratification, and lacks the flux of food particles available to fry feeding in Elrington Passage.

The Bettles Island group and the shore along Elrington Passage are bathed by water flowing through the main body of Prince William Sound. This water originates in the Gulf of Alaska and enters the Sound through Hinchinbrook Entrance (Schmidt, 1977). Elrington and Latouche Passages are deep, between 100 and 200 m, and contain pelagic zooplankton (*Calanus* spp., *Metridia* spp.) not usually found in shallower coastal areas. Pink salmon fry heading to sea from Port San Juan have only a few kilometers to travel before they are in the north end of Elrington Passage, an environment with many characteristics of the open ocean and one that apparently meets their immediate needs for food and shelter.

The currents flowing through Elrington and Latouche Passages may determine which coves are used as nursery areas by pink fry. The coves are formed by rocky island shores, offshore rocks, and submerged reefs that border the larger channels and passages. The enclosures thus formed are not complete, but open in two or more directions so that the fry within face mild currents and the entrained ebb and flow of forage populations. These areas are well exposed to the sun, provide little shade, and for that reason, often face south. If they do not open to the south, they receive good exposure at least during part of the day. Water depths within nursery coves vary, though the fry appear to remain within a meter of the surface and avoid areas that are shallower.

In these coves pink fry are protected from the more powerful currents moving outside in Elrington Passage. However, because of the flow-through nature of the cove systems, zooplankton from the deep water passages are continuously available as food. The coves on the south side of the Bettles Island group (L, M, O) displayed vast collections of the copepod *Calanus plumchrus* in early May of both years that apparently washed in from Elrington Passage. Because of the constriction created by the presence of this group of islands in the north end of Elrington Passage, currents there are strong and probably create some upwelling or at least deep vertical mixing. By using the nursery areas where food is continuously supplied, or even partially concentrated, these essentially pelagic fish are afforded the benefits of schooling in large numbers, while feeding on zooplankton in a relatively low energy nearshore environment. When pelagic organisms become scarce, epibenthic harpacticoid copepods are available. Thus, the pink fry in these coves make use of the energy flowing from two relatively distinct marine food webs, one detrital-benthic and the other pelagic.

Reference is frequently made to the migration of pink salmon moving to saltwater nursery areas, but there is some confusion as to what actually constitutes nursery habitat (McDonald, 1960; Neave, 1955). The migration of wild pink salmon fry down the Bella Coola River into Burke Channel in British Columbia was discussed by Parker (1965) and Healey (1967). This movement is described as "saltatory" with the fry interspersing periods of active offshore swimming with more quiescent schooling behavior close to the beach in bays and coves. Schooling movement within the coves is described as circular, sometimes lasting several hours. In this case, the entire estuary was conceptualized as the nursery.

Unlike the fry from the Bella Coola River that travel 100 km or more, Port San Juan pink salmon need swim only 20 km before reaching the Gulf of Alaska. In 1978 fry must have been moving about in the passages when they were not schooling in coves. Their movement was saltatory and bears resemblance to what was described for pink salmon fry in British Columbia. However, the turbulent condition of the water in the main channels and the frequency with which storm conditions prevailed in 1978 in Prince William Sound, prevented this movement from being observed.

The behavior of pink salmon fry occurring in nursery coves at the north end of Elrington Passage in 1977, wherein the fry formed slowly moving schools that persisted for weeks, has not been previously described. Because the behavior was not repeated the following year, more observations are needed before something more specific than the estuary should be considered as the pink salmon fry's saltwater nursery.

The movement of pink fry away from the nearshore zones into deeper waters as spring progresses and the fish increase in size, is well documented (Gilhousen, 1962; Kaczynski *et al.*, 1973). According to LeBrasseur and Parker (1964) a dramatic break in growth and behavior occurs when the fry are 60 to 80 mm in length, resulting in mass migration from enclosed waters. Though the pink salmon has evolved beyond the necessity for a specific smolting stage (Hoar, 1976), LeBrasseur and Parker (1964) feel a physiological change does take place in the fry that is a remnant of the parr-smolt transformation experienced by other Pacific salmon. The sudden movement of the Port San Juan fry away from the nursery areas in June of 1977 into the open passages supports the contention that a major behavior transition takes place in relationship to size and perhaps age.

It is difficult to say what caused the observable differences in migratory behavior exhibited by the 1977 and 1978 pink fry reared at Port San Juan. A number of factors may have been involved. According to PWSAC, 1978 fry received more "temperature units" as eggs and incubating alevins because of a warm fall of 1977. This resulted in a significant difference ($z = 1.88$; $\alpha = 0.05$) in the fork-lengths of fry leaving the incubators. One hundred and eighty-four fry taken from the hatchery in 1977 averaged 31.4 mm in fork-length ($\overline{FL}$) and 0.26 g wet-weight ($\overline{W}$). In 1978, 626 fry taken from the hatchery averaged 31.8 mm $\overline{FL}$ and 0.23 g $\overline{W}$. As a result of the time spent at higher temperatures while incubating, 1978 fry outmigrating from the hatchery were longer and leaner than outmigrants the previous year. The 1978 fry also possessed less yolk. Pen experiments conducted both years showed these more advanced fry to be more susceptible to starvation (Cooney *et al.*, 1978). The 1978 outmigrating Port San Juan pink fry may have been hungrier and more willing to travel to find food in the estuary than the 1977 fry.

The weather differences between years may also have affected fry behavior. Storms and cloudy skies were more frequent in 1978 than 1977. Surface chop and cooler temperatures could have kept the 1978 fry moving and away from the surface. It was noted that schools of fry were sluggish and more easily netted at the surface on warm, sunny days than they were when it was cool and overcast. Pink salmon fry at the surface, when their silvery bellies show against darkened skies, may stand out to predators lower in the water column. Though no weather records were kept, other than estuarine surface water temperatures (Figure 13), from observation, weather differences between years at the site were striking.

Finally, it is important to consider the possibility that differences in fry migratory behavior reflect a genetic difference between stocks. Since pink salmon rigidly adhere to a two-year life cycle (Bailey, 1969), even and odd year-classes possess separate gene pools. Only rare reports are made of pink salmon returning to spawn at an age beyond two years (Anas, 1959; Turner and Bilton, 1968). Presumably, this separation is a fairly recent development in the evolution of *Oncorhynchus* because there is no evidence of morphological differences between even and odd year pinks (Hikita, 1962; Vladykov, 1963), nor are there published reports which indicate behavioral differences exist. Yet, according to Hoar (1958, 1976) and Neave (1958), speciation among the ancestral groups in the genus *Oncorhynchus* proceeded along lines involving the migratory behaviors and motivations to go to sea.

Fry Feeding

A number of authors have examined the feeding dependencies of juvenile pink salmon including Annan (1958), Manzer (1969), Okada and Taniguchi (1971), Bailey, Wing, and Mattson (1975), and Gosho (1977). They report pink fry to be zooplanktivorous, feeding in the water column above the bottom on pelagic and neretic calanoid copepods, larvaceans, larval fishes, larval barnacles, and cladocerans. Recently, in Puget Sound, Washington, other investigators reported pink fry to be feeding primarily on epibenthic harpacticoid copepods (Kaczynski *et al.*, 1973; Feller and Kaczynski, 1975; Bax *et al.*, 1978). Since then a number of articles have pointed to the significance of commercially valuable fishes coupling with an energy-rich benthic food web (Sibert *et al.*, 1977; Brown and Sibert, 1977; Sibert, 1979; Naiman and Sibert, 1979).

Pink fry released from the Port San Juan facility made use of both epibenthic harpacticoid copepods and the zooplankton found in the water column. We agree with Kaczynski *et al.* (1973) that the initial feeding period in the life cycle of these fishes is a distinct ecological stage

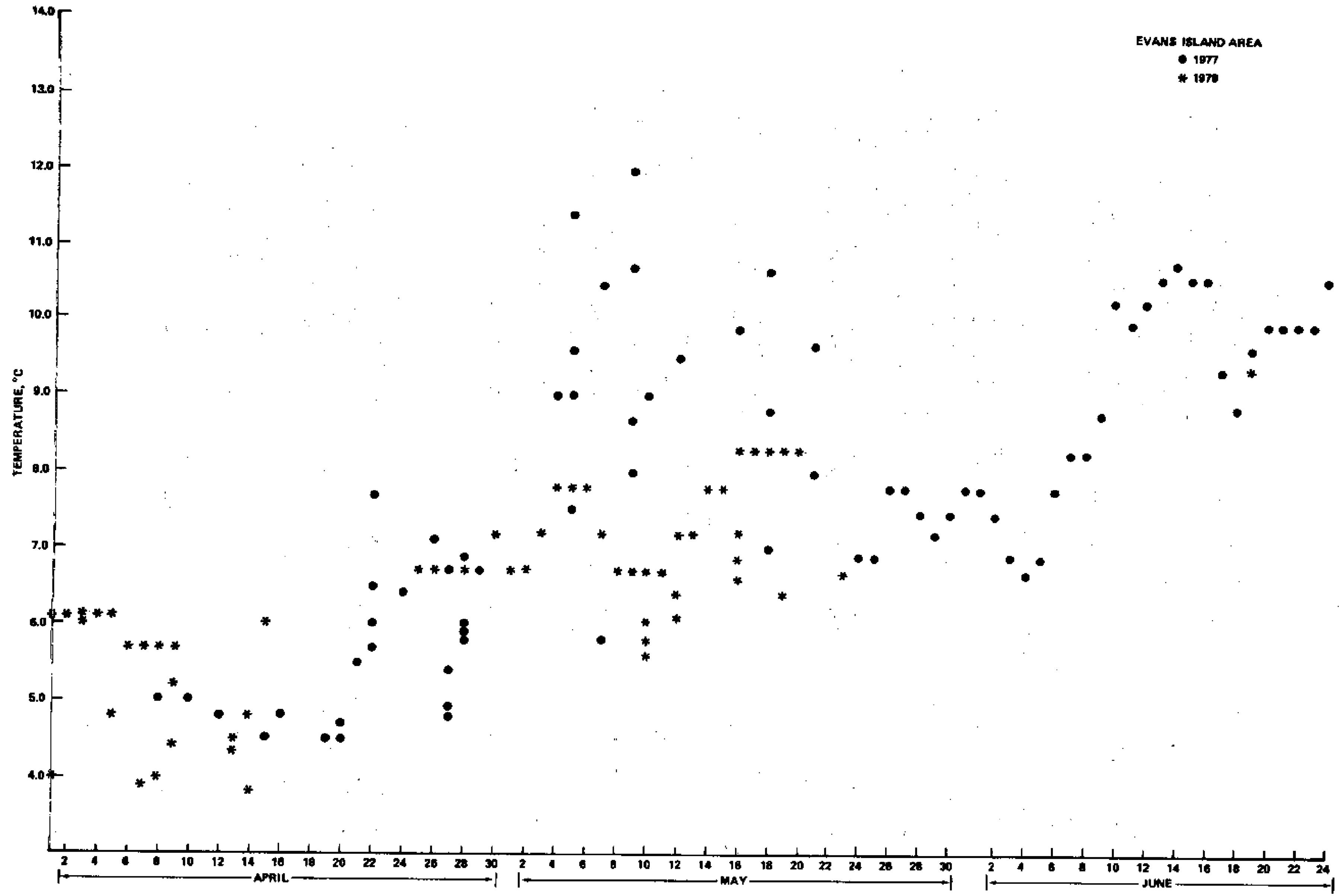


Figure 13. Estuarine surface water temperatures at Evans Island in 1977 and 1978.

during which epibenthic prey constitute the bulk of the prey. In Puget Sound, however, this developmental stage was occupied by the fry until they were 40 to 50 mm long, while at Evans Island it apparently lasts only a few days. Though harpacticoid copepods were a later component of the diet, calanoids were of much greater importance to the fry outside Sawmill Bay in M-cove.

Calanoid copepods are of high nutritional value, and unlike the harpacticoids do not appear to be difficult to digest. According to Brodsky (1950), calanoid copepods are 59 percent protein and 7 to 20 percent fat, with the fat content highest in those samples consisting mainly of *Calanus*. In British Columbia, *Calanus plumchrus* is most abundant near the surface during the early period of marine existence of juvenile salmon and is the best apparent prey for efficient growth (LeBrasseur, 1969). Chum salmon fry were also shown to select for this and other copepods between 2 and 5 mm in length.

Other investigations have shown pink salmon fry to be highly selective feeders. According to Bailey, Wing, and Mattson (1975), larvaceans were an important prey item for fry in Traitors Cove, Alaska, because they were a highly visible organism, even when scarce. Kaczynski *et al.* (1973) found no direct relationship between surface zooplankton abundance and the composition of stomach contents of fry in Puget Sound.

In Sawmill Bay pink fry fed primarily on harpacticoid copepods though few were available in the surface waters except in the shallows close to shore. Examinations of live nearshore plankton collections suggest this initial preference is due to the fact harpacticoid copepods are more visible than many of the transparent, motionless, neritic copepods. Harpacticoids are active swimmers, move with rapid undulations, and they are brightly colored, often red. During April, female harpacticoids carry a large pair of reddish egg sacs. In this context both *Pseudocalanus* and *Calanus*, actively sought as food, appear red or orange because of the oil droplet they synthesize. *Calanus plumchrus* also displays stripes of red along its antennules and thorax.

When *Calanus* and *Pseudocalanus* were abundant in M-cove, the pink salmon fed on them. At other times, such as when the fry fed on *Metridia* or harpacticoid copepods, the community of zooplankton sampled with nets at the cove's surface bore little relationship to the fry's diet. *Metridia* is known to undergo diurnal vertical migration and may have been available to the fry only at night. Epibenthic harpacticoid copepods in M-cove were rarely at the surface.

Kaczynski *et al.* (1973) and Feller and Kaczynski (1975) define as epibenthic those organisms "that live very near, on, or slightly within the sediment surface". They imply the pink salmon fry in Puget Sound pick these organisms off the sediment water interface. At Evans Island, this behavior was not observed. Rather it appeared the pink fry feed on harpacticoids swimming in the water column. Ito (1971) and Jewett and Feder (1977), in their discussion of the biology of *Harpacticus uniremis* make no mention of its distribution in the water column. Yet, in the nearshore environment of southwestern Prince William Sound, pink salmon fry feed on "clouds" of harpacticoid copepods available off the bottom and vertical rock walls. Samples taken with nets and the pump revealed the harpacticoids to be concentrated in the water column, hundreds of centimeters beyond the traditional epibenthic interface.

In general, the fry examined from M-cove support the notion that juvenile pink salmon feed principally on zooplankton. However, the young salmon were flexible in using their environment and obtaining food. For pink fry that have been in the estuary for several weeks, the epibenthic harpacticoid copepods may function as a backup source of nutrition during those periods when more preferred pelagic forage species are unavailable.

Pink and Chum Fry Feeding Interactions

Reports on the diets of juvenile pink and chum salmon from several areas in the North Pacific are available in the literature (Manzer, 1969; Okada and Taniguchi, 1970; Kaczynski *et al.*, 1973; Bailey *et al.*, 1975; and Feller and Kaczynski, 1975). Manzer (1969) described pink and chum fry collectively as being planktophagous, feeding mainly on copepods and larvacea. This was true at Port San Juan also. These two prey taxa accounted numerically for a majority of the prey items of both fry species during most of the sampling periods.

Studies of pink and chum fry conducted in Puget Sound (Kaczynski *et al.*, 1973) revealed some differences between the diets of these species. Chum fry there ate significantly more harpacticoid copepods and adult diptera than pink fry. Pink fry stomachs contained more invertebrate eggs than chum fry stomachs. The authors attributed these differences to electivity by the fry which reflect true behavioral preference. Insects also were consistently more numerous in chum fry stomachs and were eaten more frequently by chum fry than pink fry at Port San Juan. Harpacticoid copepods, however, seemed almost equally important to the diets of both species.

The diets of pink and chum fry in southeastern Alaska are discussed by Bailey *et al.* (1975). Pink fry stomachs from their study contained mostly planktonic prey, mainly copepods and cirripedia juveniles. Chum fry also fed heavily on copepods and cirripedia but also utilized larvacea, cladocera, and insects as major prey. The authors noted that chum fry tended to eat larger and harder shelled prey such as harpacticoid copepods, insects, and cumacea. This is also similar to the dietary information collected at Port San Juan.

The diet of a species is a function of many factors such as habitat, mouth size, dentition, and methods of feeding (Zaret and Rand, 1971). The results of stomach analyses are lists of prey organisms that may or may not give clues to the roles of the fry's morphology and behavior in the diet. The presence and abundance of prey species in fry stomach contents were rarely reflected in the community of potential prey species. This disproportion due to selection on the part of the fry of preferred prey is common in studies of juvenile salmon diets.

The basis of prey selection is in part visual. Juvenile salmon are dependent on their eyes for the location and capture of food (Hoar, 1958). Urquhart (1979) suggested that some copepods may be selected by fry because of their high visibility. Bailey *et al.* (1975) also attributed the presence of larvaceans in the diet of pink and chum fry to their visibility. Potential prey which are abundant in the water column may not show up in fry stomach contents due to their small size or transparent bodies. Two other factors which enter into the selection process are the ease of capture and the size of prey. Some potential prey may be able to escape predation by out-swimming or hiding from pursuing fry. This seems unlikely, however, because salmon fry are very strong swimmers, while zooplankton are not. The size of potential prey also enters into the process of selection. Prey too large to be grasped or swallowed are unlikely to be seen in stomach contents. Feeding experiments conducted on chum fry by LeBrasseur (1969) indicated that copepods within a certain size range were selected over copepods that were smaller or euphausiids which were larger. It would seem, then, that the process of prey selection by pink and chum is to some extent based on their morphological characteristics.

The pink and chum fry collected and analyzed in this study presumably used about the same habitat and were thus exposed to the same potential prey community. Whether or not there are morphological differences between the species which could account for differences in their diets is not known. Since the two species of fry were nearly the same size and have very similar morphologies, it was assumed that differences in prey preferences were not due to morphological differences, but rather to behavioral differences.

The feeding behavior of pink and chum fry has received little attention in the literature. Studies conducted by LeBrasseur (1969) indicated that chum fry not only feed selectively on prey of preferred sizes but can also be conditioned to select certain organisms as prey. This conditioning was also demonstrated with chum fry by Levy (1979). He found that fry which had learned to feed on a mysid, *Neomysis mercedis*, while in captivity, were more likely to use this organism for food in the wild than unconditioned fry. This may also be characteristic of pink fry. The pattern of feeding has also been described for chum fry. Congleton (1979) found that the timing of chum fry feeding is keyed to tidal rhythms. Fry fed more intensively during high tide when marsh areas were submerged than at low tide when the fry were restricted to tidal channels.

It would seem, then, that differences between the diets of pink and chum fry are mostly due to behavioral differences, either learned or innate. Since one goal of this study was to describe the differences and similarities of pink and chum diets, the specifics of the feeding behavior of these species was not investigated.

Diet Overlap

Overlap measures are designed to quantify the degree to which two species share common resources or utilize the same part of the environment (Lawlor, 1980). There are several formulae used to calculate overlap, all of which have different application and responses (see Hurlbert, 1978;

Cailliet and Barry, 1979). The formulae are mostly derived from mathematical theories of probability and are not really measurements of competition except under special circumstances (Hurlbert, 1978). The overlap measures applied in this study were not used as measures of competition but as measures of common resource utilization by two species. At no time during the study was there thought to be any resource (food) limitations. Had food resources become limiting, the overlap measures may have indicated competitive interactions. Chances are, however, that interspecies interactions would have been different under competitive circumstances (Colwell and Futuyma, 1971; Zaret and Rand, 1971). Colwell and Futuyma (1971) discuss the relationships between overlap and competition in some detail. According to their criteria the data presented here are insufficient to prove or disprove the existence of competition between pink and chum fry.

The use of the overlap measures in this study should be quite straightforward. The assumption of both species utilizing the same habitat, and thus in some way the same prey community, renders comparisons of diet free of complications common to studies of species using different habitats.

In general, the trend for the eight sampling periods is one of variable but generally similar diets. The variability of overlap from one week to the next is probably due to a number of factors. Changes in the composition or availability of prey in the water column may be a factor affecting overlap. The addition of cohorts of fry with different prey selection preferences (conditioning) may affect overlap. Other factors such as weather or tides may also influence prey selection and thus the overlap of diets.

Overlap values calculated using numerical data (%N) resulted in values of overlap greater than the critical value for weeks one, two, four, and six. For week one, harpacticoid copepods were by far the most dominant prey taxa for both species of fry, hence the high overlap. Week two is similar, but the predominance of insects in the chum stomachs, and not pink, decreased overlap considerably. The near critical values of overlap for week four are probably due again to the high incidence of harpacticoids in the diets of both fry species. During week six the overlap values were quite high. This was due to harpacticoids being the dominant prey taxa and larvacea the second most abundant prey item for both pink and chum fry.

The remaining weeks had overlap values less than the critical values. The dominant prey taxa for these samples were different for the fry species. Organisms selected by one species were usually of less importance in the diet of the other. The overlap value calculated using the eight week summary is reflective of values for the separate weeks. The summary value for $C\lambda_1$ lies quite close to the critical value. Again, the importance of harpacticoid copepods in the diets of both fry species is largely responsible for these results.

However, values of $C\lambda_2$ calculated from the %DW data generally lie well below the critical values. Overlap for week one is largely due to the importance of harpacticoid copepods in the diets of both fry species. Harpacticoids become less important to the fry during week two, especially in the case of pink fry. The relatively high value of $C\lambda_2$ for week three is due to the importance of both calanoid and harpacticoid copepods in the diet of both fry species. Harpacticoid copepods again can account for much of the overlap for weeks four through seven as well as cumacea in week four, insects in week five, insects and amphipods in week six, and calanoid copepods in week seven. The high overlap value of 0.75 during week eight is largely due to the importance of larvacea in both species' diets, as well as cladocera to a lesser extent. The overlap value calculated for the eight week summary, 0.25, is considerably lower than that calculated from the %N data. Most of this overlap is due to the high numbers of harpacticoid copepods, and hence biomass, in the diets of the two fry species.

Again, overlap values calculated from the %DW data were much lower than those calculated using numerical data. Though perhaps not surprising, this result was most interesting. The numerical data give no real indication of the importance of prey to the diet. Large numbers of small prey such as *Oithona* spp. or larvacea may be less important nutritionally than a few large prey organisms such as *Calanus* spp. or insects. It appears that partitioning of food resources in this instance is on a nutritional (mass) rather than numerical basis. Numerical data showed pink and chum fry to have very similar diets. The %DW data, however, indicates that the bulk of their diets, by weight and, therefore, most likely their nutrition, are based in quite different prey. For pink fry, calanoid copepods are the major source of nutrition, while chum fry rely mainly on insects and, to some extent, larvacea and harpacticoid copepods.

Fry Growth in M-cove

LeBrasseur and Parker (1964) report that pink salmon grow continuously and in an exponential way during the first 40 days spent in the estuary. From collections of wild pink fry in Fitz Hugh Sound, British Columbia, they obtained instantaneous daily growth rates in length (g_ℓ) of 0.0158, 0.0150, and 0.0146 natural log units per day during 1961, 1962, and 1963.

LeBrasseur and Parker (1964) felt these rates were low because pink fry school in non random distributions with larger fry occurring farther offshore, thus making representative sampling difficult. Also, pink fry enter the sea over a four to six week period, and an apparent growth rate for a particular school is frequently low through the addition of newly released cohorts of smaller fry. Further, larger, faster growing individuals are probably the first to move away from shore and the main body of a population. LeBrasseur and Parker (1964) suggested a rate (g_ℓ) of 0.0186 natural log units per day as more representative of the growth rate in length of pink fry during the first 40 days in the marine environment. This corresponds to a change in the fork-length of the fry from 34 to 85 mm and a 6.2 percent increase in body weight per day (ΔW). They obtained this estimate by marking 170,000 wild pink salmon fry and later recapturing 154 individuals between April 29 and June 9, 1963.

Calculated daily growth rates (g_ℓ) for fry residing in M-cove are lower than those obtained by LeBrasseur and Parker (1964), though the estimate $g_\ell = 0.0137$ compares well with the values they obtained by collecting unmarked wild fry in Fitz Hugh Sound. M-cove growth rates compare quite favorably with the growth reported for juvenile pink salmon in the Strait of Georgia and Saanich Inlet, British Columbia (Phillips and Barraclough, 1978). M-cove fry are estimated to have increased body weight at the daily rate (ΔW) of 4.6 percent in 1977 and 3.2 percent per day in 1978. Phillips and Barraclough (1978) showed pink salmon fry to grow at rates of 3.5 to 4 percent in body weight per day. Unfortunately, their rates were calculated for fry between 40 and 100 mm in length, and growth may not be constant over the time interval involved. LeBrasseur and Parker (1964) felt the growth rate of pink salmon fry was highest during the first 40 days in the estuary and halved the following month to a daily growth rate in weight of 3.5 percent.

No doubt, calculated growth rates for M-cove fry underestimate true growth for the same reasons as those discussed by LeBrasseur and Parker (1964). Larger fry in M-cove were adept at avoiding nets and may have moved outside the area before the main body of the school. Though LeBrasseur and Parker (1964) make no mention of sampling techniques, the equipment they used may have produced fry samples more representative of real growth than those taken in M-cove, accounting for the apparent differences in growth rates.

That differences may represent real differences cannot be dismissed. Prince William Sound is hundreds of kilometers north of Fitz Hugh Sound. Lower estuarine water temperature probably tends to reduce the growth rate of salmon fry. Though other authors (Gosho, 1977; Ivankov and Shershnev *in* Okada and Taniguchi, 1971) have also reported pink fry gaining length by more than 1.0 mm per day, growth rates of this magnitude were not observed in the waters near Evans Island.

Figure 12 indicates pink fry in M-cove grew more rapidly in 1977 than they did in 1978. Since the 1977 fry stayed in M-cove for six weeks and the 1978 fry did not, the two groups are difficult to compare. The growth rate obtained for 1977 M-cove fry provides an indication the same school of fish was sampled each week because the rate is similar to the growth rates reported in the literature for wild pink salmon fry. However, the growth rate calculated for 1978 M-cove fry may be low because different schools seem to have been sampled there each week. Cooler surface water temperatures in the estuary adjacent to Evans Island may also have slowed the growth of the 1978 fry, relative to the growth of the fry collected in M-cove the previous year.

CONCLUSIONS

This study was intended as a preliminary investigation of factors influencing the survival of juvenile pink and chum salmon released in large numbers from coastal hatcheries in Alaska. We chose to address the behavior, feeding biology, and growth of fry largely because the small fishes were readily available with the capture and observation techniques we had at our disposal. We are certainly aware that the problems of survivorship and carrying capacity are extremely complex. In this context we hope the information reported here will be valuable to those agencies and private groups who are concerned with this matter both from an economic and ecological point of view.

One obvious question is that of the impact of large numbers (several tens of millions) of hatchery released fry on local prey stocks. Our work at Evans Island suggests that at least in certain areas, food limitation may not be nearly the problem it might intuitively seem to be. Pink salmon fry released into Sawmill Bay migrate quickly to areas where tidal currents supply consistently adequate daily fluxes of food to the large semi-stationary schools. If we assume that juvenile salmon in the size range 35 to 50 mm consume about 200 prey items per day (see Appendix VI), then a current of only 0.13 m s^{-1} (1/4 nautical mile h^{-1}) flowing for an eight hour feeding period can support up to 18,720 fry m^{-3} given a stock of forage species of 1000 m^{-3}. Our measurements of zooplankton abundance indicate that during the period of time that fry utilize the northern portion of Elrington Passage, only in mid-May do stocks of forage organisms drop below this value. While this exercise is an admittedly crude evaluation, it does point to the relationship between the physical dynamics of Prince William Sound and the supply and consumption of food by large localized predator populations, in this case, salmon fry. We suspect that, in the case of this system, food limitations may only be a problem for fry released very early in the season, February and March. At that time local stocks of the small overwintering copepods such as *Pseudocalanus* spp. approach their seasonal lows. Also, the fact that the more planktivorus pinks can "fall back" on harpacticoid copepods demonstrates a feeding plasticity that provides even greater food reserves.

The partitioning of the food resources we observe between pink and chum salmon fry using about the same nursery habitat in southwestern Prince William Sound suggests sharing of rather than competition for prey. The more detritally directed benthic food web appears to be important for the chum fry and has been so described before. We have only scant information about populations of other planktivorus fishes that use this same habitat in April, May, and June (Cooney *et al.*, 1978). Several species of juvenile fishes were occasionally observed in the nursery areas during the study. However, none seemed to occur in numbers that would suggest an active competition for food.

There were no facilities to study the effects of predation on schools of pink and chum fry released from the hatchery at Evans Island. As previously reported (Cooney *et al.*, 1978), very large concentrations of Pacific tomcod were attracted to the waters adjacent to the hatchery docks in the summer of 1977. This occurrence was the only instance of clearly observed predation. In response to this problem, the fry were held in fine-meshed pens and then towed to areas outside the Bay for release. During the summer of 1979 (Cooney, unpublished), a variable-mesh gill net was set repeatedly and fished overnight in previously designated nursery areas to assess whether or not deep-dwelling or offshore predators moved in to take fry during the evening hours. Catches were astonishingly low; no obvious predators were sampled. This does not mean that losses to predators are inconsequential, but that as far as we could ascertain, the large, seemingly vulnerable fry schools were not routinely visited by obvious predators.

We conclude that hatchery-reared pink and chum salmon fry released in waters adjacent to Sawmill Bay exhibit behavior patterns and preferences for food similar to those reported for these species at other locations along the Pacific coast of North America. The apparent attraction of pink fry to so-called nursery habitat may be no more than a characteristic of the stocks at Evans Island. However, if this use pattern continues, then questions of carrying capacity related to both space and food may need to be addressed. During years when large numbers of pink salmon fry use the Island nursery habitat, it is not known what happens to fishes that must seek space outside these areas for reasons of crowding.

FUTURE STUDIES

Studies of salmon fry survivorship in coastal and estuarine waters of Alaska are presently being undertaken by both state and federal researchers. A recently developed Estuarine Environmental and Zooplankton Studies program has been implemented to standardize observations among state, federal, and private coastal hatcheries. The intent is to monitor certain environmental factors suspected as being important to the survival of fry. Sea water temperature and the abundance of forage species are the major factors currently being considered in this program.

We recommend specifically that studies of fry survival be continued in Prince William Sound since several additional hatcheries are either now semi-operational or will soon be added to the system. One facility, the Esther Lake hatchery, plans to rear all five species of Pacific salmon.

In our view, there are numerous basic questions which should continue to be addressed from a survey and experimental point of view to further describe the relationship between hatchery fry and their environment early in their life history. Both intra- and interspecific competition should be examined as it relates to interaction between naturally occurring planktivorus stocks (wild salmon fry, other juvenile pelagic species--walleye pollock, Pacific herring, etc.) in waters shared by these populations. Prey-predator relationships, particularly problems associated with one- or two-year-old silver and king salmon juveniles utilizing pink and chum salmon-of-the-year, should be investigated. Finally, at a slightly different level of complexity, studies of the interaction of fry and juvenile salmon stocks with the estuarine system of Prince William Sound as a whole should be undertaken. These studies would describe the functional role of salmon in this large coastal ecosystem and provide a framework for assessing the effects of accidentally spilled petroleum or other contaminants.

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APPENDIX I

Dry-weights of selected prey organisms from zooplankton samples and the stomachs of pink salmon fry collected in M-cove, April 28 through June 6, 1977, and April 1 through June 16, 1978. One group of 61 *Calanus cristatus* was sorted from a zooplankton sample collected in the Bering Sea on August 11, 1978. Average dry-weights are provided at the end of both tables. The values are used in the tables in Appendix III to calculate the dry-weight fractions of these organisms in the stomach contents of pink salmon fry taken from M-cove at the same time.

APPENDIX I

Table 1. Dry-weights of selected prey organisms taken from M-cove between April 28 and June 6, 1977

Sample Date	Prey organism	Number weighed	Total dry-weight (mg)	Individual dry-weight (mg)
4/28	*Pseudocalanus* spp.	150	4.01	.027
	**Calanus*	40	20.67	.517
	Thysanoessa spp. (larvae)	20	0.40	.020
5/3	*Pseudocalanus* spp.	150	4.56	.030
	Metridia spp.	100	8.35	.084
	Polychaetes (larvae)	50	0.87	.017
	Gadid (larvae)	43	3.57	.083
	**Calanus* spp.	40	20.84	.521
5/5	*Pseudocalanus* spp.	150	5.00	.033
	Metridia spp.	70	9.36	.134
	**Calanus* spp.	50	25.15	.503
5/9	*Pseudocalanus* spp.	100	3.46	.035
	**Calanus* spp.	60	28.66	.478
	Metridia spp.	50	3.30	.066
5/16	**Calanus* spp.	50	16.82	.336
	Parathemisto spp. (larvae)	30	3.07	.102
5/22	*Pseudocalanus* spp.	100	2.63	.026
	Decapod (zoeae)	50	0.50	.010
	Metridia spp.	16	1.24	.078
5/29	*Oithona similis*	400	0.93	.002
	Harpacticoid copepods	355	4.81	.014
6/6	Larvaceans	200	1.56	.008
	Pseudocalanus spp.	162	5.10	.031
	Metridia spp.	100	6.40	.064

Table 1. Continued

Average dry-weights of individual prey organisms (1977)

Prey organism	Average dry-weight (mg)
**Calanus* spp.	.471
Parathemisto spp.	.102
Metridia spp.	.085
Gadid (larvae)	.083
Pseudocalanus spp.	.030
Thysanoessa spp.	.020
Polychaetes (larvae)	.017
Harpacticoid copepods	.014
Decapods (zoeae)	.010
Larvaceans	.008
Oithona similis	.002

* Refers primarily to *Calanus plumchrus* but also includes *C. marshallae* and *C. pacificus*.

Table 2. Dry-weights of selected prey organisms taken from M-cove between April 1 and June 16, 1978 (one group was taken from the Bering Sea August 11, 1978)

Sample Date	Prey organism	Number weighed	Total dry-weight (mg)	Individual dry-weight (mg)
4/1	Barnacle nauplii	150	0.36	.002
	Pseudocalanus spp.	100	1.46	.015
	Metridia spp.	50	2.50	.050
5/2	*Pseudocalanus* spp.	125	4.23	.034
	Calanus plumchrus	35	17.90	.511
	Barnacle cyprids	27	1.31	.049
5/10	*Pseudocalanus* spp.	110	2.60	.024
	Calanus plumchrus	100	91.79	.918
5/13	Harpacticoid copepods	92	0.55	.006
5/19	*Pseudocalanus* spp.	175	4.82	.028
	Harpacticoid copepods	100	2.51	.025
	Barnacle cyprids	37	1.40	.038
	**Calanus* spp.	30	17.59	.586
	Metridia spp.	15	1.54	.103
5/27	*Pseudocalanus* spp.	150	3.52	.023
	Polychaetes (*Exogone* spp.)	43	1.51	.035
	**Calanus* spp.	19	4.40	.232
6/3	Harpacticoid copepods	20	0.42	.021
	Pseudocalanus spp.	13	0.30	.023
	Calanus marshallae	3	0.93	.310
6/9	Harpacticoid copepods	456	10.01	.022
	Larvaceans	100	0.63	.006
	Polychaetes (*Exogone* spp.)	23	0.70	.030
	Calanus cristatus	9	9.53	1.059
	Fish (larvae)	5	8.03	1.606

Table 2. Continued

Sample Date	Prey organism	Number weighed	Total dry-weight (mg)	Individual dry-weight (mg)
6/16	Harpacticoid copepods	375	6.75	.018
	Metridia spp.	34	2.09	.061
8/11	***Calanus cristatus*	61	153.61	2.518

Average dry-weights of individual prey organisms (1978)

Prey organism	Average dry-weight (mg)
Calanus cristatus	1.789
Fish (larvae)	1.606
Calanus plumchrus	.715
**Calanus* spp.	.511
Metridia spp.	.071
Barnacle cyprids	.044
Polychaetes (*Exogone* spp.)	.033
Pseudocalanus spp.	.025
Harpacticoid copepods	.018
Larvaceans	.006
Barnacle nauplii	.002

* Refers primarily to *Calanus plumchrus* but also includes *C. marshallae* and *C. pacificus*.

** Sorted from a zooplankton sample collected in the Bering Sea on August 11, 1978.

APPENDIX II

The first prey items of 267 pink salmon fry migrating from the Port San Juan hatchery at Evans Island, Alaska, and collected in Sawmill Bay during the springs of 1977 and 1978. Total number (N), percent number (%N), and percent frequency of occurrence (%FO) are listed for all prey categories.

APPENDIX II

Table 1. Stomach contents of 182 pink salmon fry collected in Sawmill Bay between April 8 and April 22, 1977

Sample F#3
4/8/77
8 stomachs examined
$\bar{L}$ = 31.9 mm

Prey category	N	%N	%FO
Harpacticoid copepods	6	100	50

Sample B#1
4/10/77
15 stomachs examined
$\bar{L}$ = 29.9 mm

Prey category	N	%N	%FO
Harpacticoid copepods	17	58.6	47
Unidentified particles	6	20.7	27
Polychaetes (larvae)	2	6.9	13
Barnacle cyprids	2	6.9	13
Acartia longiremis	2	6.9	13

Sample HPB#2
4/10/77
16 stomachs examined
$\bar{L}$ = 30.6 mm

Prey category	N	%N	%FO
Harpacticoid copepods	1	100	6

Table 1. Continued

Sample G#1
4/12/77
20 stomachs examined
$\bar{L}$ = 31.6 mm

Prey category	N	%N	%FO
Harpacticoid copepods	24	85.7	15
Unidentified particles	2	7.1	10
*Calanoid copepods	1	3.6	5
Eggs (invertebrate)	1	3.6	5

Sample HPB#3
4/12/77
20 stomachs examined
$\bar{L}$ = 31.8 mm

Prey category	N	%N	%FO
Harpacticoid copepods	12	54.5	50
Barnacle cyprids	6	27.3	10
Acartia longiremis	2	9.1	5
Barnacle nauplii	1	4.5	5
Oithona similis	1	4.5	5

Sample F#4
4/12/77
20 stomachs examined
$\bar{L}$ = 30.9

Prey category	N	%N	%FO
Harpacticoid copepods	76	95.0	65
Unidentified particles	1	1.3	5
Amphipods	1	1.3	5
Oikopleura spp.	1	1.3	5
Polychaetes	1	1.3	5

Table 1. Continued

Sample A#1
4/15/77
15 stomachs examined
$\overline{L}$ = 32.3 mm

Prey category	N	%N	%FO
Harpacticoid copepods	138	90.8	100
*Calanoid copepods	7	4.6	13
Barnacle cyprids	5	3.3	27
Amphipods	1	0.7	7
Polychaetes	1	0.7	7

Sample H#1
4/15/77
15 stomachs examined
$\overline{L}$ = 31.2 mm

Prey category	N	%N	%FO
Harpacticoid copepods	24	58.5	53
*Calanoid copepods	7	17.1	20
Unidentified particles	4	9.8	7
Eggs (invertebrate)	3	7.3	7
Polychaetes	2	4.9	7
Amphipods	1	2.4	7

Sample K#1
4/19/77
15 stomachs examined
$\overline{L}$ = 32.5 mm

Prey category	N	%N	%FO
Harpacticoid copepods	42	91.3	47
Barnacle cyprids	2	4.3	7
Fish (larvae)	1	2.2	7
Decapod (zoeae)	1	2.2	7

Table 1. Continued

Sample B#2
4/20/77
8 stomachs examined
$\bar{L}$ = 30.8 mm

Prey category	N	%N	%FO
Harpacticoid copepods	26	96.3	75
Barnacle cyprids	1	3.7	13

Sample A#2
4/22/77
15 stomachs examined
$\bar{L}$ = 32.5 mm

Prey category	N	%N	%FO
Harpacticoid copepods	20	71.4	33
*Calanoid copepods	5	17.9	7
Unidentified particles	1	3.6	7
Barnacle cyprids	1	3.6	7
Unidentified insects	1	3.6	7

Sample H#2
4/22/77
15 stomachs examined
$\bar{L}$ = 31.0 mm

Prey category	N	%N	%FO
Harpacticoid copepods	19	86.4	46
Barnacle cyprids	1	4.5	8
Fish (larvae)	1	4.5	8
Unidentified insects	1	4.5	8

* Calanoid copepods were placed within this group when digestion or missing pieces prevented identification to a lower taxonomic level.

Table 2. Stomach contents of 85 pink salmon fry collected in Sawmill Bay between April 3 and May 19, 1978

Sample H#1
4/3/78
20 stomachs examined
$\bar{L}$ = 32.0 mm

Prey category	N	%N	%FO
Copepod nauplii	158	52.8	25
Harpacticoid copepods	113	37.8	70
Calanoid copepodids	16	5.4	20
Barnacle nauplii	4	1.3	10
Oikopleura spp.	3	1.0	5
Fish (larvae)	3	1.0	5
Euphausids (larvae)	1	0.3	5
Oithona similis	1	0.3	5

Sample PB#1
4/9/78
15 stomachs examined
$\bar{L}$ = 31.6 mm

Prey category	N	%N	%FO
Harpacticoid copepods	114	77.0	100
*Calanoid copepods	17	11.5	47
Polychaetes (juveniles)	8	5.4	33
Calanus spp.	3	2.0	20
Barnacle nauplii	2	1.4	7
Oithona similis	1	0.7	7
Copepodids	1	0.7	7
Barnacle cyprids	1	0.7	7
Decapod (zoeae)	1	0.7	7

Table 2. Continued

Sample CC#1
4/10/78
15 stomachs examined
L = 31.1 mm

Prey category	N	%N	%FO
Harpacticoid copepods	75	60.0	80
Pseudocalanus spp.	26	20.8	33
Barnacle nauplii	6	4.8	20
*Calanoid copepods	5	4.0	20
Copepodids	4	3.2	13
Gadid (larvae)	4	3.2	7
Calanus spp.	2	1.6	13
Barnacle cyprids	2	1.6	7
Euphausids (larvae)	1	0.8	7

Sample CC#2
5/1/78
15 stomachs examined
L = 31.7 mm

Prey category	N	%N	%FO
Harpacticoid copepods	503	90.0	73
Pseudocalanus spp.	23	4.1	53
*Calanoid copepods	16	2.9	20
Unidentified insects	10	1.8	20
Amphipods	3	0.5	20
Polychaetes	2	0.4	13
Calanus spp.	1	0.2	7
Barnacle cyprids	1	0.2	7

Table 2. Continued

Sample CC#3
5/11/78
10 stomachs examined
L̄ = 33.6 mm

Prey category	N	%N	%FO
Harpacticoid copepods	62	72.9	80
Calanus spp.	7	8.2	50
*Calanoid copepods	7	8.2	40
Polychaetes	3	3.5	30
Unidentified insects	3	3.5	30
Cumaceans	1	1.2	10
Chaetognaths	1	1.2	10
Amphipods	1	1.2	10

Sample IS#1
5/19/78
10 stomachs examined
L̄ = 34.1 mm

Prey category	N	%N	%FO
Harpacticoid copepods	163	57.0	100
Pseudocalanus spp.	79	27.6	70
Calanus spp.	13	4.5	70
Copepodids	12	4.2	50
Polychaetes	6	2.1	10
Unidentified insects	4	1.4	10
*Calanoid copepods	3	1.0	10
Barnacle cyprids	3	1.0	30
Euphausids (larvae)	2	0.7	20
Amphipods	1	0.3	10

* Calanoid copepods were placed within this group when digestion or missing pieces prevented identification to a lower taxonomic level.

APPENDIX III

The stomach contents of 194 pink salmon fry collected in M-cove during the springs of 1977 and 1978. Total number (N), percent number (%N), and percent frequency of occurrence (%FO) are listed for all prey categories. Dry-weight values from Appendix I for selected prey organisms are used to calculate the total dry-weight (mg) for some prey categories as one indication of their food contribution to the fish. The abundance of each prey category in M-cove's surface water, at the time of fry capture, is given as a percent (P%N) as well as Ivlev's electivity index (E).

APPENDIX III

Table 1. Stomach contents of 86 pink salmon fry taken from M-cove, including prey organism abundance at the time of fry capture in the associated surface waters, between April 28 and June 6, 1977

Sample M#1
4/28/77
15 stomachs examined
$\bar{L}$ = 33.0 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	409	74.9	93	11.0	30.2	+ .43
Harpacticoid copepods	35	6.4	67	*0.5	1.0	+ .73
Larvaceans	32	5.9	27	--	12.5	- .36
Thysanoessa spp.	31	5.7	60	0.6	0.2	+ .93
Calanus plumchrus	21	3.8	67	10.9	5.1	- .15
Oithona similis	7	1.3	13	--	16.7	- .86
Metridia spp.	4	0.7	20	--	0.6	+ .08
Calanoid copepodids	4	0.7	27	--	1.3	- .30
Polychaetes (juveniles)	3	0.5	13	--	1.6	- .52
Acartia longiremis	0	0.0	0	0.0	6.3	-1.00
Cyphonautes larvae	0	0.0	0	0.0	7.3	-1.00

Sample M#2
5/3/77
10 stomachs examined
$\bar{L}$ = 34.6

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	39	31.7	90	1.2	46.3	- .19
***Calanoid copepods	16	13.0	60	--	--	--
Metridia spp.	16	13.0	60	1.3	3.9	+ .54
***Calanus* spp.**	15	12.2	80	7.8	1.0	+ .85
Gadid (larvae)	11	8.9	40	0.9	1.9	+ .65
Polychaetes (juveniles)	10	8.1	60	0.2	0.5	+ .88
Thysanoessa spp.	9	7.3	50	--	0.9	+ .78
Harpacticoid copepods	4	3.3	40	--	1.8	+ .29
Calanoid copepodids	2	1.6	20	--	--	--
Oithona similis	1	0.8	10	--	8.5	- .83
Larvaceans	0	0.0	0	0.0	19.3	-1.00
Acartia longiremis	0	0.0	0	0.0	1.1	-1.00

Table 1. Continued

Sample M#3
5/5/77
11 stomachs examined
$\bar{L}$ = 34.7 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	70	44.9	82	2.3	60.8	- .15
***Calanus* spp.	34	21.8	91	17.1	0.0	+1.00
Harpacticoid copepods	18	11.5	45	*0.3	0.6	+ .90
Fish (larvae)	10	6.4	27	--	0.0	+1.00
Polychaetes (juveniles)	8	5.1	45	--	1.8	+ .48
***Calanoid copepods	8	5.1	45	--	--	--
Metridia spp.	4	2.6	18	0.5	9.6	- .57
Thysanoessa spp.	4	2.6	9	--	0.6	+ .63
Oithona similis	0	0.0	0	0.0	7.8	-1.00
Cyphonautes larvae	0	0.0	0	0.0	6.6	-1.00
Acartia longiremis	0	0.0	0	0.0	3.0	-1.00

Sample M#4
5/9/77
10 stomachs examined
$\bar{L}$ = 36.1 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	411	52.5	100	14.4	28.3	+ .30
Calanoid copepodids	137	17.5	70	--	3.5	+ .67
Metridia spp.	88	11.2	80	5.8	1.2	+ .81
***Calanoid copepods	42	5.4	70	--	--	--
Oithona similis	38	4.9	50	*0.1	49.3	- .82
Harpacticoid copepods	33	4.2	80	+0.5	0.5	+ .79
***Calanus* spp.	14	1.8	50	6.7	4.5	- .43
Polychaetes (juveniles)	13	1.7	40	--	0.1	+ .89
Euphausids (larvae)	3	0.4	30	--	0.3	+ .14
Oncaea spp.	3	0.4	20	--	0.3	+ .14
Acartia longiremis	1	0.1	10	--	4.9	- .96
Cyphonautes larvae	0	0.0	0	0.0	3.4	-1.00

Table 1. Continued

Sample M#5
5/16/77
10 stomachs examined
$\overline{L}$ = 37.4

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	309	66.5	100	*9.3	3.0	+ .91
***Calanus* spp.	56	12.0	90	18.8	6.0	+ .33
Calanoid copepodids	37	8.0	40	--	1.5	+ .68
***Calanoid copepods	17	3.7	60	--	--	--
Metridia spp.	13	2.8	40	*1.1	0.0	+1.00
Parathemisto spp.	13	2.8	20	1.3	1.5	+ .30
Harpacticoid copepods	12	2.6	50	--	7.5	- .49
Oithona similis	3	0.6	20	--	45.9	- .97
Cyphonautes larvae	2	0.4	20	--	5.3	- .86
Polychaetes (juveniles)	2	0.4	10	--	1.5	- .58
Decapods (zoeae)	1	0.2	10	--	0.7	- .56
Acartia longiremis	0	0.0	0	0.0	5.3	-1.00

Sample M#6
5/22/77
10 stomachs examined
$\overline{L}$ = 41.5 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	222	39.2	100	5.8	38.5	+ .01
Exogone spp.	90	15.9	70	--	0.5	+ .94
Metridia spp.	89	15.7	100	6.9	0.0	+1.00
***Calanoid copepods	70	12.4	90	--	--	--
Calanoid copepodids	36	6.4	60	--	7.0	- .04
Harpacticoid copepods	27	4.8	50	*0.4	10.3	- .36
***Calanus* spp.	16	2.8	70	*7.5	0.5	+ .70
Unidentified insects	5	0.9	30	--	0.9	0.00
Oithona similis	5	0.9	30	--	20.7	- .92
Eggs (invertebrate)	3	0.5	10	--	1.4	- .47
Decapods (zoeae)	3	0.5	20	0.0+	6.6	- .86
Copepod nauplii	0	0.0	0	0.0	2.8	-1.00
Acartia longiremis	0	0.0	0	0.0	1.4	-1.00

Table 1. Continued

Sample M#7
5/29/77
10 stomachs examined
L = 42.5 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	698	26.7	100	*20.9	7.6	+ .56
Oithona spp.	629	24.0	70	1.3	45.7	- .31
Metridia spp.	565	21.6	100	*48.0	1.4	+ .88
Copepodids	247	9.4	100	--	5.6	+ .25
***Calanoid copepods	140	5.3	90	--	--	--
Gastropods (juveniles)	79	3.0	60	--	0.0	+1.00
Copepod nauplii	48	1.8	50	--	0.2	+ .80
Barnacle nauplii	45	1.7	50	--	14.2	- .79
Exogone spp.	45	1.7	30	--	0.0	+1.00
***Calanus* spp.	44	1.7	80	*20.7	0.2	+ .79
Harpacticoid copepods	32	1.2	60	0.4	10.1	- .79
Monstrilloid copepods	13	0.5	20	--	0.2	+ .43
Decapods (zoeae)	12	0.5	50	--	0.4	+ .11
Oncaea spp.	9	0.3	30	--	0.4	- .14
Larvaceans	5	0.2	20	--	1.2	- .71
Euphausids (larvae)	4	0.2	30	--	0.0	+1.00
Insects (larvae)	2	0.1	20	--	0.0	+1.00
Acartia longiremis	0	0.0	0	0.0	4.3	-1.00

Sample M#8
6/6/77
10 stomachs examined
L = 56.2 mm

Prey category	N	%N	%FO	mg	P%N	E
Metridia spp.	483	38.2	100	30.9	0.0	+1.00
Larvaceans	434	34.3	100	3.5	42.2	- .10
Pseudocalanus spp.	151	11.9	90	4.7	2.7	+ .63
***Calanoid copepods	65	5.1	70	--	--	--
Copepodids	41	3.2	70	--	6.7	- .35
Harpacticoid copepods	19	1.5	40	--	0.0	+1.00
Gastropods (juveniles)	16	1.3	60	--	2.4	- .30
Ostracods	11	0.9	30	--	0.0	+1.00
Exogone spp.	11	0.9	30	--	0.0	+1.00

Table 1. Continued

Sample M#8 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
***Calanus* spp.	6	0.5	50	*2.8	0.0	+1.00
Evadne spp.	6	0.5	20	--	1.9	- .58
Unidentified insects	6	0.5	10	--	0.0	+1.00
Oithona similis	4	0.3	30	--	25.3	- .98
Decapods (zoeae)	4	0.3	30	--	0.1	+ .50
Copepod nauplii	3	0.2	20	--	3.4	- .89
Barnacle nauplii	2	0.2	10	--	5.5	- .93
Pteropods	2	0.2	10	--	0.0	+1.00
Fish Eggs	1	0.1	10	--	3.5	- .94
Acartia longiremis	0	0.0	0	0.0	0.7	-1.00

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* Average prey organism dry-weight, from Table 1 Appendix D, was used in calculation since no dry-weight value was obtained for the prey organism on that date.

** Refers primarily to *Calanus plumchrus* but also includes *C. marshallae* and *C. pacificus*.

*** Calanoid copepods were placed within this group when digestion or missing pieces prevented identification to a lower taxonomic level.

Table 2. Stomach contents of 108 pink salmon fry taken from M-cove, including prey organism abundance at the time of fry capture in the associated surface waters, between April 5 and June 16, 1978[1]

Sample M#1
4/5/78
16 stomachs examined
$\overline{L}$ = 31.1 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	41	64.1	63	0.6	2.4	+ .93
Barnacle nauplii	7	10.9	38	0.0+	34.2	- .52
Metridia spp.	6	9.4	25	0.3	0.0	+1.00
Harpacticoid copepods	4	6.3	25	*0.1	0.3	+ .91
Euphausids (larvae)	2	3.1	6	--	0.0	+1.00
Decapods (zoeae)	2	3.1	6	--	0.0	+1.00
Amphipods	1	1.6	6	--	0.0	+1.00
Fish (larvae)	1	1.6	6	--	0.3	+ .68
Acartia longiremis	0	0.0	0	0.0	1.4	-1.00
***Calanus* spp.	0	0.0	0	0.0	2.2	-1.00
Oithona similis	0	0.0	0	0.0	17.1	-1.00

Sample M#2
5/2/78
12 stomachs examined
$\overline{L}$ = 33.7 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	94	57.3	83	3.2	11.3	+ .67
Calanus plumchrus	36	22.0	75	18.4	0.2	+ .98
***Calanoid copepods	9	5.5	33	--	--	--
Polychaetes	8	4.9	42	--	0.2	+ .92
Harpacticoid copepods	4	2.4	17	--	0.2	+ .85
Decapods (zoeae)	3	1.8	17	--	0.0	+1.00
Chaetognaths	3	1.8	17	--	0.2	+ .80
Parathemisto spp.	2	1.2	17	--	0.0	+1.00
Euphausids (larvae)	2	1.2	17	--	0.2	+ .71
Barnacle nauplii	2	1.2	17	--	38.3	- .94
Calanoid copepodids	1	0.6	8	--	3.4	- .70

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[1] A zooplankton sample was not collected May 13 with fry sample M#4.

Table 2. Continued

Sample M#2 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
Oithona similis	0	0.0	0	—	30.2	-1.00
Copepod nauplii	0	0.0	0	0.0	4.7	-1.00
Bryozoans (cyphonautes)	0	0.0	0	0.0	4.2	-1.00
Acartia longiremis	0	0.0	0	0.0	1.2	-1.00
Metridia spp.	0	0.0	0	0.0	0.0	0.00

Sample M#3
5/10/78
14 stomachs examined
$\overline{L}$ = 36.8 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	120	42.6	86	2.9	24.1	+ .28
Calanus plumchrus	54	19.1	93	49.6	46.1	- .41
Harpacticoid copepods	39	13.8	43	*0.7	0.2	+ .97
Metridia spp.	25	8.9	21	*1.8	0.2	+ .96
***Calanoid copepods	25	8.9	21	—	—	—
Unidentified insects	14	5.0	21	—	0.0	+1.00
Thysanoessa spp.	3	1.1	14	—	0.2	+ .69
Polychaetes	1	0.4	7	—	0.6	- .20
Decapods (zoeae)	1	0.4	7	—	0.0	+1.00
Oithona similis	0	0.0	0	—	8.1	-1.00
Acartia longiremis	0	0.0	0	—	7.8	-1.00

Table 2. Continued

Sample M#4
5/13/78
14 stomachs examined
$\bar{L}$ = 35.0 mm

Prey category	N	%N	%FO	mg	P%N	E
Harpacticoid copepods	211	52.4	79	1.3	--	--
Exogone spp.	68	16.9	50	*2.2	--	--
Pseudocalanus spp.	63	15.6	71	*1.6	--	--
Calanus plumchrus	17	4.2	57	*12.2	--	--
Metridia spp.	16	4.0	36	*1.1	--	--
Acartia longiremis	9	2.2	29	--	--	--
Oithona similis	7	1.7	21	--	--	--
Decapods (zoeae)	6	1.5	21	--	--	--
Calanoid copepodids	2	0.5	7	--	--	--
Barnacle cyprids	2	0.5	7	--	--	--
Euphausids (larvae)	1	0.2	7	--	--	--
***Calanoid copepods	1	0.2	7	--	--	--

Sample M#5
5/27/78
14 stomachs examined
$\bar{L}$ = 42.0 mm

Prey category	N	%N	%FO	mg	P%N	E
Harpacticoid copepods	227	46.9	93	*4.1	1.5	+ .94
Pseudocalanus spp.	99	20.5	86	2.3	21.8	- .03
Exogone spp.	89	18.4	79	3.1	0.4	+ .96
***Calanus* spp.	17	3.5	64	3.9	0.4	+ .79
Monstrilloid copepods	17	3.5	14	--	0.0	+1.00
Barnacle cyprids	14	2.9	43	*0.6	0.4	+ .76
***Calanoid copepods	5	1.0	7	--	--	--
Acartia longiremis	4	0.8	21	--	24.9	- .94
Metridia spp.	3	0.6	14	--	0.8	- .14
Calanoid copepodids	3	0.6	7	--	10.0	- .89
Amphipods	2	0.4	7	--	0.0	+1.00
Unidentified insects	2	0.4	14	--	0.0	+1.00
Euphausids (larvae)	1	0.2	7	--	0.0	+1.00
Oikopleura spp.	1	0.2	7	--	5.0	- .92
Oithona similis	0	0.0	0	0.0	17.6	-1.00
Barnacle nauplii	0	0.0	0	0.0	5.0	-1.00

Table 2. Continued

Sample M#6
6/3/78
12 stomachs examined
$\bar{L}$ = 45.8 mm

Prey category	N	%N	%FO	mg	P%N	E
Pseudocalanus spp.	304	34.9	92	7.0	0.8	+ .96
Harpacticoid copepods	179	20.6	92	3.8	2.8	+ .76
Exogone spp.	58	6.7	50	*1.9	0.0	+1.00
Calanoid copepodids	54	6.2	58	--	6.3	- .01
Larvaceans	50	5.7	75	*0.3	10.7	- .30
Copepod nauplii	39	4.5	58	--	3.6	+ .11
Calanus cristatus	28	3.2	42	*50.1	0.0	+1.00
Thysanoessa spp.	22	2.5	83	--	0.0	+1.00
Acartia longiremis	21	2.4	58	--	43.1	- .89
Calanoid copepods	21	2.4	58	--	--	--
Metridia spp.	16	1.8	58	*1.1	0.0	+1.00
***Calanus* spp.	15	1.7	50	*7.7	0.0	+1.00
Parathemisto spp.	15	1.7	33	--	0.0	+1.00
Unidentified insects	13	1.5	25	--	0.0	+1.00
Unidentified organisms	10	1.1	8	--	--	--
Monstrilloid copepods	6	0.7	25	--	0.0	+1.00
Oithona similis	5	0.6	33	--	13.8	- .92
Fish (larvae)	4	0.5	17	--	0.0	+1.00
Eggs (invertebrate)	3	0.3	25	--	5.5	- .90
Barnacle cyprids	2	0.2	17	--	0.4	- .33
Bryozoans (cyphonautes)	2	0.2	8	--	2.8	- .87
Ostracods	2	0.2	8	--	0.0	+1.00
Decapods (zoeae)	1	0.1	8	--	0.4	- .60

Sample M#7
6/9/78
12 stomachs examined
$\bar{L}$ = 50.3 mm

Prey category	N	%N	%FO	mg	P%N	E
Harpacticoid copepods	1539	80.4	92	33.9	1.0	+ .98
Larvaceans	97	5.1	83	0.6	23.9	- .65
Exogone spp.	67	3.5	75	2.0	0.3	+ .84
Barnacle cyprids	31	1.6	42	*1.4	0.3	+ .68
Fish (larvae)	26	1.4	50	41.8	0.0	+1.00
***Calanoid copepods	25	1.3	58	--	--	--

Table 2. Continued

Sample M#7 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
Decapods (zoeae)	21	1.1	58	--	0.6	+ .29
Gastropods (larvae)	21	1.1	33	--	5.9	- .69
Calanus cristatus	16	0.8	33	16.9	0.0	+1.00
Amphipods	11	0.6	67	--	0.1	+ .71
Metridia spp.	10	0.5	25	*0.7	0.0	+1.00
Chaetognaths	7	0.4	25	--	0.1	+ .60
Unidentified insects	7	0.4	42	--	0.0	+1.00
***Calanus* spp.	7	0.4	25	*3.6	0.0	+1.00
Pseudocalanus spp.	6	0.3	25	--	1.2	- .60
Euphausids (larvae)	4	0.2	25	--	0.3	- .20
Ostracods	4	0.2	25	--	0.0	+1.00
Turbellaria	4	0.2	8	--	0.0	+1.00
Monstrilloid copepods	3	0.2	8	--	0.0	+1.00
Cumaceans	2	0.1	17	--	0.0	+1.00
Barnacle nauplii	2	0.1	17	--	16.7	- .99
Epilabidocera amphitrites	1	0.1	8	--	0.0	+1.00
Centropages spp.	1	0.1	8	--	1.3	- .86
Fish (eggs)	1	0.1	8	--	0.0	+1.00
Oithona similis	0	0.0	0	0.0	12.6	-1.00
Acartia longiremis	0	0.0	0	0.0	7.8	-1.00
Evadne spp.	0	0.0	0	0.0	6.8	-1.00

Sample M#8
6/16/78
14 stomachs examined
$\bar{L}$ = 51.4 mm

Prey category	N	%N	%FO	mg	P%N	E
Harpacticoid copepods	540	21.6	100	9.7	0.5	+ .95
Larvaceans	540	21.6	86	*3.2	18.4	+ .08
Metridia spp.	439	17.5	79	26.8	0.0	+1.00
Copepod nauplii	289	11.5	86	--	2.7	+ .62
Eggs (invertebrate)	163	6.5	57	--	7.7	- .08
Pseudocalanus spp.	88	3.5	86	*2.2	0.5	+ .75
Exogone spp.	85	3.4	93	*2.8	0.1	+ .94
Decapods (zoeae)	78	3.1	79	--	0.0	+1.00
***Calanoid copepods	47	1.9	29	--	--	--

Table 2. Continued

Sample M#8 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
Amphipods	44	1.8	50	--	0.0	+1.00
Calanoid copepodids	33	1.3	50	--	6.3	- .66
Evadne spp.	31	1.2	50	--	5.1	- .62
Unidentified insects	24	1.0	50	--	0.0	+1.00
Gastropods (larvae)	17	0.7	50	--	0.0	+1.00
Podon spp.	16	0.6	43	--	0.0	+1.00
Barnacle cyprids	15	0.6	29	--	0.4	+ .20
Calanus spp.	13	0.5	29	*6.6	0.0	+1.00
Calanus cristatus	9	0.4	43	*16.1	0.0	+1.00
Oithona similis	9	0.4	29	--	9.9	- .92
Centropages spp.	6	0.3	14	--	0.1	+ .50
Barnacle nauplii	4	0.2	14	--	0.1	+ .33
Thysanoessa spp.	4	0.2	21	--	1.3	- .73
Epilabidocera amphitrites	2	0.1	14	--	0.0	+1.00
Acartia longiremis	2	0.1	14	--	4.1	- .95
Cumaceans	1	0.0+	7	--	0.0	--
Monstrilloid copepods	1	0.0+	7	--	0.0	--
Bryozoans (cyphonautes)	1	0.0+	7	--	0.6	--
Fish (larvae)	1	0.0+	7	--	0.0	--
Chaetognaths	1	0.0+	7	--	0.2	--
Ophiopluteus	1	0.0+	7	--	2.2	--
Noctiluca spp.	0	0.0	0	0.0	36.4	-1.00

* Average prey organism dry-weight, from Table 2 Appendix D, was used in calculation since no dry-weight value was obtained for the prey organism on that date.

** Refers primarily to *Calanus plumchrus* but also includes *C. marshallae* and *C. pacificus*.

*** Calanoid copepods were placed within this group when digestion or missing pieces prevented identification to a lower taxonomic level.

APPENDIX IV

Fry samples collected in Sawmill Bay

APPENDIX IV

Table 1. Twelve pink salmon fry samples[1] collected in Sawmill Bay between April 8 and April 22, 1977

Sample	Date collected	Number of fry (N)	Average fork-length (mm)	Range (mm)	σ (mm)	Average wet-weight (g)	Number of fry examined (n)	Average fork-length (mm)	s (mm)
F#3	4/8	13	32.0	31-34	1.0	0.19	8	31.9	1.0
B#1	4/10	15	29.9	28-30	1.1	--	15	29.9	1.1
HPB#2	4/10	65	30.0	27-33	1.5	0.19	16	30.6	1.7
G#1	4/12	27	31.0	28-34	1.4	0.19	20	31.6	1.4
HPB#3	4/12	65	30.7	29-34	1.1	0.22	20	31.8	1.3
F#4	4/12	33	30.8	28-33	1.1	0.20	20	30.9	1.2
A#1	4/15	43	31.0	27-34	1.6	0.19	15	32.3	1.2
H#1	4/15	18	31.1	29-33	1.6	0.20	15	31.2	1.6
K#1	4/19	61	32.0	29-35	1.3	0.22	15	32.5	0.9
B#2	4/20	8	30.8	27-33	2.2	--	8	30.8	2.2
A#2	4/22	265	31.9	30-35	1.1	0.23	15	32.5	0.6
H#2	4/22	15	31.0	29-34	1.2	--	15	31.0	1.2

[1] The stomach contents of 182 fry from these samples were examined.

Table 2. Six pink salmon fry samples[1] collected in Sawmill Bay between April 3 and May 19, 1978

Sample	Date collected	Number of fry (N)	Average fork-length (mm)	Range (mm)	σ (mm)	Average wet-weight (g)	Number of fry examined (n)	Average fork-length (mm)	s (mm)
H#1	4/3	75	32.1	29–35	1.1	0.21	20	32.0	1.3
PB#1	4/9	167	31.9	29–34	1.0	0.21	15	31.6	0.9
CC#1	4/10	132	31.2	29–34	1.0	0.22	15	31.1	1.0
CC#2	5/1	102	31.1	28–33	1.5	0.19	15	31.7	0.8
CC#3	5/11	94	32.1	28–43	2.6	0.23	10	33.6	3.4
IS#1	5/19	202	33.8	30–45	1.7	0.29	10	34.1	2.5

[1] The stomach contents of 82 fry from these samples were examined.

APPENDIX V

Fry samples collected in M-cove

APPENDIX V

Table 1. Eight pink salmon fry samples[1] collected in M-cove between April 28 and June 6, 1977

Sample	Date collected	Number of fry (N)	Average fork-length (mm)	Range (mm)	σ (mm)	Average wet-weight (g)	Number of fry examined (n)	Average fork-length (mm)	s (mm)
M#1	4/28	80	32.0	29-36	1.4	0.24	15	33.0	1.9
M#2	5/3	73	34.3	30-39	2.1	0.29	10	34.6	2.0
M#3	5/5	139	35.0	31-42	2.2	0.31	11	34.7	1.3
M#4	5/9	144	36.0	32-45	2.4	0.32	10	36.1	2.5
M#5	5/16	220	36.8	30-52	3.9	0.44	10	37.4	3.4
M#6	5/22	505	39.4	29-57	6.1	0.51	10	41.5	5.5
M#7	5/29	177	40.1	32-56	6.4	0.52	10	42.5	7.1
M#8	6/6	111	55.1	39-71	7.3	1.66	10	56.2	9.7

[1] The stomach contents of 86 fry from these samples were examined.

Table 2. Eight pink salmon fry samples[1] collected in M-cove between April 5 and June 16, 1977

Sample	Date collected	Number of fry (N)	Average fork-length (mm)	Range (mm)	σ (mm)	Average wet-weight (g)	Number of fry examined (n)	Average fork-length (mm)	s (mm)
M#1	4/5	54	30.4	28-33	1.1	0.19	16	31.1	1.0
M#2	5/2	118	33.1	30-38	1.6	0.27	12	33.7	1.7
M#3	5/10	190	35.3	29-44	3.0	0.34	14	36.8	3.6
M#4	5/13	191	33.9	30-43	2.4	0.28	14	35.0	2.5
M#5	5/27	239	40.5	31-55	5.2	0.57	14	42.0	5.4
M#6	6/3	281	43.9	29-66	7.0	0.76	12	45.8	7.5
M#7	6/9	215	48.1	31-69	8.2	1.03	12	50.3	9.1
M#8	6/16	253	49.6	32-72	7.2	1.07	14	51.4	6.4

[1] The stomach contents of 108 fry from these samples were examined.

APPENDIX VI

Salmon fry samples and the results of stomach contents analyses

APPENDIX VI

Table 1. The dates, location, and number of fry of each species, the average fork-lengths and weights, and the number of fry examined for stomach contents from each sample

Date	Sample Site	Salmon Species	n	Average Fork-length (mm)	Average Weight (g)	Number Examined
May 1	CC	Chum	88	34.5	0.31	20
		Pink	102	31.1	0.19	20
May 11	CC	Chum	109	34.5	0.36	20
		Pink	94	32.1	0.23	20
May 19	B	Chum	39	36.4	0.41	10
		Pink	142	35.8	0.36	10
	Is	Chum	33	37.2	0.44	10
		Pink	202	33.8	0.29	10
May 27	BL	Chum	52	40.0	0.56	10
		Pink	105	37.6	0.42	10
June 4	B	Chum	243	41.7	0.66	10
		Pink	92	47.4	0.94	10
	BL	Chum	89	47.1	0.99	10
		Pink	263	49.2	1.08	10
June 11	B	Chum	267	44.4	0.83	10
		Pink	59	58.4	1.87	10
	BL	Chum	115	48.7	1.09	10
		Pink	145	54.0	1.43	10
June 20	B	Chum	145	43.0	0.69	10
		Pink	26	46.7	0.78	10
	BL	Chum	41	52.0	1.26	10
		Pink	110	61.6	2.08	10
June 27	BL	Chum	155	53.1	1.46	10
		Pink	129	52.5	1.21	10

Table 2. Results of stomach analyses. Listed for each prey taxa are the number (N), percent number (%N), and percent frequency of occurrence (%FO). (A + indicates a value less than 0.1)

Date: May 1, 1978
Week: 1

Number of samples: 1
Sample site: CC

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 34.6 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 31.9 mm N	%N	%FO
Harpacticoid copepods	552	74.6	85	427	87.3	80
Diptera (adult)	154	20.8	75	3	0.6	15
Diptera (larvae)	5	0.7	10	1	0.2	5
Amphipod (gammarid)	13	1.8	35	1	0.2	5
Calanus spp.	0	-	-	2	0.4	10
Polychaete (larvae)	4	0.5	10	2	0.4	10
Pseudocalanus spp.	5	0.7	20	52	10.6	60
Barnacle cyprids	6	0.8	20	1	0.2	5
Coleoptera (adult)	1	0.1	5	0	-	-
TOTAL	740			489		

Date: May 11, 1978
Week: 2

Number of samples: 1
Sample site: CC

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 35.2 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 33.4 mm N	%N	%FO
Harpacticoid copepods	198	41.0	60	134	69.8	70
Diptera (adult)	252	52.2	80	6	3.1	25
Diptera (larvae)	0	-	-	1	0.5	5
Pseudocalanus spp.	6	1.2	15	8	4.2	25
Calanus spp.	13	2.7	45	17	8.9	45
Barnacle cyprids	7	1.5	15	1	0.5	5
Barnacle nauplii	0	-	-	1	0.5	5
Polychaete (larvae)	6	1.2	5	19	9.9	15
Amphipod (gammarid)	0	-	-	2	1.1	10
Chaetognath	0	-	-	1	0.5	5
Cumacea	0	-	-	1	0.5	5
Acartia tumida	1	0.2	5	0	-	-
Fish larvae	0	-	-	1	0.5	5
TOTAL	483			192		

Table 2. Continued

Date: May 19, 1978
Week: 3

Number of samples: 2
Sample sites: B, Is

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 36.6 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 34.9 mm N	%N	%FO
Harpacticoid copepods	504	81.3	90	248	28.1	95
Diptera (adults)	67	10.8	55	4	0.4	5
Calanus spp.	15	2.4	30	28	3.2	75
Pseudocalanus spp.	1	0.2	5	456	51.8	85
Calanoid copepods (unident.)	0	-	-	3	0.3	5
Calanoid copepodids	0	-	-	20	2.3	30
Acartia spp.	0	-	-	20	2.3	10
Amphipods (gammarid)	1	0.2	5	12	1.4	25
Euphausids (furcillia)	2	0.3	5	10	1.1	45
Barnacle cyprids	7	1.1	20	6	0.7	25
Barnacle nauplii	0	-	-	59	6.7	15
Copepod nauplii	0	-	-	6	0.7	5
Polychaete (larvae)	23	3.7	15	6	0.7	5
Epilabidocera amphitrites	0	-	-	2	0.2	5
Acarina	0	-	-	1	0.1	5
TOTAL	620			881		

Date: May 27, 1978
Week: 4

Number of samples: 1
Sample site: BL

Prey taxa	CHUM FRY n = 10 $\overline{FL}$ = 40.0 mm N	%N	%FO	PINK FRY n = 10 $\overline{FL}$ = 38.7 mm N	%N	%FO
Harpacticoid copepods	92	37.3	80	233	58.4	90
Cumacea	77	31.2	40	35	8.9	30
Diptera (adult)	62	25.1	100	0	-	-
Pseudocalanus spp.	0	-	-	84	21.1	80
Barnacle nauplii	0	-	-	27	6.8	30
Barnacle cyprids	3	1.2	20	4	1.0	20
Acartia spp.	0	-	-	8	2.0	30
Amphipod (gammarid)	6	2.4	30	1	0.2	10
Trichoptera (larvae)	3	1.2	30	0	-	-
Calanus spp.	2	0.8	20	0	-	-
Euphausid (furcillia)	1	0.4	10	2	0.5	20
Isopods	1	0.4	10	1	0.2	10
Copepod nauplii	0	-	-	2	0.5	10
Polychaete (larvae)	0	-	-	1	0.2	10
Acarina	0	-	-	1	0.2	10
TOTAL	247			399		

Table 2. Continued

Date: June 4, 1978
Week: 5

Number of samples: 2
Sample sites: B, BL

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 44.7 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 47.0 mm N	%N	%FO
Harpacticoid copepods	270	35.3	85	184	32.3	75
Diptera (adult)	38	5.0	70	9	1.6	20
Diptera (larvae)	10	1.3	25	2	0.3	10
Cumacea	94	12.3	25	2	0.3	10
Larvacea	50	6.5	25	13	2.3	35
Pseudocalanus spp.	1	0.1	5	210	36.8	70
Calanus spp.	0	-	-	49	8.6	65
Metridia spp.	0	-	-	40	7.0	20
Cyphonautes larvae	210	27.4	20	1	0.2	5
Barnacle cypris	23	3.0	45	13	2.3	25
Barnacle nauplii	19	2.5	30	7	1.2	15
Calanoid copepodids	2	0.3	10	11	1.9	5
Copepod nauplii	4	0.5	10	1	0.2	5
Amphipod (gammarid)	3	0.4	10	4	0.7	20
Amphipod (hyperiid)	3	0.4	10	4	0.7	15
Euphausid (calyptopis)	0	-	-	2	0.3	5
Euphausid (furcillia)	2	0.3	10	5	0.9	10
Crab zoea	1	0.1	5	0	-	-
Acarina	1	0.1	5	0	-	-
Pteropods	14	1.8	10	0	-	-
Gastropod egg cases	12	1.6	25	2	0.3	10
Fish larvae	1	0.1	5	5	0.9	20
Lamellibranch (larvae)	3	0.4	10	0	-	-
Isopods	2	0.3	5	0	-	-
Polychaete (trochophore)	1	.1	5	1	0.2	5
Polychaete (larvae)	0	-	-	1	0.2	5
Acartia spp.	1	0.1	5	0	-	-
Eurytemora herdmani	1	0.1	5	0	-	-
Oithona spp.	0	-	-	1	0.2	5
Chaetognath	0	-	-	2	0.3	10
Fish eggs	0	-	-	1	0.2	5
TOTAL	766			570		

Table 2. Continued

Date: June 11, 1978
Week: 6

Number of samples: 2
Sample sites: B, BL

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 46.1 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 55.1 mm N	%N	%FO
Harpacticoid copepods	999	58.5	80	170	37.6	75
Larvacea	425	24.9	55	119	26.3	65
Diptera (adult)	103	6.0	75	13	2.9	40
Diptera (larvae)	17	1.0	35	0	-	-
Cumacea	39	2.3	30	0	-	-
Pseudocalanus spp.	2	0.1	10	38	8.4	45
Calanus spp.	0	-	-	27	6.0	35
Metridia spp.	0	-	-	14	3.1	20
Acartia spp.	0	-	-	3	0.7	5
Evadne spp.	5	0.3	15	3	0.7	10
Barnacle cyprids	17	1.0	35	19	4.2	55
Amphipods (gammarid)	18	1.0	50	7	1.6	10
Amphipods (hyperiid)	1	0.1	5	2	0.4	10
Gastropod egg cases	3	0.2	15	23	5.1	20
Fish larvae	1	0.1	5	6	1.3	20
Trichoptera (larvae)	1	0.1	5	0	-	-
Acarina	6	0.3	20	2	0.4	10
Nematoda	4	0.2	15	1	0.2	5
Euphausid (furcillia)	1	0.1	5	1	0.2	5
Euphausid (adult)	0	-	-	1	0.2	5
Coleoptera (adult)	0	-	-	1	0.2	5
Polychaete (larvae)	20	1.2	15	0	-	-
Crab zoea	16	0.9	25	2	0.4	5
Pteropods	11	0.6	15	0	-	-
Fish eggs	10	0.6	10	0	-	-
Barnacle nauplii	1	0.1	5	0	-	-
Ostracods	5	0.3	15	0	-	-
Araneae	1	0.1	5	0	-	-
TOTAL	1706			452		

Table 2. Continued

Date: June 20, 1978
Week: 7

Number of samples: 2
Sample sites: B, BL

Prey taxa	CHUM FRY n = 20 $\overline{FL}$ = 51.1 mm N	%N	%FO	PINK FRY n = 20 $\overline{FL}$ = 53.7 mm N	%N	%FO
Harpacticoid copepods	581	17.3	60	688	38.5	80
Larvacea	2200	65.7	65	215	12.0	50
Diptera (adult)	42	1.3	60	5	0.3	20
Diptera (larvae)	133	4.0	20	11	0.6	20
Cumacea	50	1.5	20	1	0.1	5
Pseudocalanus spp.	34	1.0	45	193	10.8	80
Calanus spp.	5	0.1	10	121	6.8	50
Metridia spp.	26	0.8	20	363	20.3	50
Evadne spp.	14	0.4	25	8	0.4	30
Podon spp.	1	+	5	0	-	-
Barnacle cyprids	16	0.5	25	53	3.0	60
Barnacle nauplii	2	0.1	5	1	0.1	5
Copepod nauplii	2	0.1	5	5	0.3	15
Euphausid (nauplii)	13	0.4	25	3	0.2	15
Euphausid (furcillia)	4	0.1	20	12	0.7	40
Amphipod (gammarid)	14	0.4	35	13	0.7	25
Amphipod (hyperiid)	15	0.4	35	21	1.2	55
Polychaete (larvae)	27	0.8	40	5	0.3	15
Polychaete (trochophore)	5	0.1	15	0	-	-
Polychaete (adult)	1	+	5	0	-	-
Chaetognath	8	0.2	15	20	1.1	35
Eggs (unidentified)	95	2.8	35	10	0.5	15
Fish eggs	20	0.6	30	4	0.2	15
Fish larvae	6	0.2	15	4	0.2	15
Isopods	1	+	5	0	-	-
Oithona spp.	1	+	5	1	0.1	5
Ophiopluteus	1	+	5	0	-	-
Gastropod egg cases	3	0.1	15	1	0.1	5
Insect (unidentified)	1	+	5	0	-	-
Conchoecia sp.	7	0.2	15	24	1.3	30
Crab zoea	13	0.4	5	4	0.2	5
Pteropods	1	+	5	0	-	-
Acarina	2	0.1	10	1	0.1	5
Araneae	1	+	5	0	-	-
Hemiptera (adult)	3	0.1	10	0	-	-
Pseudoscorpiones	1	+	5	0	-	-
TOTAL	3349			1787		

Table 2. Continued

Date: June 27, 1978
Week: 8

Number of samples: 1
Sample site: BL

	CHUM FRY n = 10 $\overline{FL}$ = 53.6 mm			PINK FRY n = 10 $\overline{FL}$ = 52.5 mm		
Prey taxa	N	%N	%FO	N	%N	%FO
Larvacea	2527	67.6	100	964	21.1	100
Evadne spp.	615	16.1	100	478	10.4	100
Copepod nauplii	341	9.0	100	2469	53.9	100
Oithona spp.	208	5.5	80	387	8.5	80
Eggs (unidentified)	0	-	-	104	2.3	60
Euphausid (nauplii)	0	-	-	79	1.7	60
Calanoid copepodids	0	-	-	54	1.2	40
Pteropods	21	0.5	70	5	0.1	20
Harpacticoid copepods	16	0.4	40	7	0.2	40
Pseudocalanus spp.	5	0.1	20	11	0.2	50
Barnacle cyprids	5	0.1	40	0	-	-
Barnacle nauplii	3	0.1	20	4	0.1	20
Polychaete (trochophore)	4	0.1	20	0	-	-
Polychaete (larvae)	2	0.1	20	0	-	-
Crab zoea	2	0.1	20	0	-	-
Acartia spp.	1	+	10	2	+	20
Acarina	1	+	10	0	-	-
Amphipods (hyperiid)	2	0.1	10	0	-	-
Euphausid (calyptopis)	2	0.1	20	2	+	10
Scyphozoa (larvae)	1	+	10	0	-	-
Lamellibranch (larvae)	1	+	10	0	-	-
Fish eggs	2	0.1	20	4	0.1	20
Diptera (adult)	1	+	10	0	-	-
Trichoptera (larvae)	1	+	10	0	-	-
Podon spp.	1	+	10	3	0.1	20
Euphausid (furcillia)	0	-	-	1	+	10
Cumacea	0	-	-	4	0.1	10
TOTAL	3807			4579		