THE FEEDING, MOVEMENT, AND GROWTH OF PINK SALMON, *ONCORHYNCHUS GORBUSCHA*, FRY RELEASED FROM A HATCHERY IN PRINCE WILLIAM SOUND, ALASKA

RECOMMENDED:

Chairman, Advisory Committee

Program Head

Director of Division of Marine Science

APPROVED:

Dean of the College of Environmental Sciences

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Date

Vice Chancellor for Research and Advanced Study

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A

THESIS

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David Lindsay Urquhart, A.B.
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ABSTRACT

As part of a study that investigated the ability of Prince William Sound to support large numbers of juvenile salmon, the movements, feeding, and growth of pink salmon, *Oncorhynchus gorbuscha*, fry released in the springs of 1977 and 1978 from the Port San Juan hatchery, are described. Fry were released in Sawmill Bay but preferred the waters of adjacent Elrington Passage where they remained for up to two months. Nursery areas in the Passage established by the fry in 1977 were not occupied to the same degree in 1978. Fry fed initially on epibenthic harpacticoid copepods but soon switched to feeding on calanoid copepods. Fry growth rates and diet are comparable with results of other studies. Fry behavior affected sampling and may account for between-year differences detected in growth. Weather, food abundance, and the condition of outmigrants may also account for between-year differences in fry behavior and growth.

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CHAPTER 1

INTRODUCTION

1.1 The Life History of Alaskan Pink Salmon: A Synopsis

The pink (humpback) salmon, *Oncorhynchus gorbuscha*, is one of the seven species collectively known as Pacific salmon. It is the smallest and most abundant of the five species of Pacific salmon found in Alaska which also include the chinook (king), chum (dog), coho (silver), and sockeye (red). The natural range of the pink salmon encompasses both the coastal and open ocean zones of the entire North Pacific from approximately 40°N latitude through the Bering Strait, and the coastal regions bordering the Arctic Ocean as far west as the mouth of the Lena River and east to the McKenzie River (Neave, 1958, 1962).

Adult pink salmon return from the pelagic zones of the North Pacific from July through September each year to spawn. In Alaska spawning takes place in small coastal streams, frequently within the intertidal zone (Bailey, 1969). A few stocks of pink salmon in other areas of North America travel several hundred kilometers up larger rivers before spawning in smaller tributaries (Neave, 1966).

Females deposit between 1500 and 2500 eggs in depressions (redds) dug in the gravel of streambeds during several pairings with different males (Helle, 1976). Milt and eggs are deposited in the redd simultaneously and then covered with sand and gravel by the female. The eggs incubate for 60 to 90 days before hatching. Once free of the chorion (egg case) the larval pink salmon (alevins) move deeper into the substrate and spend the next few months developing within the interstices of the streambed gravel (Hunter, 1959).

Development and the timing of pink fry emergence is determined by stream temperatures during the incubation period (Sheridan, 1962). When yolk reserves are nearly depleted and development about complete, the fry migrate individually upward out of the gravel. In Alaska this takes place during April and May and for a stock spans a period of about a month. Pink salmon fry have a fork-length of approximately 32 mm at this stage in their development.

Downstream migration takes place at night (Neave, 1955; MacDonald, 1960), and unless the trip is protracted because of distance from the coast, no food items are taken until the fry is established within saltwater. Once in an estuary, pink salmon fry form tight schools that remain near the surface (Hoar *et al.*, 1957; Hoar, 1958). Feeding is initiated in the estuary, and the schools soon begin moving along the shore toward the sea. The pink fry gradually move into deeper water as summer progresses. By August many individuals exceed 100 mm in length, and are found well offshore moving out to sea (Manzer and Shepard, 1962). Little is known about the ecology and behavior of pink salmon in the ocean. Pinks are thought to be one of the more planktophagous species of salmon, and reportedly have a diet similar to that of the sockeye (Ishida, 1966).

Mature adult pink salmon reenter the coastal zone after spending 12 to 14 months at sea. In some poorly understood way that involves the sense of smell, at least nearshore, individual fishes are able to find their way back to the streams where life for them began two years before (Hasler *et al.*, 1978). On the average only about 2 percent of the pink salmon fry survive the marine period of their existence to return and spawn. This percentage varies from year to year.

Once near shore adult pink salmon begin the most drastic metamorphosis in color and shape found among members of the genus *Oncorhynchus* (Neave, 1958). They cease to feed, and their silver scales are reabsorbed and replaced by a white belly and dark sides with black spots on the tail and back. The teeth and jaws are elongated and enlarged, particularly in the male which also develops the characteristic hump for which the species is often named. After about two weeks in fresh or brackish water, the changes are complete. The adult fish then move upstream, pair off and spawn. The commitment of body resources to reproduction is total and in all instances results in death a few days later.

1.2 The History of Commercial Pink Salmon Fishing and Enhancement in Alaska: A Synopsis

Because of their relative abundance, pink salmon are referred to as the "bread and butter" fish of the Alaskan salmon industry (Bailey, 1969). Today, pinks consistently represent more than half of the total annual Pacific salmon catch in North America, even though they are less valuable than any of the other four Alaskan species on a per pound basis.

Commercial harvest of Alaska's salmon began in 1878 with construction of two canneries in southeast Alaska. Processing companies had exhausted the stocks of salmon in California and Washington, so with the availability of new territory recently purchased from Russia, the push to the north and west began. Six canneries were operating in Alaska by 1885; development had reached Bristol Bay. Initially, this was a period of unbridled exploitation. Dams and weirs were used to barricade streams and many runs of salmon were totally destroyed (Rogers, 1976).

Federal management of the territorial fisheries began with the Alaska Salmon Act of 1896 which outlawed barricades and established closed fishing periods (Royce, 1962). Government agents were sent to Alaska to study the problem and report in detail. Federal programs encouraged the cannery operators to consider establishment of hatcheries as the means of maintaining the stocks. Concern for the plight of the salmon surfaced as early as 1891 with the construction of the first hatchery on Kodiak Island (Hunt, 1976). This venture failed, but other attempts were made, and by 1914 five private and two federal sockeye salmon hatcheries were in existence. Until after World War I these hatcheries represented the only efforts made toward conservation or regulation while the salmon industry continued to grow. Forty-two canneries were operating in Alaska in 1900, 146 in 1920, and by 1929 there were 159 (Royce, 1962).

When the salmon failed to return to the hatcheries, it became obvious that the biology and requirements of the fish were not well understood. In the 1920's other management strategies concerning escapement, fishing in streams, closures, and the spacing of traps were tried. The use of gill nets and seines was encouraged. Laws were enforced for the first time. Relaxation of this control came with the fall of the stock market in 1929. Money stopped flowing and by 1934 none of the hatcheries were operating. Yet, salmon production continued to climb.

Salmon were packed in one-pound cans with 48 cans to the case. At the turn of the century, about 2.5 million cases were packed each year. This production climbed to an average of 5 million cases during the 1920's (Rogers, 1976). Production peaked during the period 1935-1939 when the total catch of salmon averaged nearly 100 million fish per year. Over eight million cases of salmon were packed in 1936. Thereafter, the effects of decades of overfishing and poor stock recruitment caused production to decline until 1959 when only 1.5 million cases of canned salmon made up the Alaska pack. Fewer than 60 canneries were operating in the state in 1960.

Initially, the canners had concentrated on catching the valuable sockeye salmon, actively avoiding only the less palatable chum salmon. Pink salmon production expanded rapidly, beginning in 1910, as demand for canned salmon increased. Canned pink salmon dominated the pack by 1925. The total catch of pink salmon in Alaska averaged 60 million fish a year from 1934 to 1943. Pink production peaked in 1941 when 4.6 million cases were packed, but after that it too declined. By 1959 pink salmon production was down to 600,000 cases. Fifty-nine percent of the total decline in production of Alaskan canned salmon was attributable to decreases in the pink salmon catch (McNeil, 1976).

Federal funds for salmon management and research again became available after 1950, permitting enforcement of new gear restrictions, complete closure of some districts to fishing, and the establishment of research programs. The State of Alaska obtained management responsibility for salmon in 1960. The total catch of salmon made moderate recovery during the first years of the following decade but fell again in 1967. During the first half of the 1970's, the total salmon catch remained low, averaging only 30 million fish per year.

In efforts to halt the decline in catch, the State created the Fisheries Rehabilitation and Enhancement Division (FRED) of the Alaska Department of Fish and Game. In 1971 FRED implemented a program to establish an array of carefully planned and technologically advanced salmon hatcheries in cooperation with the National Marine Fisheries Service (NMFS). NMFS currently operates two field stations in southeast Alaska where research into the biology and artificial propagation of salmon is conducted. Together these agencies hope to bring Alaska's stocks of salmon to former levels of abundance through release of hundreds of millions of artificially reared salmon fry each year (Wilson and Buck, 1978). Also, provision was made to stablilize the industry in 1974 by limiting the entry of fishermen into the commercial salmon fishery. The Private Nonprofit Salmon Hatchery Act of 1974 was enacted to provide the public sector with the means through which it might actively participate in the rehabilitation of the common property salmon fishery (Robinson, 1976).

Today, FRED has plans for releasing artificially reared salmon fry from 18 hatcheries around the state by 1980. FRED officials hope that the annual commercial catch of salmon will be over 100 million fish by the year 2000. Despite the hazards associated with a salmon rehabilitation program heavily dependent on artificial propagation (Bams, 1976; Helle, 1976), 40 percent of Alaska's planned future salmon catch are to be hatchery reared fish (Wilson and Buck, 1978).

Though salmon enhancement programs in the State of Alaska have just begun, there is reason to believe the stocks of salmon will now increase in abundance. The public has exhibited a willingness to support the activities of FRED, and several private non-profit hatcheries are now operating. With research has come a better understanding of what it takes to rear salmon in an artificial environment. Finally, and possibly as a result of careful management of wild stocks by the Alaska Department of Fish and Game, the annual catch of salmon has increased every year since 1974. In 1978 the total catch of salmon in Alaska was 80.2 million fish of which 66 percent were pink salmon.

1.3 Prince William Sound: Port San Juan Hatchery

Commercial fishing in Prince William Sound began in the early 1920's. The Sound primarily supports pink and chum salmon with only a few runs of sockeye. Prince William Sound has never produced as many salmon as southeast Alaska or Kodiak, but until 1945, annual catches of 8 to 10 million fish were common. During the subsequent decline Prince William

Sound experienced stock reductions greater than any other area in Alaska. Complete closures of the Sound to fishing were necessary in 1954, 1955, and again in 1959 (Royce, 1962). The annual total catch for the area averaged only 2.3 million salmon during the 1950's (Rogers, 1972). The 1964 earthquake, centered in Prince William Sound, ruined many spawning streams and slowed recovery during the decade. Early in the 1970's the stocks were reduced again to such an extent that it was necessary to close the fishery to purse seining in 1972 and 1974 (Köernig and Nöerenberg, 1976).

In 1975 local native corporations, fishermen, canners, and the cities of Valdez and Cordova formed the Prince William Sound Aquaculture Corporation (PWSAC). Under the Private Nonprofit Hatchery Act of 1974, their goal was to develop a system of hatcheries that would produce and release into Prince William Sound 200 million pink and chum salmon fry each year. PWSAC hoped to stabilize the economy of the fishing-based communities through action that would guarantee the annual return of 4 to 5 million adult salmon to the Sound's fishery.

In 1975 PWSAC received a permit to operate a medium sized, non-profit pink and chum salmon hatchery in southwest Prince William Sound. The site selected for the facility was the abandoned salmon cannery at Port San Juan on Evans Island (Fig. 1). Operations began in the summer of 1975, with collection of 6 million pink salmon eggs for incubation and release the following spring. Scheduled to release 20 million pink fry during the spring of 1977, PWSAC approached the Alaska Sea Grant Program of the University of Alaska for assistance in evaluating

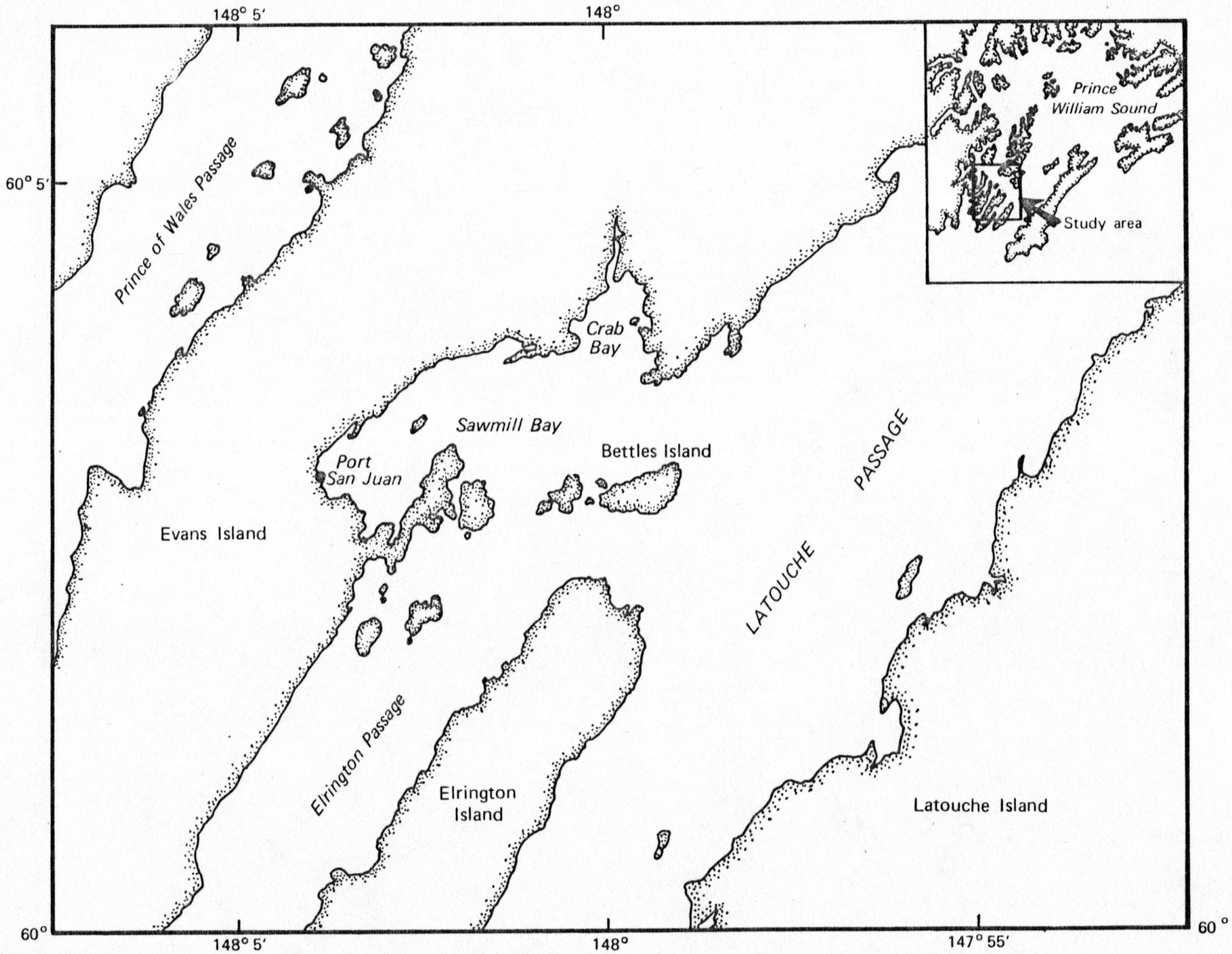

Figure 1. Study area and location of Port San Juan, site of the Prince William Sound Aquaculture Corporation pink and chum salmon hatchery.

the productivity of the nearby estuary in terms of its ability to support these fish. In April of 1976 the Institute of Marine Science, with funds provided by Sea Grant, initiated a three-year study designed to (1) determine the numbers of pink and chum salmon fry the local estuarine system could reasonably be expected to support, and (2) address the problem of juvenile pink and chum salmon survival in the estuary.

1.4 Hatchery Reared Pink Salmon and the Need for Research

Salmon hatcheries along the eastern North Pacific coast traditionally were concerned with chinook, coho, and sockeye salmon. The fry produced were invariably smaller and weaker than their wild relatives. Some returns were obtained only because fry of these species spend time in fresh water where artifical foods were used to bring them up to condition before release. Within the last ten years research in Canada and the U.S., as well as exchange of information with Japan, where salmon have been reared for a hundred years (Mathews and Senn, 1975), have provided insight into the needs of incubating salmon fry. New developments in hatchery technology now make pink salmon attractive candidates for artificial rearing (Bams, 1970; Baily and Heard, 1973; McNeil and Bailey, 1975; Bams and Crabtree, 1976; Bams and Simpson, 1977).

Mortality of pink salmon eggs and alevins is high in natural streambed systems. Only 10 to 20 percent of the eggs deposited in a redd result in outmigrating fry the following spring. Modern hatcheries, using recently developed techniques, have increased this egg to fry stage survival to values frequently greater than 80 percent (Bams, 1972; Bailey and Taylor, 1974). Artificially reared pink salmon fry now appear equivalent at outmigration to wild fry in terms of their ability to survive in the marine environment (Bams, 1974). Early marine mortality for pink salmon is largely due to predation, and is higher for smaller, weaker fish (Parker, 1971). Through the use of various substrates which support, protect, and immobilize the alevins, hatcheries are able to produce the large, healthy pink fry capable of avoiding predators as effectively as wild fry.

The result of this increase in understanding has been new confidence in the economic advantage of attempting to artificially propagate pink salmon. Plans for the development of pink salmon hatcheries have proliferated. In Alaska, eleven permits have been issued to private organizations intent on building non-profit pink salmon hatcheries. Additionally, many of the hatcheries planned by FRED will produce large numbers of pink salmon fry.

The costs involved in artificially rearing these large numbers of pink salmon make it desirable to know the number of fry a hatchery can release into an estuary before effecting compensatory mortality.

Parker (1964, 1965) estimated that as many as 75 percent of the outmigrating pink salmon fry die during the first 40 days spent in an estuary. This period is judged by most salmon biologists to be critical to the survival of each run. Yet, conditions for survival in the marine environment are so variable that the number of fry outmigrating in a natural system is unrelated to adult year-class strength (Gilhousen, 1962). There is no reason to expect large numbers of adult salmon to return to a hatchery merely because large numbers of fry are released into the estuary. Facilities producing high quality fry and designed to operate in harmony with the nearshore environment may prove more effective (Cooney and Urquhart, 1978). According to Bailey *et al.* (1975), it is time to speculate on the abilities of these estuaries to support more salmon fry.

Before one can detail the carrying capacity of an area in terms of its ability to support pink salmon fry, much must be known about the fish's natural history, behavior, and environment. A wealth of literature exists concerning the ecology and behavior of juvenile salmon in Washington State and British Columbia while little information is available from Alaska. Salmon, because of their tendency to return to the natal stream, form distinct groups or stocks that do not fully share the same gene pool (Simon and Larkin, 1972). It is not unlikely that widely separate stocks of salmon meet varying environments with distinctly different behavior patterns. It was important, therefore, at Evans Island to describe relevant aspects of the behavior of pink and chum salmon fry migrating from the Port San Juan hatchery before addressing the problems of carrying capacity in the nearby estuary.

In 1977 and 1978 I attempted to follow and observe the pink fry entering Prince William Sound from the Port San Juan hatchery to determine what portion of the nearby estuary was important as a habitat. Since the ability of an estuary to support a population of pink salmon depends on the availability of forage and the food preferences of the fish, zooplankton was collected and the feeding of the fry described. Emphasis was placed on these descriptions during the first two months the fry were swimming free. Samples of both zooplankton and pink fry were collected through time to provide an indication of prey succession in the zooplankton community as well as changes in the feeding behavior of the fry as they increased in size. Fry growth rates were calculated to provide reference for comparisons with the results of other investigators and to examine between-year differences at Evans Island. This thesis presents the results of this study in the hope that it will aid in answering questions concerning the survival of pink salmon in the marine environment.

CHAPTER 2

METHODS AND MATERIALS

2.1 Study Area

Prince William Sound is a fjord-type estuarine system of glacial origin on Alaska's south central coast bordering the northern Gulf of Alaska. Evans Island is one of four major islands in the southwest corner of the Sound. Average air temperatures in the region range between -1°C and 13°C annually. Total precipitation is high; nearly 500 cm of rain and 380 cm of snow fall 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 (Fig. 1). Sawmill Bay is five kilometers in length 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 at the north end of Sawmill Bay. These streams and other seeps occasionally support spawning 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 semidurnal tidal currents flowing into and out of Latouche Passage. The tidal range is between 1.8 and 4.3 meters for this district.

2.2 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 project personnel who stayed on the Island and collected samples of fry and zooplankton beginning April 1 in 1977 and March 20 in 1978. This timing was dictated by the initiation of outmigration of pink salmon from the hatchery. In 1977 fry outmigration began in March, peaking on 22 April. In 1978 the peak in outmigration occurred on 8 April (Fig. 2). Roughly 10 million pink fry were released by the hatchery in 1977 and 16.9 million in 1978.

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.

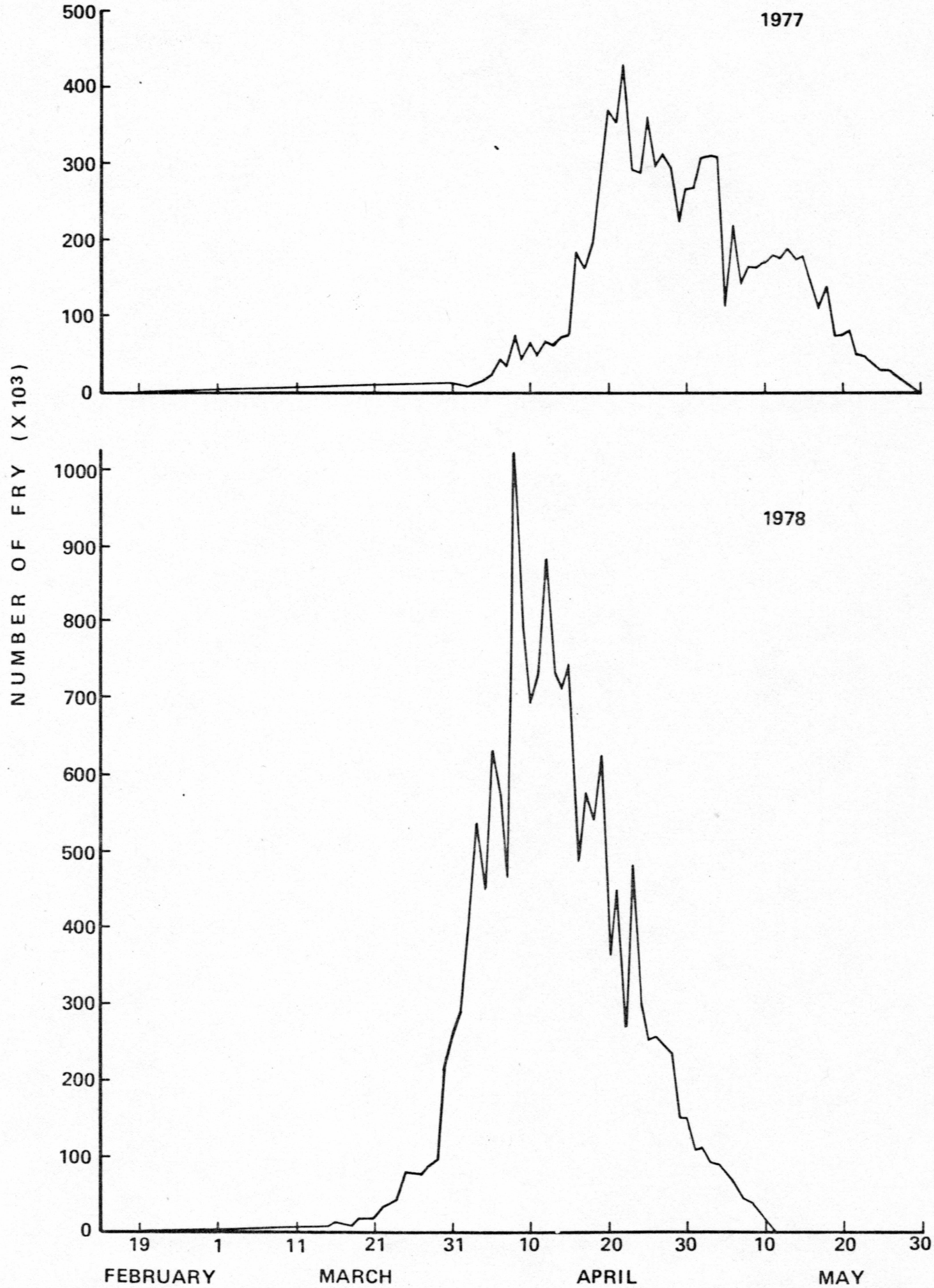

Figure 2. Daily outmigration curves for pink salmon fry leaving the Port San Juan hatchery in 1977 and 1978.

2.3 Zooplankton Sampling

Zooplankton was sampled during the day 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 (Fig. 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 items. 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 zooplankton were not attempted.

Particular attention was paid to obtaining a time series of zooplankton samples from a location frequented by the fry. One area, labelled M-cove, was a preferred habitat in 1977 and frequently contained schools of fry in 1978 (Fig. 3). Nearshore horizontal tows for zooplankton were taken there 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 nets three-arm bridle and by either towing it

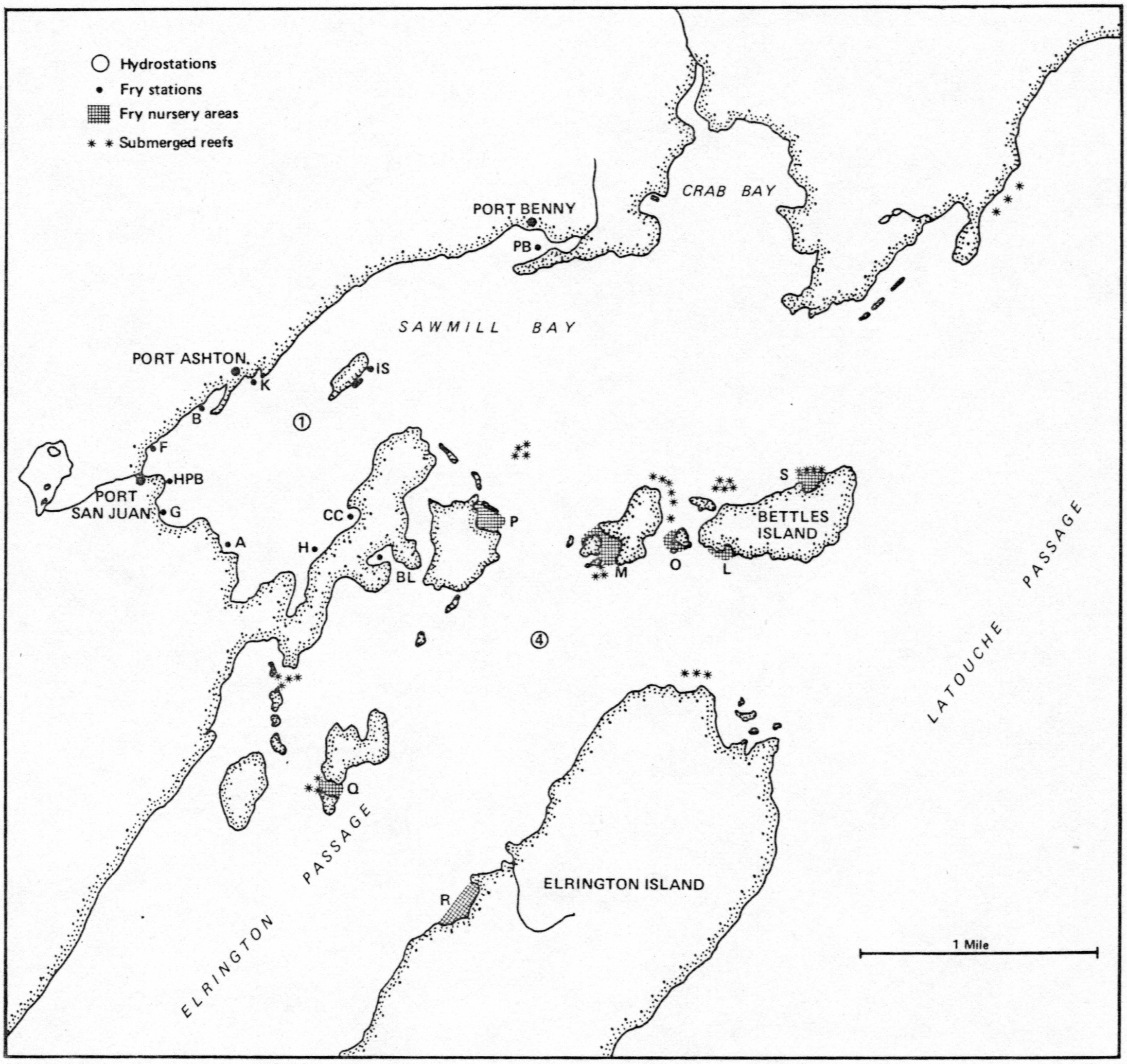

Figure 3. Pink salmon fry and zooplankton sampling stations in waters adjacent to Port San Juan, 1977 and 1978.

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 to each net a flow meter[1]. 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 fed on 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 could be 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 epibenthic organisms nearshore. The pump was fitted with 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 normal to the surface of the water when lowered. Calibration revealed the device pumped 19.1 liters/min. Water passing through the pump was sieved through the 0.216 mm plankton nets. Any particles or zooplankton retained were later identified and counted.

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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.

Using this device, samples were pumped in over the side of the skiff from fixed points at varying distances from bottom and nearshore substrates. Pumping point positions were maintained by mooring the skiff at both ends with several anchors. In order to maintain station but vary pumping points horizontally from shore, the skiff was moored with its keel at right angles to the shoreline. Samples could be taken horizontally over a range of 7 m and vertically to 10 m.

2.4 Zooplankton Sample Analysis

Zooplankton samples were preserved on site 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 freshwater and diluted to a known volume. Subsamples representing a known portion of the complete sample were taken with a Stemple pipet, washed into a petri dish, and placed under the binocular dissection microscope. That portion of the sample not prepared for examination was returned for storage to a 4 percent solution of formaldehyde and freshwater buffered with hexamethylenetetramine.

All organisms in the petri dish were counted and identified to the lowest convenient taxonomic level. Attempts were made to classify the abundant or otherwise important prey organisms to the species level. Total counts were used to calculate the number of zooplanktonic particles/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.

Larger pink salmon fry feeding outside Sawmill Bay in M-cove fed on zooplankton that varied considerably in size. Thus, the food these fish obtained from a particular species or taxon was not necessarily indicated by the frequency with which the item was taken. 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 freshwater 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 desiccator 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. Individual dry-weight values for selected prey organisms were determined for most M-cove zooplankton samples. Average dry-weight values were also calculated and used to show the relative amount of food an organism contributed to fry diet, when the organism was not present in the surface waters of M-cove at the time both the fry and the zooplankton were collected. The tables listing these prey organism dry-weights for both 1977 and 1978 are presented in Appendix D.

2.5 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 possessed tapered wings of 13 mm (1/2 in.) mesh nylon and a center bag of 3 mm mesh. Depending on the variance in the length of fry being sampled, between 100 and 300 individuals were included in a sample to assure representativeness. Several samples were collected in the hatchery each year to monitor the size of fry outmigrating.

Visual surveys of the nearshore environment were made to describe pink fry habitat preference and to gain an understanding of the pathway hatchery fry used in reaching the Gulf of Alaska. In this 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 during these surveys. Later, as patterns in fry behavior became apparent, surveying nearshore continued, but sampling stations were established and visited at least weekly. In the absence of a 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 fry.

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 (Fig. 3).

2.6 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 measurement.

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. The stomach of each fish was removed with forceps by breaking it free from its 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 depending on the state of digestion.

The results obtained from the stomach analysis of each subsample of fry were pooled and listed (Appendix B and E). These tables present the number of individual prey organisms counted and identified to the species level or the lowest convenient taxon. The count for each prey taxon 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 (Appendix E). These values are given in Appendix E in milligrams (mg) and are obtained by multiplying the individual dry-weight value of the selected prey organism from Appendix D, by the total count N, which is the number of times the organism was taken by the fish in that group.

In addition, the concentration of prey organisms in the surface waters of M-cove at the time of fry capture are presented in Appendix E. Electivity coefficients (Ivlev, 1961) were calculated using:

$$E = (\%N - P\%N)/(\%N + P\%N), \qquad (1)$$

where %N is the percent abundance of the prey organism in the pooled stomach contents of the fry examined, and P%N is the percent abundance of the organism in the surface zooplankton community at the time of fry capture. The coefficients were included as an aid to understanding pink fry prey selectivity. E ranges from -1 to +1 with positive values indicating selection and negative values avoidance or rejection. Zero means prey organisms were taken in proportion to their abundance as measured in the environment.

CHAPTER 3

RESULTS

3.1 Nearsurface Zooplankton

Eighty-five zooplankton samples were collected at stations 1, 4, and M 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 feed. 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 varied by as much as a factor of 2.0 ($n = 1$; $\alpha = 0.05$) as a result of patchiness, sampling error, and subsampling and counting error in the laboratory. Despite this, zooplankton concentrations change with time at each station in a consistent way within and between years (Figs. 4 and 5).

Following a bloom composed of centric and chain forming diatoms (*Coscinodiscus* spp., *Thalassiosira* spp., *Chaetoceros* spp., *Stephanopyxis* spp.) and dinoflagellates (*Ceratium* spp.) which formed in early April, nearsurface concentrations of zooplankton increased. Populations peaked at 3.0 to 5.0 x 10^3 animals/m^3 during late April and early May. Thereafter, zooplankton concentrations fell consistently among stations each year to a low which occurred around May 20 (Cooney *et al.*, 1979, show this low in abundance of zooplankton occurred in the waters

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

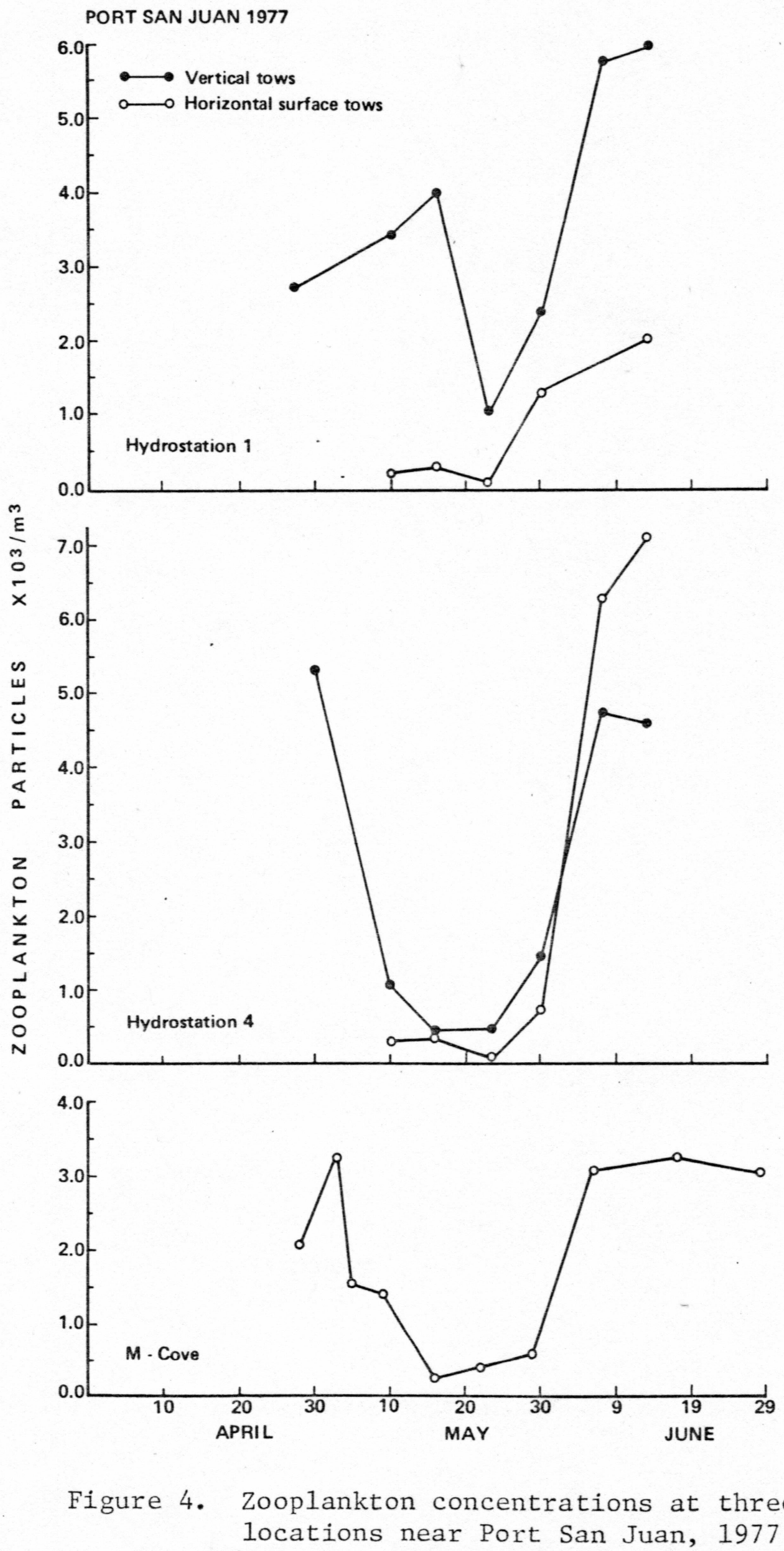

Figure 4. Zooplankton concentrations at three locations near Port San Juan, 1977.

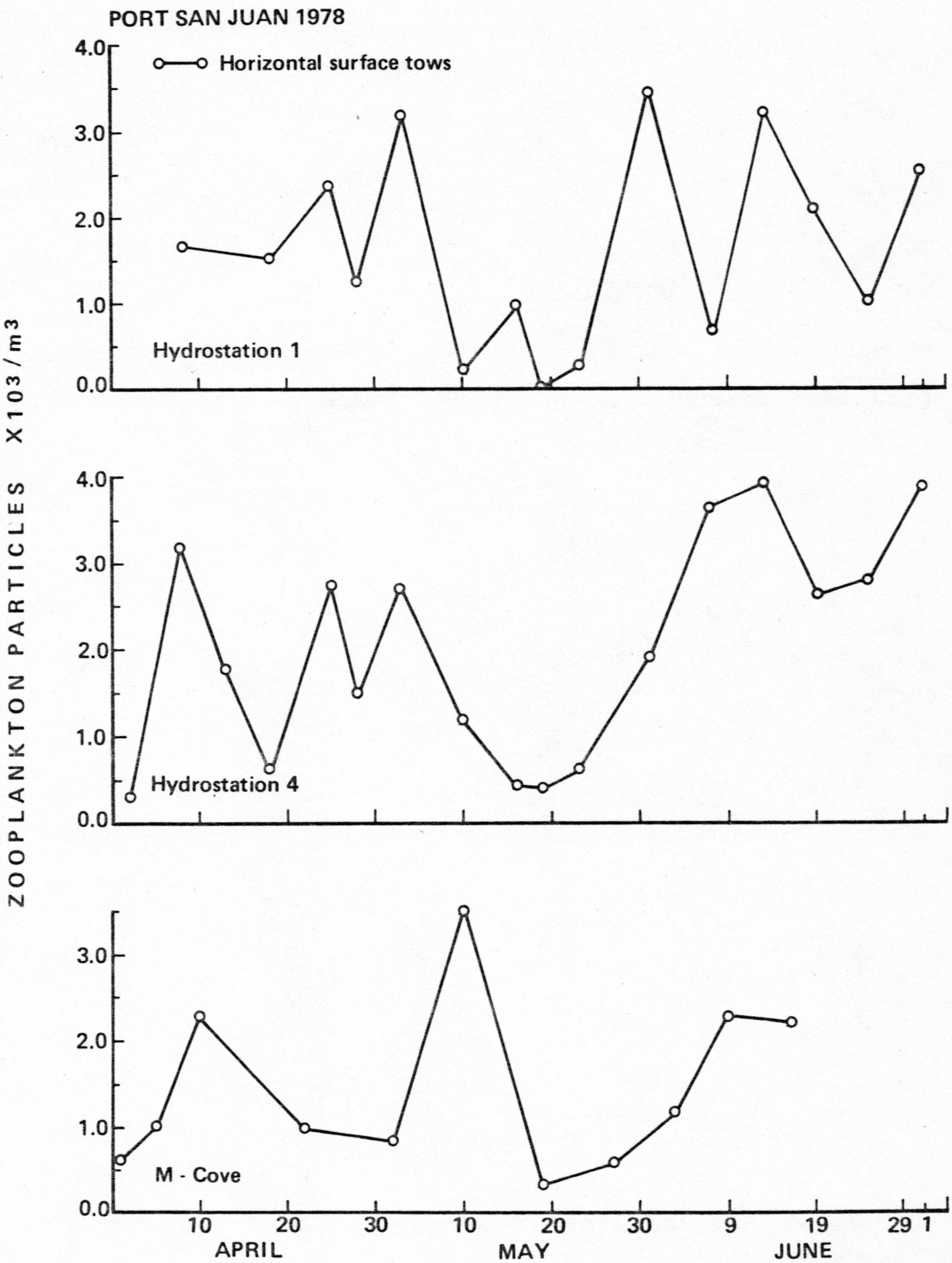

Figure 5. Zooplankton concentrations at three locations near Port San Juan, 1978.

adjacent to Port San Juan at the same time in 1976). Zooplankton concentrations climbed again to high values during late May and June in association with a secondary bloom of primary producers.

The succession of organisms dominating the nearsurface 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 species at the surface. A summation of the concentrations of these numerically dominant species indicates that nearsurface zooplankters in the local estuary were generally more abundant in 1977 than they were the following year (Tables 2 and 3).

Between stations there were differences in the nearsurface 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

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

Organisms	No./m^3									
	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.

No./m^3

Organisms	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

	No./m³						
Organisms	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 nearsurface zooplankton sampled at three stations near Port San Juan during April, May, and June of 1977 and 1978. (+: < $1/m^3$, *: 1-$10/m^3$, **: 10-$100/m^3$, ***: > $100/m^3$).

	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		**	*	*	*	*
Nematoda						
(unidentified spp.)				+	*	**

Table 4. Continued

Taxonomic group	Relative Abundance 1977 1	4	M-cove	1978 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

	Relative Abundance					
	1977			1978		
Taxonomic group	1	4	M-cove	1	4	M-cove
Cyclopoida						
Oithona similis	***	***	***	***	***	***
O. spinirostris	*	*	+	*	**	**
Oncaea spp.	*	*	*	*	+	+
(unidentified spp.)			*	*	*	+
Harpacticoida						
Microsetella spp.		+				+
(unidentified spp.)	*	*	**	*	*	**
Monstrilloida						
(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	+	+	*		+	

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

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.

3.2 Fry Migration, 1977

In 1977 outmigrating 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 farther 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 be out of the Bay. On days when the hatchery held all outmigrating fry, few were found in Sawmill Bay. During June occasional schools of smolt size pink salmon could be seen offshore inside Sawmill Bay. Otherwise, the only pink salmon fry captured at various sampling stations inside Sawmill Bay (Fig. 3) were recent releases (evidenced by their size between 30 and 34 mm in fork-length) with few and 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 fish within an area less than 25 meters across.

Smaller groups of fry probably did leave or join a particular school, but this movement was not seen. Some of these large schools of fry, however, 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 5 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 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 beach seines were needed to collect samples, though the fry remained in the coves. When the fry did depart from the nursery coves it was

Table 5. 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

sudden and *en masse*. At most coves the departure behavior occurred in June. Apparently, once the pink fry were 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 pinks exceeded 100 mm in length and usually were so far offshore that 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 impression the hatchery fry were using Elrington Passage in reaching the open ocean (Fig. 6).

3.3 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. In 1978, however, pink fry outside Sawmill Bay spent much of their time elsewhere. Early outmigrating fry were held by the hatchery in saltwater pens, and none were released until 30 March. As mentioned, the peak in outmigration in 1978 came early (Fig. 2),

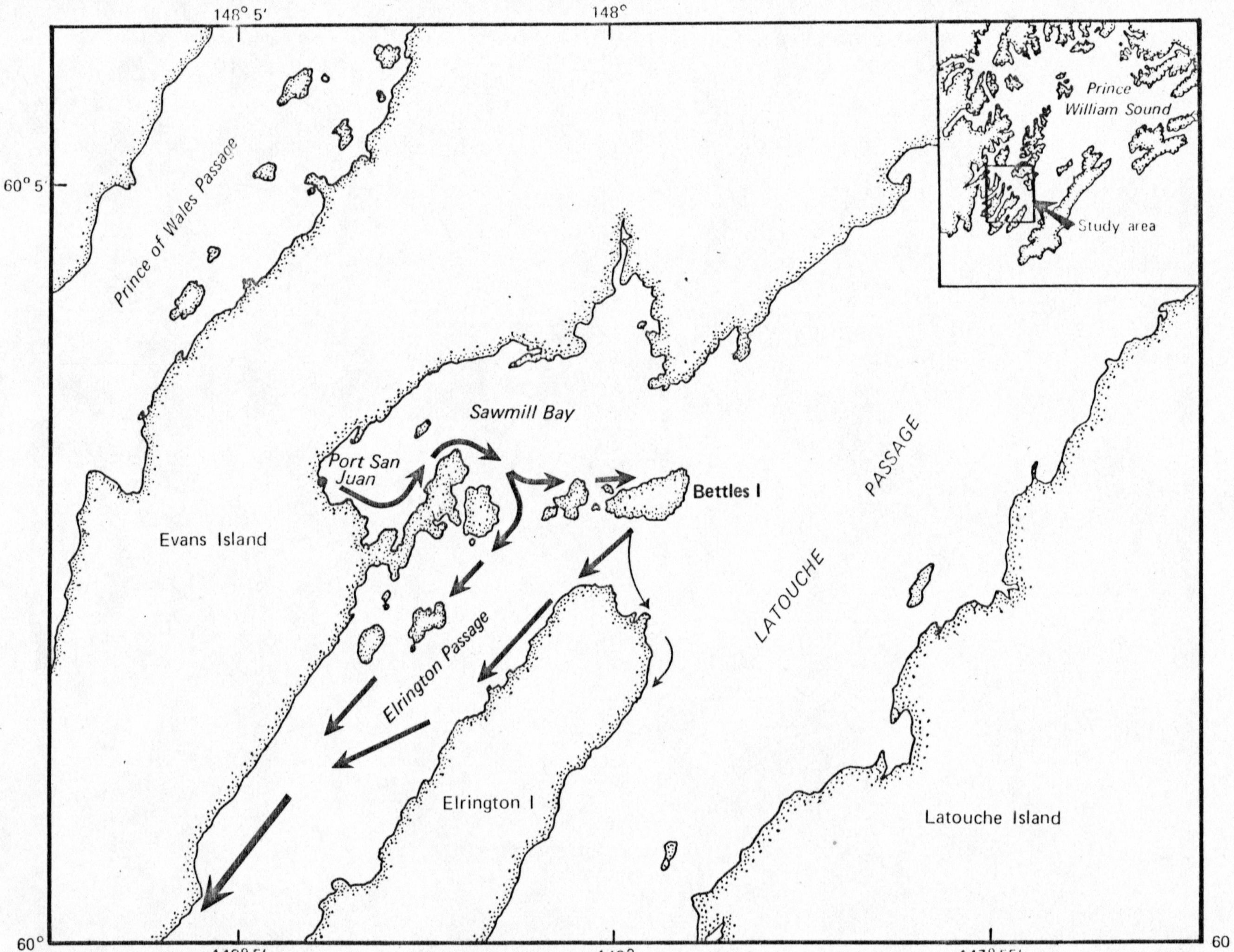

Figure 6. Major migration paths for pink salmon fry leaving the Port San Juan hatchery in 1977 and 1978.

and by the end of April nearly 17 million pink salmon had been observed swimming at the surface out of Sawmill Bay just as they had the year before.

However, once the 1978 pink fry left Sawmill Bay, few were seen again until May. In 1977 the large schools of pink fry were not located in Elrington Passage until the end of April, presumably because I did not until then look outside Sawmill Bay. Yet, even though millions of fry left the hatchery in April of 1978, only occasional groups of a few thousand fry could be found anywhere that month in the waters around Bettles Island or in Elrington Passage. Early in May of 1978 some larger groups 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. When the fry were not holding position close to shore, they were simply not observed.

Migration paths in 1978 appeared in general to be the same as those described for 1977 (Fig. 6). This statement is based again on the frequency with which concentrations of fry were observed within a 10-15 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 in 1977.

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 mimicked what had been observed the year before. Fry occurred well offshore, jumped at the surface, and held position in fast currents.

3.4 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 incubation boxes. In 1978 the hatchery attempted to artificially feed fry ready to migrate before it released them. Thus, many of the fish captured in Sawmill Bay in the second year 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 B) from 18 different samples collected in Sawmill Bay (Appendix A).

Epibenthic harpacticoid copepods were the numerically and volumetrically dominant prey organism found in pink fry captured in Sawmill Bay (Fig. 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.), barnacle and copepod nauplii also contributed as prey. Many fish 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 B). 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 B).

3.5 Fry Feeding in M-cove

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

Pink fry fed primarily on calanoid copepods while in M-cove (Fig. 8) with *Pseudocalanus* spp. most frequently dominating the diet.

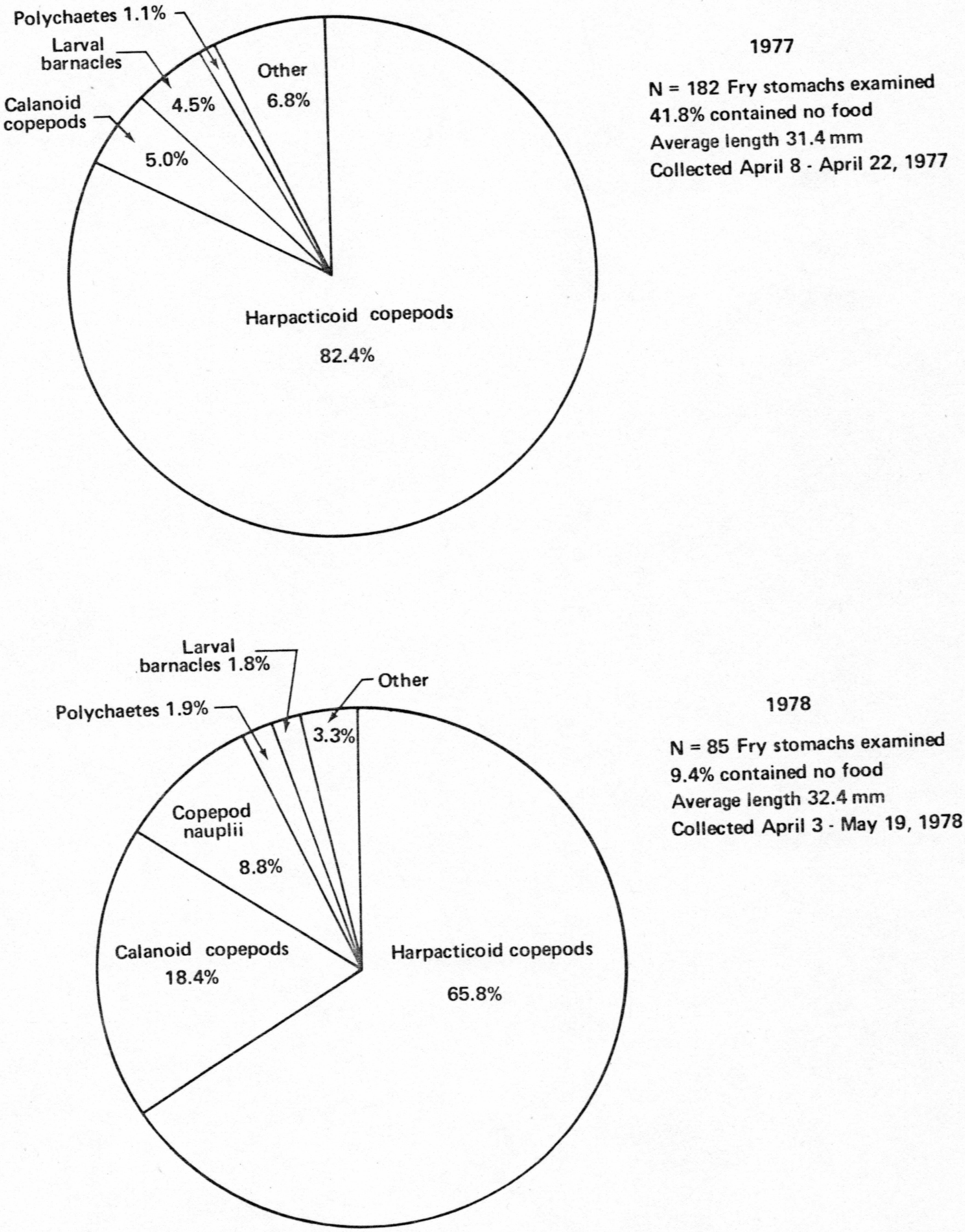

Figure 7. The percentage of prey organisms first taken by pink salmon fry migrating from the Port San Juan hatchery at Evans Island, Alaska.

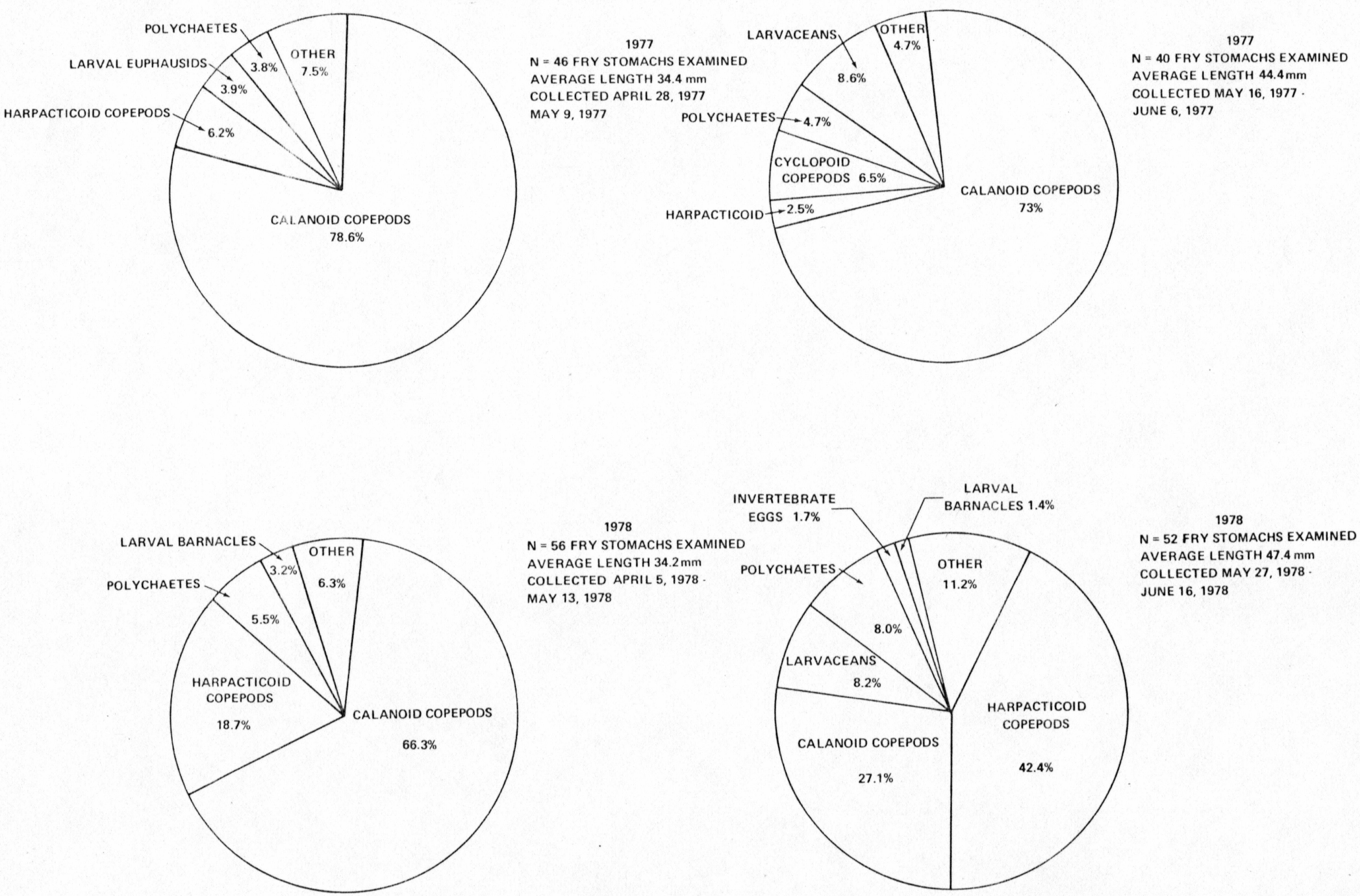

Figure 8. The percentage of prey organisms taken by M-cove pink salmon fry in April and early May, and during late May and June of 1977 and 1978.

Calanus cristatus, *C. marshallae*, *C. plumchrus*, *Metridia lucens*, and *M. okhotensis* also contributed substantially to the nutrition of the fry because of their large size.

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 to the fry. In late May and June of 1978, harpacticoids did dominate the diet of M-cove fry in terms of the number consumed (Table 2 in Appendix E). However, because harpacticoids are small, the copepods *Calanus* and *Metridia* remained more important in terms of biomass contribution (Appendix D and E).

As the season progressed and the fry in M-cove increased in size, the number of taxa comprising their diet also increased (Appendix E). The first fry collected both years failed to capture some 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 ($r = -0.20$; $df = 41$; $\alpha = 0.01$).

The Ivlev electivity indices given in the tables in Appendix E, which relate the abundance of nearsurface zooplanktonic organisms 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). When they were eaten, it was when these copepods carried egg sacs making them more attractive.

Pseudocalanus may have been taken more nearly in proportion to its abundance at the surface. Larger, more visible calanoids like *Calanus* and *Metridia* were actively sought. The negative coefficient (Table 6) indicating M-cove fry partially avoided *Calanus* near May 10 of both years is an artifact of the index calculation. *Calanus plumchrus* was so abundant at that time in May it covered the surface in places and merely a few would fill the stomachs of the smaller fry. Late in the season of both years, M-cove fry fed heavily on *Metridia* though none were to be found in any of the nearsurface plankton tows. Also, it was not clear where the fry were getting *Exogone* spp. These small polychaetes appeared to be taken along with the harpacticoid copepods, making a contribution to the diet late in the 1978 season (Table 2 in Appendix E). Figures 9 and 10 show 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 8 groups of fry collected there each year.

Table 6. Ivlev electivity coefficients relating the stomach contents of M-cove pink fry to the nearsurface abundance of five copepods (from Appendix E). Size ranges are for Stage III copepodids to adults, in millimeters.

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
1977						
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

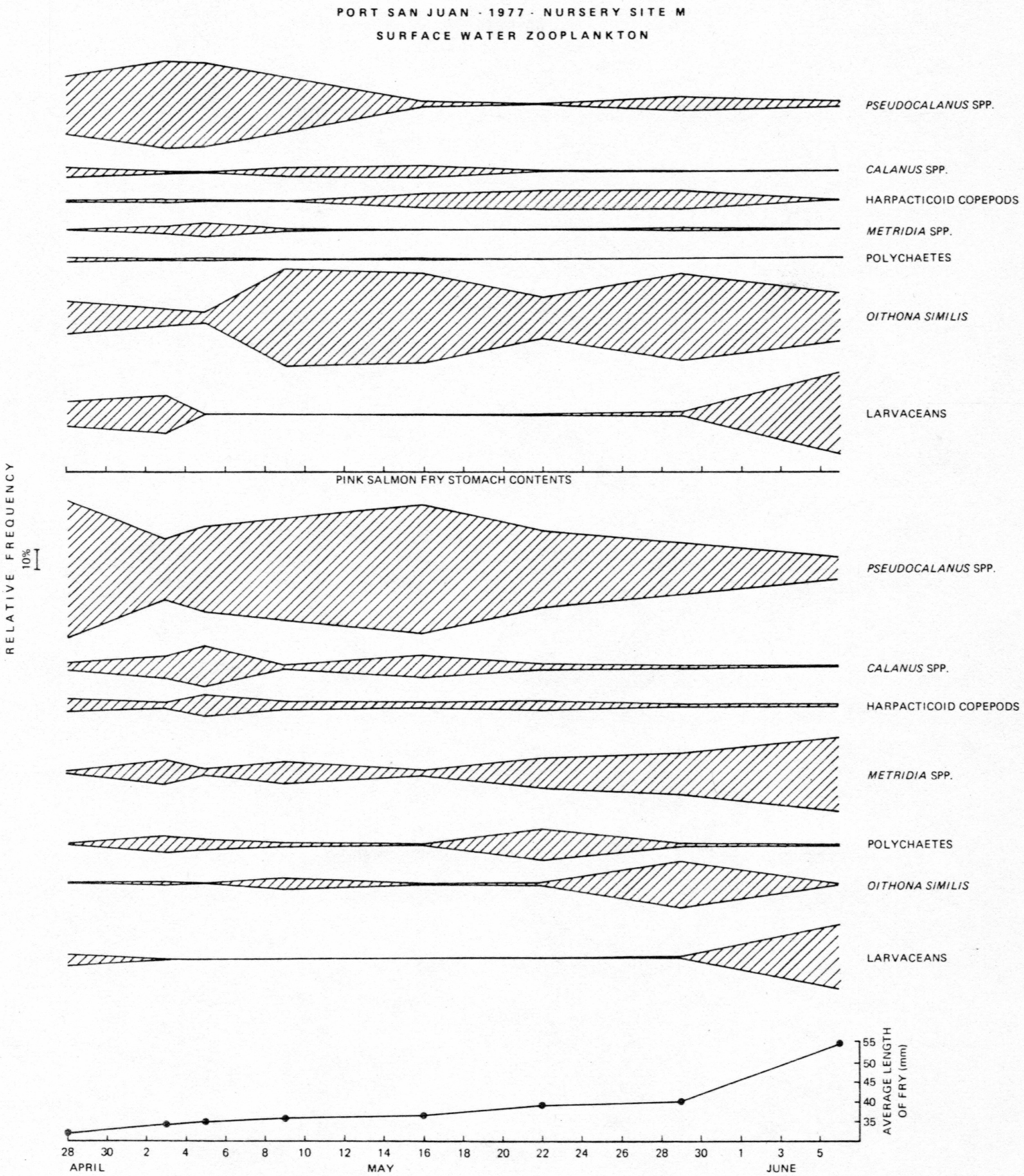

Figure 9. The relative abundance of zooplankton in the nearsurface waters of M-cove and in the stomachs of pink fry collected there during the spring of 1977. Vertical distance presents the relative frequency of occurrence.

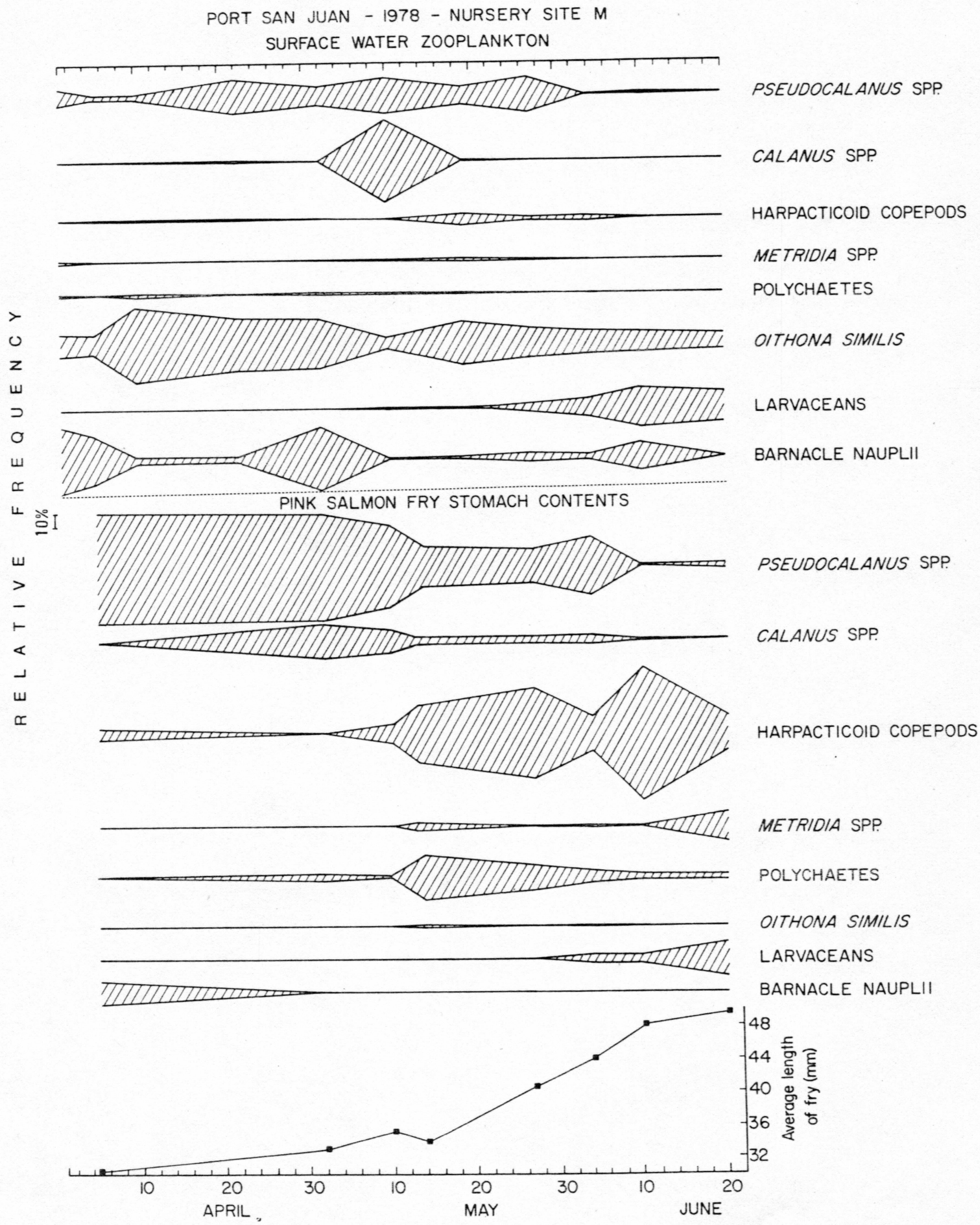

Figure 10. The relative abundance of zooplankton in the nearsurface waters of M-cove and in the stomachs of pink fry collected there during the spring of 1978. Vertical distance presents the relative frequency of occurrence.

3.6 The Nearshore 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 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 7).

The pump was used at three other sites in June of 1978 to determine the relative abundance of harpacticoid copepods with vertical and horizontal distance from bottom and nearshore substrates. The sites were the Black Lagoon (BL), S-cove, and Sawmill Bay Island (IS) (Fig. 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 8, 9, and 10).

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.

3.7 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

Table 7. The number of epibenthic harpacticoid copepods per m^3 in seven zooplankton and two epibenthic pump samples taken from M-cove in June, 1978. The zooplankton samples were either surface, deep horizontal, or nearshore "off-the-bow" (otb) tows. The epibenthic pump samples were taken in the intertidal zone.

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

Table 8. 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 9. 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 10. 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	

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:

$$g_\ell = \frac{\text{Ln } \ell_t - \text{Ln } \ell_o}{t}, \qquad (2)$$

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:

$$g_\omega = bg_\ell, \qquad (3)$$

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:

$$\Delta W = (e^{g_\omega} - 1) \text{ X } 100, \qquad (4)$$

(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 11 and 12). 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 ($r = +0.74$; $df = 798$; $\alpha = 0.01$) (Fig. 11). The growth rate (slope)

Table 11. 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.

		Percent Fry in Sample							
Group limits (cm)	Group mark (Ln l)	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 12. 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

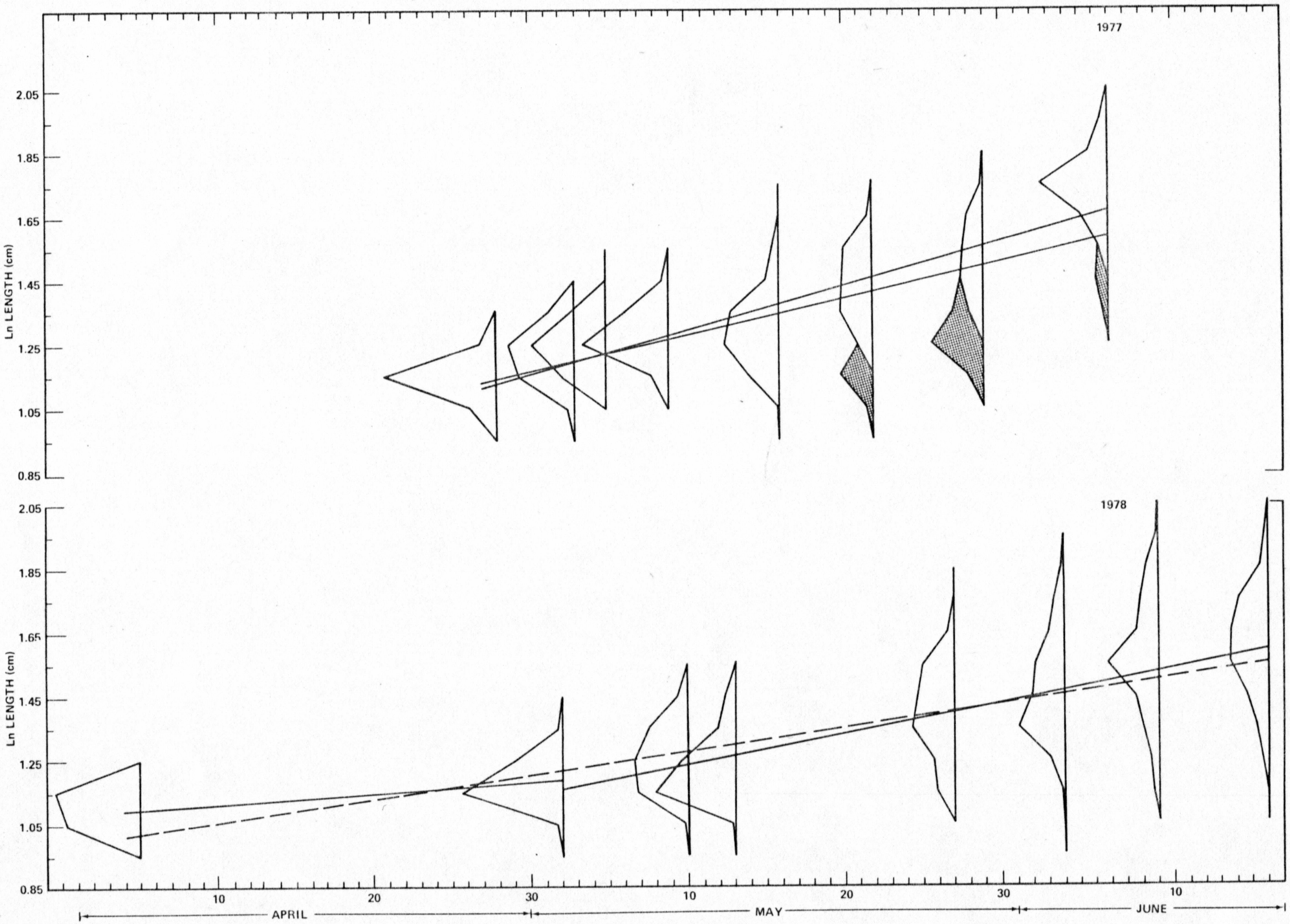

Figure 11. Logarithm transformed length-frequency curves for pink salmon fry captured in M-cove during April, May, and June of 1977 and 1978.

increased to 0.0137 when a fry cohort (indicated by cross hatching), first appearing May 16 in sample M#5, was excluded from the calculations. The 95 percent confidence interval 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 (Fig. 11, 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 in May 1, 1978. When comparing the growth of fry between these two years, the sample M#1, collected on 5 April 1978 was omitted (Table 12, Appendix C). 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 2 May and 16 June 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.

CHAPTER 4

DISCUSSION AND CONCLUSIONS

4.1 Fry Movements and Nursery Areas

Unlike other Pacific salmon, pink salmon fry 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 freshwater. 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 (Cooney *et al.*, 1979).

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.

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 ebb and flow of tides. 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 by 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 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 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 are scarce, epibenthic harpacticoid copepods are available. Thus, the pink fry in these coves make use of the energy from two relatively distinct marine food webs.

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

Unlike the fry from the Bella Coola River that travel a hundred kilometers or more, Port San Juan pink salmon need swim only 20 kilometers before reaching the Gulf of Alaska. In 1978, fry must have been moving about in the passages when they were not schooling in a cove. 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, which results in mass migration of the population 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 takes 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 a major behavior transition takes place in relationship to size and 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, than did fry the previous year. This resulted in a significant difference ($z = 1.88$; $\alpha = 0.05$) in the fork-lengths of fry leaving the incubators between years. 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 material when leaving the incubators. Pen experiments conducted both years showed these more advanced fry to be more susceptible to starvation (Cooney *et al.*, 1978, 1979). 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 may have in some way 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 (Fig. 12), from observation, weather differences between years at the site were striking.

Finally, it is important to consider the possibility that differences in 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. 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

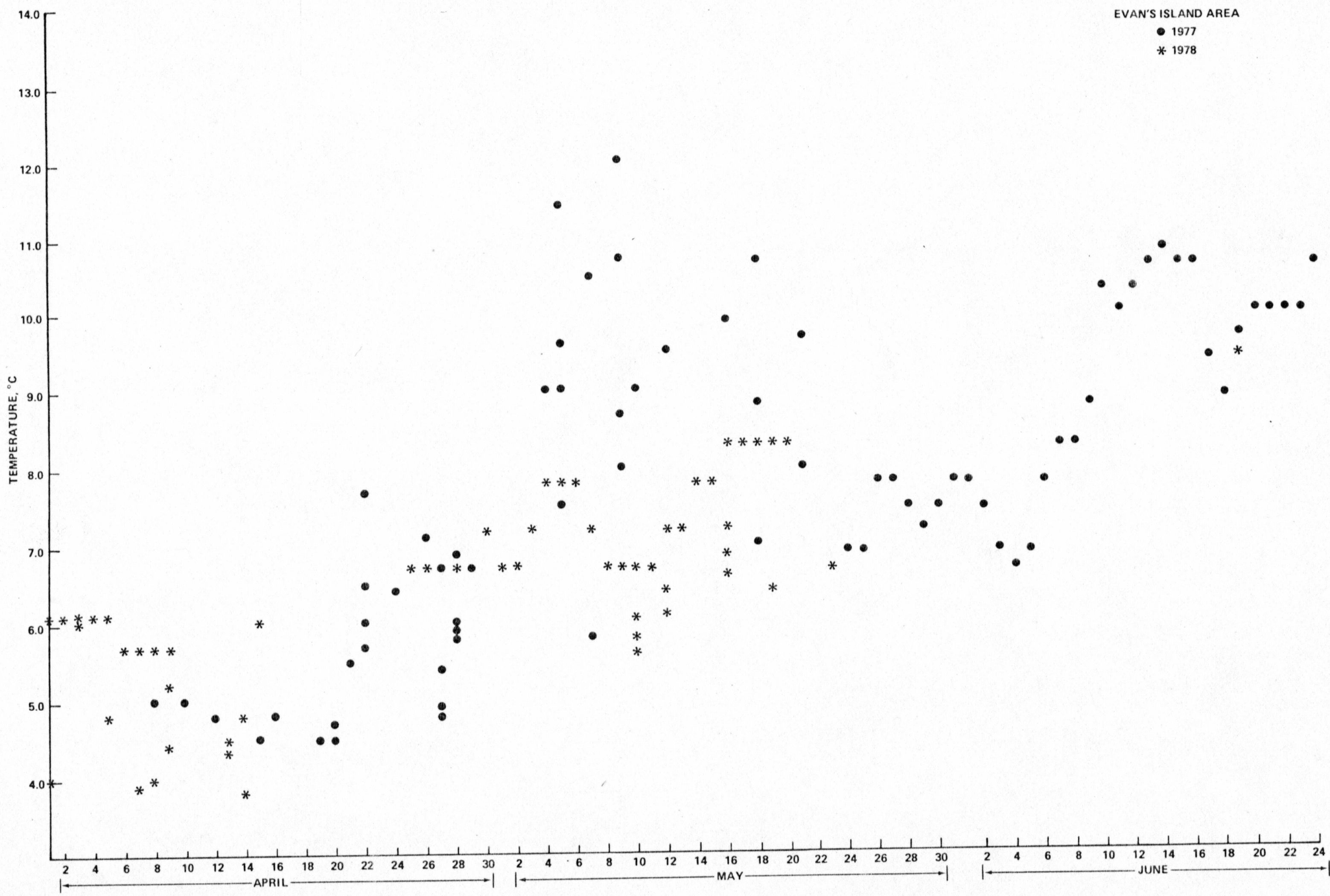

Figure 12. Estuarine surface water temperatures at Evans Island in 1977 and 1978.

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 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.

4.2 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 *et al.* (1975), and Gosho (1977). They report pink fry to be zooplanktivorous, feeding in the water column above the bottom on pelagic and neritic 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, through ingestion of epibenthic organisms (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 higher in the water column. I agree with Kaczynski *et al.* (1973) that the initial feeding period in the life cycle of these fishes is a distinct ecological stage 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 lasted only a few days. Though harpacticoid copepods were later a component of the diet, calanoid copepods 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 hard 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 have been shown to select for this organism and other copepods between 2 and 5 mm in length (LeBrasseur, 1969).

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

In Sawmill Bay pink fry fed primarily on harpacticoid copepods though none were available in the surface waters except in the shallows close to shore. Examinations of live nearshore plankton 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* copepods, actively sought as food, appear red or orange because of the oil they carry in their hydrostatic organ. *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 the surface. 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. However, epibenthic harpacticoid copepods in M-cove were not found 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 of Puget Sound pick these organisms off the sediment water interface. At Evans Island this was not observed. Rather it appears the pink fry feed on harpacticoids 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 fry feed on a "cloud" 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 meeting their environment and obtaining food. For pink fry that have been in the estuary for several weeks, the epibenthic harpacticoid copepods may possibly be a backup source of nutrition during those periods when more palatable forage is unavailable.

4.3 Fry Growth

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 move earlier 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 29 April and 9 June 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 could have produced fry samples more representative of real growth than those taken in M-cove, accounting for the apparent differences in growth rates.

The differences may too represent a real difference. Prince William Sound is hundreds of kilometers north of Fitz Hugh Sound. Lower estuarine water temperatures, as a result of higher latitude, may tend 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 11 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 a different school seems to have been sampled there each week. Yet, there were differences in the apparent abundance of zooplankton between years that could account for the differences in the growth rates of the fry. 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.

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APPENDIX A

Fry samples collected in Sawmill Bay

Table 1. Twelve pink salmon fry samples collected in Sawmill Bay between 8 April and 22 April 1977. The stomach contents of 182 fry from these samples were examined.

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

Table 2. Six pink salmon fry samples collected in Sawmill Bay between 3 April and 19 May 1978. The stomach contents of 82 fry from these samples were examined.

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

APPENDIX B

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.

Table 1. Stomach contents of 182 pink salmon fry collected in Sawmill Bay between 8 April and 22 April 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
$\overline{L}$ = 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
$\overline{L}$ = 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
$\overline{L}$ = 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
$\bar{L}$ 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
$\bar{L}$ = 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
$\bar{L}$ = 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

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*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 3 April and 19 May 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
$\overline{L}$ = 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
$\overline{L}$ = 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
$\overline{L}$ = 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
$\overline{L}$ = 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 C

Fry samples collected in M-cove

Table 1. Eight pink salmon fry samples collected in M-cove between 28 April and 6 June 1977. The stomach contents of 86 fry from these samples were examined.

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

Table 2. Eight pink salmon fry samples collected in M-cove between 5 April and 16 June 1978. The stomach contents of 108 fry from these samples were examined.

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

APPENDIX D

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 E 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.

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

Sample date	Prey organism	Number weighed	Total dry-weight (mg)	Individual dry-weight (mg)
4/28	*Pseudocalanus* spp.	150	4.01	.027
	**Calanus* spp.	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 1 April and 16 June 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 E

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 D 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).

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 28 April and 6 June 1977.

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

Table 1. Continued

Sample M#8 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
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
***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 5 April and 16 June 1978. A zooplankton sample was not collected 13 May with fry sample M#4.

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

Table 2. Continued

Sample M#2 (cont'd)

Prey category	N	%N	%FO	mg	P%N	E
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
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
$\overline{L}$ = 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
$\overline{L}$ = 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.