Nearshore Epibenthos of the Campbell River Estuary and Discovery Passage, 1982, in Relation to Juvenile Chinook Diets

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ABSTRACT

Kask, B. A., T. J. Brown, and C. D. McAllister. 1986. Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1982, in relation to juvenile chinook diets. Can. Tech. Rep. Fish. Aquat. Sci. 1449: 53 p.

Following the experimental rehabilitation of the Campbell River estuary in 1981-82, a program was begun to monitor the use of the new as well as the established habitats by juvenile salmonids, particularly wild and hatchery reared chinook. The role of each of the nearshore habitats in providing food for the young fish was also monitored using an epibenthic sled. From March to December, 1982, one hundred forty-six nearshore samples were collected from three different habitat areas -- estuarine, transition, and marine zones. Copepod nauplii, nematodes, and harpacticoids dominated the estuarine and transition zones; harpacticoids, copepod nauplii, and amphipods the marine zone. Densities of nearshore epibenthos were highest in the marine zone and lowest in the estuarine zone. The juvenile chinook were found to consume prey items from freshwater and terrestrial, estuarine and nearshore epibenthic and marine pelagic (planktonic) environments, the nearshore epibenthos comprising the largest part of the diet in the transition zone.

RESUME

Kask, B. A., T. J. Brown, and C. D. McAllister. 1986. Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1982, in relation to juvenile chinook diets. Can. Tech. Rep. Fish. Aquat. Sci. 1449: 53 p.

A la suite de la remise en état expérimentale de l'estuaire de la rivière Campbell en 1981-1982, on a mis en oeuvre un programme pour surveiller l'utilisation des habitats nouveaux et antérieurs par les saumons juvéniles, surtout le saumon quinnat sauvage et d'élevage. On a également étudié le rôle de chacun des habitats côtiers dans l'apport de nourriture aux jeunes poissons à l'aide d'un traîneau épibenthique. De mars à décembre 1982, cent quarante-six échantillons côtiers ont été prélevés dans trois zones d'habitat différentes -- estuaire, zone de transition et mer. Les nauplius de copépodes, les nématodes et les harpacticoides dominaient dans les zones d'estuaire et de transition; les harpacticoides, les nauplius de copépodes et les amphipodes dans la mer. Les densités d'épibenthos côtier étaient les plus hautes dans la zone marine et les plus basses dans la zone estuarienne. On a constaté que le quinnat juvénile consommait des proises des environnements épibenthiques dulcicole, terrestre, estuarien et côtier et du milieu pélagique marin (plancton), l'épibenthos côtier composant la plus grande partie du régime alimentaire dans la zone de transition.

INTRODUCTION

The Campbell River estuary, on the east coast of Vancouver Island, has been used as a log handling site for over eighty years. It is also a rearing area for juvenile salmon, mainly chum and chinook, from the Campbell and Quinsam River systems (Raymond et al. 1985; Goodman et al. 1974). In 1981 a joint agreement was reached between British Columbia Forest Products and fisheries agencies to undertake an experimental rehabilitation of this estuary. To increase the food and rearing area available to the young salmon, the estuarine booming ground was replaced with a new dry land sort and dredged pond. Four new intertidal islands were built and planted with marsh vegetation (Brownlee et al. 1984).

In early 1982, a study was begun to evaluate the effects of the rehabilitation on the survival of the young salmon. From March to December, twenty trips were made to the Campbell River area and distribution of these fish was estimated from forty-seven beach seining sites in the estuary and Discovery Passage (Brown et al. 1983). Some chinook were also retained for stomach analysis (Anderson et al. 1984). In addition, the nearshore epibenthos was sampled at eighteen sites to monitor densities and compare the organisms to those in the chinooks' diets.

Sampling was carried out in three zones. The estuarine zone was defined as the intertidal area at the mouth of the Campbell River up to the end of Tyee Spit. The transition zone included the area in Discovery Passage influenced by the Campbell River, and the remainder of Discovery Passage and Seymour Narrows comprised the marine zone. A more complete description of the three zones may be found in Levings et al. (in prep.).

One hundred and forty-six epibenthic samples were collected: here we compare the densities and taxonomic composition in the three zones and discuss the nearshore epibenthos as a source of food for the young salmon. The raw counts, site descriptions, tide type and height, salinity and temperature measurements may be found in Kask et al. 1984. Identification of the calanoid copepods is reported in Brown et al. 1984 and Brown et al. in prep.

MATERIALS AND METHODS

The epibenthic sled used had a 10 cm x 10 cm mouth opening and was fitted with a 100 μ mesh net. It was pulled along the shoreline in the shallow water of the littoral zone for 5 m (Sibert et al. 1977). Duplicate 0.5 m^2 samples were collected at each site and preserved in 4% formalin and rose bengal. This sled captured mainly epibenthic meiobenthos (intermediate size animals) but also sampled some larger organisms as well. Surface temperature and salinity were measured with a hand-held thermometer and AO Goldberg T/C refractometer or a Beckman RS-5 salinometer.

In the laboratory the samples were decanted through a 44 μ sieve and counted using a dissecting microscope and rotary counter. Some samples were split with a Folsom splitter to include one hundred of the dominant organisms in the subsample. Counts were then multiplied by the splitting factor and recorded. Animals were identified to the lowest level possible in the time available and one hundred harpacticoids and calanoids were kept for identification.

A dissecting microscope was used to identify the harpacticoids or, if dissections were necessary, a compound microscope. All identifications were checked against the species descriptions. If applicable, the counts were multiplied by the split factor to equal the sample total.

RESULTS AND DISCUSSION

A. ESTUARINE ZONE

A-1 Sampling Regime

The Campbell-Quinsam River system supports five species of salmon, steelhead and cutthroat trout, and Dolly Varden char. In particular it is renowned for its chinook, the juveniles of which rear in the estuary for up to several months during their seaward migration (McAllister et al. 1984; Levings et al. in prep.). There is increasing concern for the survival of these wild chinook, especially since the construction of the Quinsam hatchery on this system in 1975. This hatchery releases approximately one million young chinook into the system each spring along with other juvenile salmon and trout. Construction of the new islands was designed to increase the shallow nearshore areas which young salmon seem to prefer and to provide more littoral areas to generate food for these fish.

The islands were completed in February 1982. In March beach seining was begun to determine whether the juvenile chinook were utilizing the new island habitats. Established sites were also seined for comparison and samples of chinook were kept from selected stations for stomach analysis. In mid May, the catch per unit effort (CPUE) for chinook, weighted by station, reached a mean of one hundred six in the estuary.

Beginning in March and continuing at approximately two week intervals, the epibenthos was monitored at seven sites to compare the densities and determine if the nearshore areas, especially the new islands, were colonizing and contributing to the diet of the young salmon. Stations 1, 2, 3 and 7 were in established habitats and stations 13, 17 and 18 were in the islands (Fig. 1).

As this was to be a preliminary faunistic survey, sampling was intermittent at most sites except station 7 which showed consistent catches of juvenile salmon. Stations 3, 17 and 18 were only visited irregularly and stations 1, 2 and 13 were sampled just once. Seventy samples were collected from all sites combined (Table 1).

Due to the sporadic sampling pattern, any conclusions drawn must be preliminary. The data are presented here because of the unique nature of the rehabilitation and the lack of previous information from this area.

A-2. Density and Taxa Composition of the Estuarine Epibenthos.

The epibenthic fauna in the estuary averaged 561 ± 92 m^{-2} ($\bar{x}$ ± 1SE) during the year. There were three peaks in abundance made up largely of copepod nauplii, nematodes and harpacticoids (Fig. 3 and 4).

The highest densities were recorded at station 18 on island 4 followed by those at an established site, station 7. Although only twenty samples were collected from the islands, they seemed to colonize rapidly and densities recorded at stations 13, 17, and 18 appeared to be comparable to those from some of the established sites (Fig. 5).

The dominant taxa varied from site to site, perhaps partially due to the irregular sampling pattern (Table 2). Most sites were dominated by either copepod nauplii or nematodes and harpacticoids were usually third in abundance. The new islands appeared to exhibit epibenthic populations similar in composition to the rest of the estuary.

There were thirty-one categories of epibenthic animals found in the estuary (Kask et al. 1984). However, only eight taxa made up 94.5% of the epibenthos, dominated by copepod nauplii, nematodes and harpacticoids (Table 2).

These results are comparable to those recorded by Raymond et al. 1984 who used cores to sample the meiofauna from the new islands and an established site (Nunn's Island) in May 1982. Their data also suggests that densities of meiofauna at some of the new island sites were similar to those at the established control sites. Like the sleds, the cores were dominated by nematodes, harpacticoids and copepod nauplii.

A-3. Density and Taxa Composition of Harpacticoid Copepods

The harpacticoids averaged 96 ± 22 m^{-2} in the estuary during the year (Fig. 4). There were three peaks in abundance, dominated by the unidentified copepodites and *Huntemannia jadensis* at station 18 and the unidentified copepodites, *Zaus* sp. and *Tisbe* sp. at station 7.

Comparison of the established and island sites showed different patterns of abundance. The harpacticoids at station 18 on island 4 averaged 351 ± 127 m^{-2} followed by station 7 at 85 ± 22 m^{-2}. Stations 3 and 17 had the lowest mean number of harpacticoids (27 ± 10 and 14 ± 3 m^{-2}).

All the sites were dominated by the unidentified copepodites (Table 3). At the island sites, Huntemannia jadensis or Zaus sp. were second in abundance while each of the established sites had a different species second in the rank order.

Forty-nine categories of harpacticoids were found in the estuary, (Kask et al. 1984) but only eight species made up 93.8% of the population, dominated by the unidentified copepodites, Huntemannia jadensis and the family Ectinosomatidae.

A-4. Comparison of Chinook Diets and Epibenthos At Two Sites

Although the stomach contents of juvenile chinook were analyzed from numerous sites in the three zones (Anderson et al. 1984), our discussion is restricted to those fish collected from areas where epibenthic sled samples were also taken. All sites were treated individually except at island 3 where three closely spaced sampling locations (14, 16, 17) were combined to provide sufficient fish for analysis (Fig. 1). A more detailed discussion of chum and chinook diets at other estuarine sites and over time may be found in Macdonald et al. (in prep.).

From March to September, one hundred six juvenile chinook were analyzed for stomach contents from an established site (7) and three sites on island 3 (14, 16, 17) (Fig. 1). The stomach contents were identified to species where possible to attempt to determine the origin of the chinooks' diet -- freshwater and terrestrial, estuarine or marine, and pelagic (planktonic) or nearshore epibenthic (Anderson et al. 1984).

At station 7, thirty-nine wild and forty-three marked chinook were kept for analysis. At this site, based on numerical percent of the diet, both the wild and marked fish fed consistently on pelagic calanoids, insects, and epibenthic amphipods although in different proportions, the wild fish relying more on insects and less on calanoids than the marked fish. In addition, a few wild fish at this site consumed freshwater cladocera, while some of the marked fish also preyed on isopods. At the stations on island 3 (14, 16, 17), the calanoids were dominant in the diet of the wild chinook, followed by harpacticoids and epibenthic amphipods (Table 4).

In the estuary, both the wild and marked chinook fed on food from three sources. The estuarine epibenthos appeared to contribute mainly amphipods (Corophium sp., Eogammarus confervicolus), harpacticoids (Harpacticus sp., Huntemannia jadensis) and isopods (Gnorimosphaeroma oregonensis) to the diet of the juvenile chinook. The freshwater and terrestrial environments contributed insects (Aphididae, Diptera) and cladocerans (Bosmina sp.), flushed down from the lake and river habitats (Mundie et al. 1976; Macdonald et al. 1985) into the estuary. The salt wedge penetrating into the estuary added predominantly calanoids of marine origin (Neocalanus plumchrus, Metridia pacifica, and Pseudocalanus minutus) to the chinooks' food supply.

Of the dominant prey items in the chinooks' diet, the sled captured mainly the harpacticoids Huntemannia jadensis and Harpacticus sp. The larger epibenthic fish prey (amphipods, isopods) appear to avoid the sled. These organisms, along with larval insects, seem to be better sampled by quadrats taken at low tide (Raymond et al. 1984).

Although there were copepods present in the nearshore epibenthic community, they were mainly freshwater and unidentified cyclopoids. The dominant calanoids in the chinooks' diet, Neocalanus plumchrus and Pseudocalanus sp. only occurred in the sled samples in small numbers (Brown et al. in prep.).

B. TRANSITION ZONE

B-1. Sampling Regime

This zone was important to juvenile chinook in 1982 (CPUE in June of 173) and although only twelve sled samples were collected from four sites (Table 5) they provide some indication of the epibenthic organisms available as prey. Eighty-one juvenile chinook were also kept from the four sites and analyzed for stomach contents (Anderson et al. 1984).

B-2. Density and Taxa Composition of the Transition Epibenthos

The overall mean density of epibenthos for this zone was 2274 ± 610 animals m^{-2}. The highest mean density (6380 ± 332 m^{-2}) occurred at station 34 in July and consisted mainly of nematodes, copepod nauplii and harpacticoids.

As in the estuarine zone the dominant taxa differed at each site, probably due to the intermittent sampling and seasonal variation. Copepod nauplii were dominant at stations 20 and 34, nematodes at station 5 and calanoids at station 4.

Thirty-one categories of epifauna were found in this zone (Kask et al. 1984). Ten taxa, dominated by copepod nauplii, nematodes and harpacticoids, made up 94.0% of the epibenthos (Table 6).

B-3. Density and Taxa Compositon of Harpacticoid Copepods

The highest density (1404 ± 452 m^{-2}), of mainly unidentified copepodites and Harpacticus sp. occurred in July at station 34 (Kask et al. 1984). The species varied from site to site (Table 7), and the zone was dominated by the unidentified copepodites, Harpacticus sp. and Tisbe sp. Eighteen categories of harpacticoids were found at the four sites.

B-4. Comparison of Chinook Diets and Epibenthos At Four Sites

From late May to early September, twenty-five wild and fifty-six marked juvenile chinook from all four sled sites were analyzed for stomach contents (Anderson et al. 1984).

Based on the numerical percent of the diet, epibenthic harpacticoids and amphipods and pelagic calanoids were important in the diet of both the wild and marked fish in this zone (Table 8). Insects were also consumed by the wild fish at station 20. The marked fish relied on euphausiids at station 20 and cumaceans at station 34.

Of the food items in the chinooks' diet, the sled captured mainly harpacticoids and calanoids (Table 6). As in the estuary, Harpacticus sp. was the dominant harpacticoid in the diet in this zone. This species made up 24.5% of the harpacticoids in the epibenthos for all sites combined (Table 7). Neocalanus plumchrus was consumed by the marked chinook at all sites and by the wild ones at station 20. Although considered to be obligate zooplankton, N. plumchrus occurred in the sled samples at stations 4 and 20. It was absent from the epibenthos at stations 5 and 34 which were dominated by copepodites and cyclopoids (Brown et al. in prep.).

Of the organisms of benthic origin, the harpacticoids, littoral amphipods and cumaceans were important in the diet of the juvenile salmon in this zone. The amphipods and cumaceans were not captured in large numbers by the epibenthic sled, perhaps due to a burrowing lifestyle or avoidance by these larger animals.

C. MARINE ZONE

C-1. Sampling Regime

Between March and September sixty-four samples were collected from seven sites in this zone (Fig. 2). Five stations were sampled only once or twice (Table 9). The other two sites, representing two major habitat types available to the juvenile chinook in this zone, were sampled regularly. Station 27, on the outside of Gowlland Island, was subjected to swift tidal currents and the beach consisted of medium to coarse gravel with a moderate incline leading out to a large subtidal kelpbed. Site 31, inside Plumper Bay, experienced slower currents and the beach sloped less dramatically. The sediments changed from fine gravel and sand to mud in the intertidal eelgrass bed offshore.

Although the CPUE for chinook only reached a maximum of 14 in July in this zone they were present in the nearshore area at most sites from the end of May to the beginning of August (Brown et al. 1983).

C-2. Density and Taxa Composition of the Marine Epibenthos

For all samples combined the mean density of epibenthos (± 1SE) in the marine zone was 9876 ± 2691 m^{-2}. There appeared to be four peaks in abundance consisting of mainly harpacticoids, copepod nauplii, amphipods and calanoids (Fig. 6-8). Concentrations of copepod nauplii at stations 25, 27 and 31 were so great on 8-9 July, their densities had to be estimated. (It was assumed there was one nauplius for every harpacticoid in the sample for this one sampling period (Table 10)).

The highest total densities were recorded at stations 25 and 31 in July (Fig. 9). Compared to station 27, station 31 exhibited the greatest densities on seven out of eleven sampling periods and the mean value for this site was 12400 ± 4881 m^{-2}. In contrast, station 27 never reached such high abundances and the yearly mean was much lower at 3122 ± 416 m^{-2}. This would seem to indicate that the less disturbed habitat at station 31 was capable of producing greater numbers of epibenthos than the more dynamic environment at station 27. This may be due to the less intense currents in Plumper Bay as well as the higher organic content of the sediment and the presence of the eelgrass bed.

The taxa present at stations 23, 24, 25, 32 and 281 (Table 10) are probably a reflection of seasonal differences as these sites were not sampled at the same time (Table 9). Copepod nauplii were dominant at station 27 and harpacticoids at station 31. There was a higher percentage of marine organisms (calanoids, tunicates) at station 27, perhaps a result of the increased circulation at this site and the lower densities of true epibenthic organisms.

For the marine zone overall, out of thirty-three categories (Kask et al. 1984), only nine taxa combined made up 97.8% of the epibenthos, dominated by harpacticoids and copepod nauplii (Table 10).

C-3. Density and Taxa Composition of Harpacticoid Copepods

The harpacticoid populations averaged 3836 ± 1258 m^{-2} for this zone (Fig. 6). There were four peaks in abundance, consisting of mainly Tisbe sp. and the unidentified copepodites.

Figure 10 shows the mean numbers of harpacticoids m^{-2} at stations 27 and 31. Station 31 reached the highest abundances and the yearly mean density at this site was almost seven times greater than at station 27.

Despite the varied sampling regime, all seven sites were dominated by either Tisbe sp. or the copepodites (Table 11). Stations 31 and 27 were both dominated by Tisbe sp. Three categories combined made up 94.2% of the harpacticoids at station 31, while at station 27 seven categories comprised 93.0% of the population. The greater variety of species at station 27 may be the result of the increased current activity compared to station 31, and advection of taxa from nearby habitats.

For the marine zone overall, fifty-nine categories of harpacticoids were found (Kask et al. 1984). Seven categories comprised 95.5% of the population dominated by Tisbe sp. and the unidentified copepodites (Table 11).

C-4. Comparison of Chinook Diets and Epibenthos At Four Sites

Between mid June and early August forty-four chinook from four sites were kept for stomach content analysis. Both wild and marked hatchery fish were examined.

Although the wild chinook from this zone were usually smaller than the hatchery fish, based on the numerical percent of the diet, both groups relied on pelagic calanoids and decapod larvae (Table 12). The wild fish at sites 24 and 27 also preyed on epibenthic amphipods. At station 24 the marked fish consumed pelagic amphipods and at station 25 littoral cumaceans formed a large part of the diet for several of the marked fish analyzed.

Of the food items important in the chinooks' diet, the sled caught mainly amphipods and calanoids (Table 10). The calanoid dominant in the chinooks stomachs, Neocalanus plumchrus, occurred in large numbers at several sites in the spring in this zone (Brown et al. in prep.).

The epibenthos contributed mainly amphipods and cumaceans to the diet of the juvenile chinook. However, together these two categories only formed a relatively small part of the chinooks' food. Although present in relatively high densities at some sites, the dominant harpacticoid in the epibenthos, Tisbe sp., was not consumed by any of the chinook analyzed. Rather, the pelagic calanoids (N. plumchrus) and decapods (megalops and zoea) formed the bulk of their diet.

D. COMPARISON OF ESTUARINE, TRANSITION AND MARINE ZONES

D-1. Density and Taxa Composition of the Epibenthos in the Three Zones

The mean density of the epibenthos differed substantially between the three zones, being the lowest in the estuarine zone (561 ± 92 m^{-2}) and highest in the marine zone (9876 ± 2691 m^{-2}). Mean densities in the marine zone were seventeen times greater than in the estuarine zone and four times greater than in the transition zone. The epibenthic populations showed four seasonal peaks in the marine zone and three somewhat correlated peaks in the estuarine zone. Densities were always lowest in the estuarine and highest in the marine zone on concurrent samplings. The values in the transition zone were intermediate on three of the six samplings (Fig. 11).

Copepod nauplii and nematodes were dominant in the estuarine and transition zones and harpacticoids and copepod nauplii in the marine zone (Table 13). Isopods and insects were slightly more numerous in the estuary, while the transition zone was characterized by higher mean densities of nematodes, ectoprocts and rotifers. Most other epibenthos occurred in the greatest numbers in the marine zone, especially harpacticoids, copepod nauplii, amphipods, eggs and tunicates.

D-2. Density and Taxa Composition of Harpacticoid Copepods in the Three Zones

Harpacticoids were most numerous in the marine zone (3836 ± 1258 m^{-2}) followed by the transition zone (456 ± 166 m^{-2}) and estuary (96 ± 22 m^{-2}). The overall mean density of harpacticoids was almost forty times greater in the marine zone than in the estuary. All three zones showed seasonal peaks with some correlation in timing between zones (Fig. 12).

The species present showed some zonal preferences with the greatest variety occurring in the marine zone (Table 14). The estuary was characterized mainly by Huntemannia jadensis which also occurred in the other zones but in much lower numbers. All but two of the species in the transition zone also occurred in the marine zone, usually in higher densities, except for Harpacticus sp. and Heterolaophonte longisetigera which were marginally higher in the transition zone. The marine zone was dominated by Tisbe sp., which occurred at all the sites sampled.

D-3. Comparison of Chinook Diets and Epibenthos In the Three Zones

The epibenthic nearshore populations, especially amphipods and harpacticoids, appeared to be most important in the diet of the juvenile chinook in the transition zone, followed by the estuarine and marine zones. The transition and marine zones seemed to have the greatest food potential, the dominant prey organisms occurring in the greatest densities in these nearshore areas (Table 13).

In any of the groups of fish analyzed from the estuary, the epibenthic organisms never constituted more than 40% of the diet (Table 4). Gammaridae and Corophiidae were the dominant groups of amphipods and Harpacticus sp. and Huntemannia jadensis the dominant harpacticoids eaten in this zone. The estuary was also characterized by a greater reliance on freshwater cladocerans (Bosmina sp.) transported from the river and upstream lakes, and insects (Chironomidae).

As the chinook moved into the transition zone the proportion of epibenthos in the diet, mainly harpacticoids and amphipods, increased to over 99% in the wild chinook at station 5 and 74% in the marked chinook at station 34 (Table 8). Gammaridae and Pontogeneia sp. were the most common amphipods in the stomachs and Harpacticus sp. was among the dominant harpacticoids both in the chinooks' diet and in this zone (Table 7). They also began to prey on pelagic euphausiids.

Once into the marine zone, the chinook decreased their reliance on epibenthic harpacticoids and increased their consumption of decapods (megalops and zoea) and pelagic amphipods (Parathemisto pacifica). At most sites in the marine zone, less than 30% of the diet was made up of organisms of benthic origin except at station 25 where a few marked fish preyed on large numbers of cumaceans (Table 12). The dominant harpacticoid in this zone, Tisbe sp., was not present in the stomachs analyzed.

Pelagic calanoids, mainly Neocalanus plumchrus, were present consistently in the stomachs of the juvenile chinook in all three zones and often dominated their diet. Even in the estuarine zone, marine calanoids transported in with the salt wedge formed a major part of the food in both wild and marked fish. The epibenthic amphipods were also an important prey item in all three zones.

E. COMPARISON OF 1982 CHINOOK DIETS WITH PREVIOUS STUDIES

The diet of the juvenile chinook in the estuary in 1982 differed somewhat from that recorded by Goodman et al. (1974) in 1972-73. Pelagic calanoids, which were numerically dominant in the diet of the chinook in the estuary in 1982, were of only minor importance in 1972-73. Also, based on biomass, cumaceans, mysids, and ostracods seemed to form a greater percentage of the diet in 1972-73.

Analysis of chinook diets in the estuary over a four month period in 1980 showed a diverse diet containing mainly insects, harpacticoid copepods and epibenthic amphipods. The proportions of each group changed according to the sample time, state of the tide and proximity to the river and marsh areas. Calanoids and freshwater cyclopoids were also found in the stomachs (Raymond et al. 1985).

Outside the estuary in 1972-73, at sites equivalent to transition zone sites in 1982, Goodman et al. (1974) found the chinook consumed mainly epibenthic amphipods, followed by pelagic amphipods and fish. In 1982, epibenthic harpacticoids were the main diet item, followed by pelagic calanoids.

Although they were targeting on different prey items, the chinook in all these studies were relying on the nearshore as well as the pelagic environments to provide sufficient food. Inside the estuary, food organisms from the freshwater and terrestrial environments were also important.

This variation in prey items recorded over the years is not uncommon. Healey (1982), discussing chinook diets in various estuaries and during different years, concluded that salmon diets can vary considerably and that chinook will consume a wide variety of prey species.

F. GENERAL DISCUSSION

The Campbell River estuary restoration appears to be the first of its kind as well as the first record of large scale epifaunal colonization of a new estuarine habitat. Previous researchers have only reported on the recolonization of habitat on smaller scales (Sherman et al. 1980; Chandler et al. 1983 and references within).

Complete assessment of the effects of the habitat restoration will require observations over the period of time for the transplanted marshes, their sediments and associated biota to "mature". It has only recently been found that the epibenthic and surface dwelling meiofauna are frequently present in the water column, especially in muddy areas, and subject to dispersion by tidal currents (Bell et al. 1980; Palmer et al. 1981). The preliminary observations reported here suggest that the initial colonization of the new habitat was rapid, a phenomenon also observed by other researchers (Sherman et al. 1980).

The ultimate density of animals reached on the new islands and their contribution to the food of the juvenile salmon depends on several factors. Salinity and temperature fluctuations, and nutrient input are all important, as are the type of sediments formed. Based on the suggestions of some researchers, mud, detrital and phytal environments may produce communities of epibenthos which are the most useful to browsing higher trophic levels such as larval and juvenile fish (Coull et al. 1979; Hicks et al. 1983). Also influential are the types and densities of epifauna in the surrounding areas and the availability of transported animals to colonize the new habitats (Hagerman et al. 1981).

Compared to the transition and marine zones, and to other estuaries on this coast (Sibert et al. 1977; Sibert et al. 1982), the Campbell River estuarine zone appears to have a low average abundance of epibenthos, even in the established areas. However, historically the estuary and its watershed have been subjected to many disruptions. Before restoration was undertaken, much of the estuary was utilized by the forest industry for log storage and handling and debris and bark accumulations on the bottom were up to 2 m deep at points (Bond 1975, in Bell et al. 1977). Periodic dredging was necessary to maintain adequate depth. Reference to photographs of this area in the earlier part of the century emphasize how much the upper littoral zone and the shoreline have been altered, so much so that today approximately 80% of this area has been alienated from natural production. Marina construction, floats for seaplanes, barge facilities, pile bulkheads, and extensive riprap have further altered the natural outline of this area. Parking lots, a dryland log sort, urbanization, and lumber mills have also greatly reduced the riparian vegetative inputs to the estuary and prey production dependent on it.

Within the watershed itself, dams, mines, and the construction of a hatchery have all added to the changed regime and further removed this ecosystem from its original state. The river now has a largely controlled flow with the resulting benefits, but at the same time the natural flood stages which delivered organics to the estuary in the form of leaf litter and sediments have been lost. The lakes in the system are considered largely oligotrophic (McMynn et al. 1953) and so contribute only limited nutrients to the estuarine area. The hatchery has released juvenile salmon yearly to the system since the mid 1970's, further increasing the load on the estuarine food chain. The average biomass of all juvenile salmon of all species exceeded 1 g m^{-2} from early May to late July in 1982 (McAllister pers. comm.). Considering only the feeding of these juvenile salmon, they could each require up to 6 g of food before leaving the estuary implying considerable grazing pressure.

All of the above factors probably contribute to the low epibenthos in the estuary but there is no present data on their relative importance. The reclaimed habitat, left undisturbed, should become an important element in the estuarine food web and monitoring is continuing on the changes in this habitat.

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REFERENCES

Anderson, E. P. and M. Galbraith. 1984. Stomach contents of juvenile chinook salmon from the Campbell River estuary March-November 1982. Contract report in partial fulfillment of DSS File Number 03SB.FP957-2-7474: 30 p.

Bell, L. M. and J. M. Thompson. 1977. The Campbell River estuary status of environmental knowledge to 1977. Fish. and Environ. Canada Spec. Estuary Series No. 7: 346 p.

Bell, S. S. and K. M. Sherman. 1980. A field investigation of meiofauna dispersal: tidal resuspension and implications. Mar. Ecol. Prog. Ser. (3): 245-249.

Brown, T. J., C. D. McAllister, C. D. Levings and M. Kotyk. 1983. Salmonid catch-data from Campbell River and Discovery Passage, 1982. Can. Data Rep. Fish. Aquat. Sci. 416: 97 p.

Brown, T. J., R. F. Clarke, and B. A. Kask. 1984. Meiofauna sled samples from Campbell River Estuary and Discovery Passage 1982 - calanoid copepod species identification. Can. Data Rep. Fish. Aquat. Sci. 483: 22 p.

Brown T. J., B. A. Kask, and C. D. McAllister. (in prep.). Calanoid copepod species distribution from nearshore meiobenthic sled samples taken at Campbell River estuary and Discovery Passage in 1982. Can. MS Rep. Fish. Aquat. Sci.

Brownlee, M. J., E. R. Mattice, and C. D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Can. MS Rep. Fish. Aquat. Sci 1789: 211 p.

Chandler, G. T. and J. W. Fleeger. 1983. Meiofaunal colonization of azoic estuarine sediment in Louisiana: mechanisms of dispersal. J. Exp. Mar. Biol. Ecol. 69: 175-188.

Coull, B. C. and S. S. Bell. 1979. Perspectives of marine meiofaunal ecology, p. 189-216. In R. J. Livingston (Ed.), Ecological Processes in Coastal and Marine Ecosystems. Plenum Publ. Corp., New York.

Goodman, D. and P. R. Vroom. 1974. An assessment of the impact of proposed marina development on the fisheries resources of the Campbell River estuary. Can. Fish. Mar. Serv. Tech. Rep. Series No. PAC/T-74-13: 25 p.

Hagerman, G. M., Jr., and R. M. Rieger. 1981. Dispersal of benthic meiofauna by wave and current action in Bogue Sound, North Carolina, USA. Mar. Ecol. 2: 245-270.

Healey, M. C. 1982. Juvenile Pacific salmon in estuaries: The Life Support System, p. 315-341. In V.S. Kennedy (Ed.) Estuarine Comparisons. Proceedings of the Sixth Biennial International Estuarine Research Conference, 1981. Academic Press, N.Y.

Hicks, G. R. F. and B. C. Coull. 1983. The ecology of marine meiobenthic harpacticoid copepods. Oceanog. Mar. Biol. Annu. Rev. 21: 67-175.

Kask, B. A. and T. J. Brown. 1984. Meiofauna sled samples from Campbell River estuary and Discovery Passage 1982. Can. Data Rep. Fish. Aquat. Sci. 476: 157 p.

Levings, C. D., C. D. McAllister, and B. D. Chang. (in prep.). Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (*Oncorhynchus tshawytscha*). West Vancouver Laboratory, West Vancouver, British Columbia.

McAllister, C. D., C. D. Levings, T. Brown, and B. D. Chang. 1984. Juvenile chinook salmon in relation to new island habitat, Campbell River estuary, 1982, p. 20-23. In: The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Brownlee, M. J., E. R. Mattice, and C. D. Levings (Eds.). Can. MS Rep. Fish. Aquat. Sci 1789: 211 p.

Macdonald, J. S. and C. D. Levings. (in prep.). Feeding of juvenile salmonids in a newly restored estuarine habitat. West Vancouver Laboratory, West Vancouver, British Columbia.

Macdonald, J. S., G. M. Kruzynski, I. K. Birtwell, K. D. Seaman, L. Del Mistro, and M. Kotyk. 1985. Juvenile salmonid and plankton samples from an inner and an outer estuarine station in the Campbell River estuary, British Columbia, 1984. Can Data Rep. Fish. Aquat. Sci. 520: 27 p.

McMynn, R. G. and P. A. Larkin. 1953. The effects of fisheries of present and future water utilization in the Campbell River drainage area. B.C. Dept. Rec. and Cons. 61 p.

Mundie, J. H. and D. E.Mounce. 1976. Effects of changes in discharge in the lower Campbell River on the transport of food organisms of juvenile salmon, p. a1-a21. In: Effects of modified hydrology on Campbell River salmonids by R. Hamilton and J. W. Buell. Fish. Mar. Serv. Tech. Rep. PAC/T-76-20: 156 p.

Palmer, M. A. and R. R. Brandt. 1981. Tidal variation in sediment densities of marine benthic copepods. Mar. Ecol. Prog. Ser. (4): 207-212.

Raymond, B. and C. D. Levings. 1984. Benthic invertebrates associated with the islands in the Campbell River Estuary: a preliminary report, p. 17-19. In: The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Brownlee, M. J., E. R. Mattice, and C. D. Levings (Eds.). Can. MS Rep. Fish. Aquat. Sci. 1789: 211 p.

Raymond, B. A., M. M. Wayne, and J. A. Morrison. 1985. Vegetation, invertebrate distribution and fish utilization of the Campbell River estuary British Columbia. Can. MS Rep. Fish. Aquat. Sci. 1829: 34 p.

Sherman, K. M. and B. C. Coull. 1980. The response of meiofauna to sediment disturbance. J. Exp. Mar. Biol. Ecol. (46): 59-71.

Sibert, J., B. A. Kask, and T. J. Brown. 1977. A diver-operated sled for sampling the epibenthos. Fish. Mar. Serv. Tech. Rep. 738: 19 p.

Sibert, J. R., T. J. Brown and B. A. Kask. 1982. Meiofauna counts from the Fraser River delta, 1980 and 1981, sled samples. Can. Data Rep. Fish. Aquat. Sci. 341: 143 p.

Table 1. Date each station in the estuarine zone was visited and number of samples collected.

Station No.	Dates visited (1982)	No. of samples
1	December 14	2
2	May 17	2
3	March 23, April 5, April 13, May 3, May 26, June 5, June 17, November 9	16
7	March 23, April 5, April 28, May 5, May 17, June 6, June 16, June 29, July 9, July 21, August 4, September 10, September 29, November 9, December 14	30
13	June 17	2
17	March 23, April 5, April 13, May 3	8
18	April 13, May 3, May 17, May 28, June 5	10
Total		70

Table 2. Dominant organisms found in Campbell River estuarine zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station	1	2	3	7	13	17	18	All
Location	Mother Ramp	Nunn's Island	Nunn's Creek	North Baikie Mouth	Island No. 2	Island No. 3	Island No. 4	
No. of samples	2	2	16	30	2	8	10	70
Category								
Copepod nauplii	4.5	48.7	20.8	40.2	19.7	37.8	36.5	35.5
Nematodes	77.5	32.4	34.7	20.7	41.8	19.8	36.9	31.2
Harpacticoids	3.7	8.5	10.3	19.9	13.0	5.2	19.0	17.1
Calanoids	2.5	<1.0	3.1	2.0	8.7	10.5	2.0	2.6
Eggs	1.1	<1.0	5.4	1.7	1.9	7.0	2.2	2.6
Worms	4.2	3.6	3.0	2.6	3.9	6.3	<1.0	2.1
Ostracods	-	2.0	<1.0	3.5	-	<1.0	1.4	1.9
Amphipods	1.7	-	3.0	2.7	<1.0	2.1	<1.0	1.5
Cladocerans	1.1	<1.0	3.2	<1.0	6.7	<1.0	<1.0	<1.0
Isopods	<1.0	<1.0	5.0	<1.0	-	-	<1.0	<1.0
Barnacle nauplii	-	-	1.9	<1.0	-	7.9	<1.0	<1.0
Acarinans	1.4	1.3	2.5	<1.0	1.9	<1.0	<1.0	<1.0
Rotifers	-	-	3.6	<1.0	-	-	-	<1.0
Total %	97.7	96.5	96.5	93.3	97.6	96.6	98.0	94.5

Table 3. Dominant harpacticoid species found in Campbell River estuarine zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station	1	2	3	7	13	17	18	All
Location	Mother Ramp	Nunn's Island	Nunn's Creek	North Baikie Mouth	Island No. 2	Island No. 3	Island No. 4	
No. of samples	2	2	16	30	2	8	10	70
Category								
Unidentified copepodites	84.6	42.3	57.9	38.8	63.0	68.3	48.5	46.0
Huntemannia jadensis	-	15.4	4.8	15.0	25.9	2.2	30.5	22.2
Family Ectinosomatidae	-	11.5	8.8	13.0	-	2.2	7.8	9.7
Tisbe species	-	-	2.2	12.7	-	-	1.8	5.8
Microarthridion littorale	-	-	-	<1.0	3.7	-	6.8	3.8
Zaus species	-	-	1.8	6.5	-	9.3	<1.0	2.8
Mesochra alaskana	-	30.8	6.6	2.7	3.7	-	<1.0	1.9
Harpacticus species	-	-	1.8	1.8	-	-	1.5	1.6
Tachidius discipes	-	-	-	<1.0	3.7	2.2	<1.0	<1.0
Sarsameira sp. "B"	-	-	-	<1.0	-	-	<1.0	<1.0
Leimia vaga	-	-	<1.0	1.1	-	-	-	<1.0
Nitocra spinipes	-	-	1.8	<1.0	-	3.5	<1.0	<1.0
Amphiascoides species	-	-	2.2	<1.0	-	-	<1.0	<1.0
Mesochra pygmaea	-	-	1.5	<1.0	-	3.5	-	<1.0
Schizopera knabeni	-	-	<1.0	<1.0	-	2.2	-	<1.0
Schizopera sp. "A"	15.4	-	2.2	<1.0	-	-	-	<1.0
Remanea arenicola	-	-	2.9	-	-	-	-	<1.0
Enhydrosoma sp. "A"	-	-	1.1	-		-		<1.0
Heterolaophonte mendax	-	-	1.1	-		-		<1.0
Tachidius incisipes	-	-	1.1	<1.0		2.2		<1.0
Heterolaophonte hamondi	-	-	-	-		2.2		<1.0
Mesocletodes arenicola	-	-	-	<1.0		2.2		<1.0
Total %	100.0	100.0	97.8	91.6	100.0	100.0	96.9	93.8

Table 4. Dominant food items in juvenile chinook stomachs at two sites in Campbell River estuarine zone 1982.

Station	7			7			14, 16, 17		
Wild or marked	Wild			Marked			Wild		
Dates	24 Mar-8 Sept			10 May-27 Sept			15 Apr-17 June		
No. fish analyzed	39			43			24		
Range in length (mm)	37-97			61-125			40-55		
Range in weight (gm)	0.45-11.80			2.95-24.40			0.65-2.60		
Number stomachs empty	1			13			1		
Food group	Numerical percent	% Freq. Occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. Occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. Occur.	$\bar{x}$ # per fish
Pelagic calanoids and cyclopoids	19.7	25.6	6.4	63.9	32.6	25.6	47.4	75.0	21.9
Juvenile and adult insects	47.8	89.7	15.5	6.0	51.2	2.4	4.1	58.3	1.9
Epibenthic amphipods	7.0	38.5	2.3	11.5	48.8	4.6	10.5	75.0	4.8
Epibenthic harpacticoids	5.5	30.8	1.8	1.1	11.6	1.0	27.2	79.1	12.6
Freshwater cladocera	18.1	5.1	5.9	4.0	4.7	1.6	5.4	20.8	2.5
Pelagic amphipods	1.0	2.6	1.0	2.4	18.6	1.2	2.5	33.3	1.2
Epibenthic isopods	1.0	2.6	1.0	6.5	20.9	2.6	-	-	-
Decapod larvae	1.0	5.1	1.0	1.8	7.0	1.0	1.0	4.2	1.0
Epibenthic ostracods	1.0	2.6	1.0	1.0	11.6	1.0	1.4	20.8	1.0

Table 5. Date each station in the transition zone was visited and number of samples collected.

Station No.	Dates visited (1982)	No. of samples
5	March 23	2
20	April 13	2
34	July 9, July 21, August 18	6
4	April 5	2
Total		12

Table 6. Dominant organisms found in Campbell River transition zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station	4	5	20	34	All
Location	Spit	Bar	Boat Ramp	Painters Channel	
No. of samples	2	2	2	6	12
Category					
Copepod nauplii	23.3	8.4	31.6	36.2	32.6
Nematodes	<1.0	30.3	9.0	25.8	20.9
Harpacticoids	<1.0	9.5	<1.0	26.2	20.1
Calanoids	42.7	<1.0	14.9	1.7	9.6
Eggs	1.9	10.2	3.7	3.0	3.1
Barnacle nauplii	10.4	6.5	4.3	<1.0	2.3
Ostracods	<1.0	-	<1.0	2.1	1.6
Ectoprocts	7.9	-	1.9	<1.0	1.6
Worms	<1.0	2.0	1.6	1.2	1.2
Gastropod eggs	<1.0	<1.0	<1.0	1.3	1.0
Amphipods	<1.0	5.0	<1.0	<1.0	<1.0
Rotifers	-	21.4	-	-	<1.0
Polychaetes	4.2	<1.0	-	-	<1.0
Tunicates	1.8	-	13.3	<1.0	<1.0
Gastropods	2.8	-	<1.0	<1.0	<1.0
Cumaceans	-	-	-	<1.0	<1.0
Barnacle cypris	<1.0	-	12.4	-	<1.0
Echinoderm larvae	<1.0	-	3.4	-	<1.0
Isopods	<1.0	1.1	-	<1.0	<1.0
Acarinans	<1.0	3.2	<1.0	<1.0	<1.0
Total %	95.0	97.6	96.1	97.5	94.0

Table 7. Dominant harpacticoid species found in Campbell River transition zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station	4	5	20	34	All
Location	Spit	Bar	Boat Ramp	Painters Channel	
No. of samples	2	2	2	6	12
Category					
Unidentified copepodites	-	56.8	66.7	54.3	54.3
Harpacticus species	-	2.0	-	25.0	24.5
Tisbe species	-	23.5	33.3	7.6	7.9
Family Ectinosomatidae	-	-	-	6.0	5.9
Heterolaophonte longisetigera	50.0	-	-	4.4	4.3
Zaus species	-	2.0	-	1.2	1.2
Huntemannia jadensis	-	3.9	-	<1.0	<1.0
Nitocra spinipes	-	5.9	-	-	<1.0
Remanea arenicola	-	3.9	-	-	<1.0
Heterolaophonte hamondi	-	2.0	-	-	<1.0
Mesochra alaskana	50.0	-	-	-	<1.0
Total %	100.0	100.0	100.0	98.5	98.1

Table 8. Dominant food items in juvenile chinook stomachs at four sites in Campbell River transition zone 1982.

Station	4			5			5			20			20			34		
Wild or marked	Marked			Wild			Marked			Wild			Marked			Marked		
Dates	29 May-17 July			21 July			29 May-9 July			17 May-9 Sept			18 May-9 Sept			28 May-21 July		
Number of fish analyzed	19			5			10			20			15			12		
Range in length (mm)	76-110			74-84			85-109			45-132			64-161			76-111		
Range in weight (gm)	5.30-14.90			5.10-7.40			8.20-15.10			1.00-24.50			3.50-50.80			5.20-16.60		
Number of stomachs empty	3			0			5			0			4			0		
Food group	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish	Numerical per-cent	% Freq. occur.	$\bar{x}$ # per fish
Pelagic calanoids and cyclopoids	78.3	73.7	63.9	-	-	-	33.0	10.0	6.5	11.5	65.0	10.7	62.5	46.7	24.1	25.1	58.3	78.6
Juvenile and adult insects	<1.0	21.1	<1.0	<1.0	60.0	1.0	-	-	-	10.1	40.0	9.4	1.0	13.3	<1.0	<1.0	50.0	<1.0
Epibenthic amphipods	7.2	57.9	5.9	<1.0	100.0	14.2	58.9	40.0	11.6	5.4	65.0	5.0	3.1	40.0	1.2	4.6	50.0	14.3
Epibenthic harpacticoids	3.5	31.6	2.9	97.5	100.0	2354.4	-	-	-	65.6	70.0	61.1	9.5	20.0	3.7	54.0	75.0	169.3
Pelagic amphipods	<1.0	10.5	4.0	-	-	-	-	-	-	2.1	40.0	2.0	4.3	33.3	1.7	<1.0	8.3	<1.0
Pelagic euphausiids	<1.0	5.3	<1.0	-	-	-	-	-	-	2.6	20.0	2.5	15.5	33.3	6.0	-	-	-
Epibenthic cumaceans	3.4	42.1	2.8	1.9	80.0	44.8	2.5	30.0	<1.0	1.4	50.0	1.3	1.0	13.3	<1.0	15.8	83.3	49.6
Epibenthic ostracods	2.1	26.3	1.7	<1.0	20.0	<1.0	-	-	-	<1.0	10.0	<1.0	2.4	13.3	<1.0	-	-	-
Decapod larvae	3.9	42.1	3.2	-	-	-	-	-	-	<1.0	30.0	<1.0	<1.0	13.3	<1.0	<1.0	8.3	<1.0
Epibenthic isopods	<1.0	5.3	<1.0	-	-	-	5.1	10.0	1.0	-	-	-	-	-	-	<1.0	8.3	<1.0

Table 9. Date each station in the marine zone was visited and number of samples collected.

Station No.	Dates visited (1982)	No. of samples
23	June 5	2
24	August 18	2
25	July 8	2
27	March 23, April 6, April 27, May 4, May 18, May 27, June 16, June 28, July 9, July 20, August 4, August 18, September 9, September 29	28
31	April 6, April 14, April 27, May 27 June 4, June 18, June 29, July 8, July 20, August 4, August 18, September 9	24
32	April 14, May 4	4
281	March 23	2
Total		64

Table 10. Dominant organisms found in Campbell River marine zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station Location No. of samples	23 Middle Pt. 2	24 Menzies Bay 2	25 Maude Beach 2	27 Outer Gowlland 28	31 Plumper Bay 24	32 Deepwater Bay 4	281 South Gowlland 2	All 64
Category								
Harpacticoids	34.8	45.7	42.9	23.6	41.2	42.1	2.3	38.9
Copepod nauplii	28.8	31.4	*41.6	*35.2	*39.7	28.8	4.3	38.4
Amphipods	1.7	18.8	13.7	4.3	7.1	1.5	-	9.0
Calanoids	6.9	1.7	<1.0	12.6	3.1	5.6	3.5	3.6
Eggs	1.5	<1.0	<1.0	3.2	2.3	3.1	1.1	1.8
Tunicates	<1.0	-	<1 0	10.7	<1.0	1.2	<1.0	1.7
Nematodes	21.7	<1.0	<1.0	2.4	1.4	7.1	3.6	1.7
Barnacle nauplii	-	-	-	1.2	<1.0	1.0	79.1	1.4
Gastropod eggs	<1.0	<1.0	<1.0	<1.0	2.4	2.2	2.6	1.3
Worms	1.1	-	<1.0	2.4	<1.0	<1.0	2.4	<1.0
Ostracods	<1.0	<1.0	<1.0	<1.0	<1.0	1.1	-	<1.0
Barnacle cypris	-	-	<1.0	1.0	<1.0	2.4	-	<1.0
Polychaetes	-	-	-	1.0	<1.0	<1.0	<1.0	<1.0
Cumaceans	1.5	-	<1.0	<1.0	<1.0	-	-	<1.0
Total %	98.0	97.6	98.2	97.6	97.2	96.1	98.9	97.8

*Denotes calculated value included.

Table 11. Dominant harpacticoid species found in Campbell River marine zone epibenthic sleds 1982, expressed as percent of total population by station and for all stations combined.

Station	23	24	25	27	31	32	281	All
Location	Middle Pt.	Menzies Bay	Maude Beach	Outer Gowlland	Plumper Bay	Deepwater Bay	South Gowlland	
No. of samples	2	2	2	28	24	4	2	64
Category								
Tisbe species	19.5	30.1	37.8	41.2	63.7	17.5	1.0	49.9
Unidentified copepodites	52.2	21.5	48.3	34.0	25.5	45.5	33.7	34.2
Family Ectinosomatidae	3.6	15.4	3.6	1.9	5.0	2.7	1.0	4.8
Zaus species	-	9.7	2.1	11.7	<1.0	<1.0	10.2	2.3
Harpacticus species	15.2	5.3	1.5	1.6	<1.0	29.4	20.4	1.8
Diosaccus spinatus	2.8	-	3.7	<1.0	<1.0	-	-	1.4
Dactylopodia species	1.5	5.7	<1.0	1.3	<1.0	<1.0	3.1	1.1
Mesochra pygmaea	-	5.0	1.4	<1.0	<1.0	<1.0	1.0	<1.0
Amphiascoides species	1.0	-	-	<1.0	<1.0	-	-	<1.0
Scutellidium arthuri	-	1.2	-	-	-	-	-	<1.0
Diarthrodes unisetosus	<1.0	1.2	-	<1.0	<1.0	<1.0	-	<1.0
Microsetella species	-	-	-	<1.0	<1.0	-	1.0	<1.0
Mesocletodes arenicola	-	-	-	<1.0	-	-	7.1	<1.0
Paralaophonte perplexa	1.8	-	<1.0	<1.0	<1.0	<1.0	-	<1.0
Heterolaophonte hamondi	-	-	-	<1.0	<1.0	-	14.3	<1.0
Amphiascus undosus	-	2.5	-	<1.0	<1.0	-	-	<1.0
Nitocra spinipes	-	-	-	<1.0	<1.0	1.1	3.1	<1.0
Typhlamphiascus sp. "A"	-	-	-	1.3	-	-	-	<1.0
Schizopera knabeni	-	-	-	<1.0	<1.0	-	1.0	<1.0
Psyllocamptus sp. "A"	-	-	-	-	-	-	1.0	<1.0
Haloschizopera sp "A"	-	-	-	-	-	-	1.0	<1.0
Tachidius neotachidius triangularis	-	-	-	<1.0	-	-	1.0	<1.0
Total %	97.6	97.6	98.4	93.0	94.2	96.2	99.9	95.5

Table 12. Dominant food items in juvenile chinook stomachs at four sites in Campbell River marine zone 1982.

Station	23			24			24			25			27		
Wild or marked	Marked			Wild			Marked			Marked			Wild		
Dates	16 June			20 July-4 August			20 July-4 August			18 June-8 July			4 August		
Number of fish analyzed	5			10			9			15			5		
Range in length (mm)	101-117			82-93			100-121			82-125			69-80		
Range in weight (gm)	14.60-21.95			6.50-9.50			10.80-19.50			6.40-22.1			3.80-6.00		
Number of stomachs empty	0			0			0			2			0		
Food group	Numerical percent	% Freq. occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. occur.	$\bar{x}$ # per fish	Numerical percent	% Freq. occur.	$\bar{x}$ # per fish
Pelagic calanoids and cyclopoids	94.6	100.0	105.8	14.2	80.0	10.0	3.2	100.0	2.1	22.5	53.3	13.2	11.4	40.0	4.0
Juvenile and adult insects	-	-	-	2.1	70.0	1.5	<1.0	22.2	<1.0	2.7	26.7	1.6	7.4	80.0	2.6
Epibenthic amphipods	1.8	20.0	2.0	6.0	70.0	4.2	2.2	22.2	1.4	<1.0	20.0	<1.0	15.9	100.0	5.6
Epibenthic harpacticoids	1.4	20.0	1.6	1.9	30.0	1.3	-	-	-	<1.0	13.3	<1.0	1.7	20.0	<1.0
Pelagic euphausiids	-	-	-	<1.0	20.0	<1.0	1.5	11.1	1.0	<1.0	6.7	<1.0	-	-	-
Pelagic amphipods	-	-	-	4.8	60.0	3.4	16.7	88.9	10.9	2.2	40.0	1.3	4.6	40.0	1.6
Pelagic gastropods	-	-	-	-	-	-	<1.0	11.1	<1.0	2.0	6.7	1.2	-	-	-
Decapod larvae	<1.0	20.0	<1.0	58.5	100.0	41.1	68.5	88.9	44.8	5.7	66.7	3.3	56.8	100.0	20.0
Epibenthic ostracods	1.8	20.0	2.0	3.4	40.0	2.4	6.0	33.3	3.9	1.1	26.7	<1.0	-	-	-
Fish	<1.0	20.0	<1.0	-	-	-	<1.0	22.2	<1.0	<1.0	26.7	<1.0	1.1	20.0	<1.0
Epibenthic cumaceans	-	-	-	7.3	20.0	5.1	<1.0	22.2	<1.0	62.4	13.3	36.7	-	-	-
Epibenthic tanaidaceans	-	-	-	1.3	30.0	<1.0	-	-	-	-	-	-	<1.0	20.0	<1.0

Table 13. Comparison of dominant organisms between zones. Mean numbers of major categories m^{-2} ± 1SE averaged over all samples for all stations.

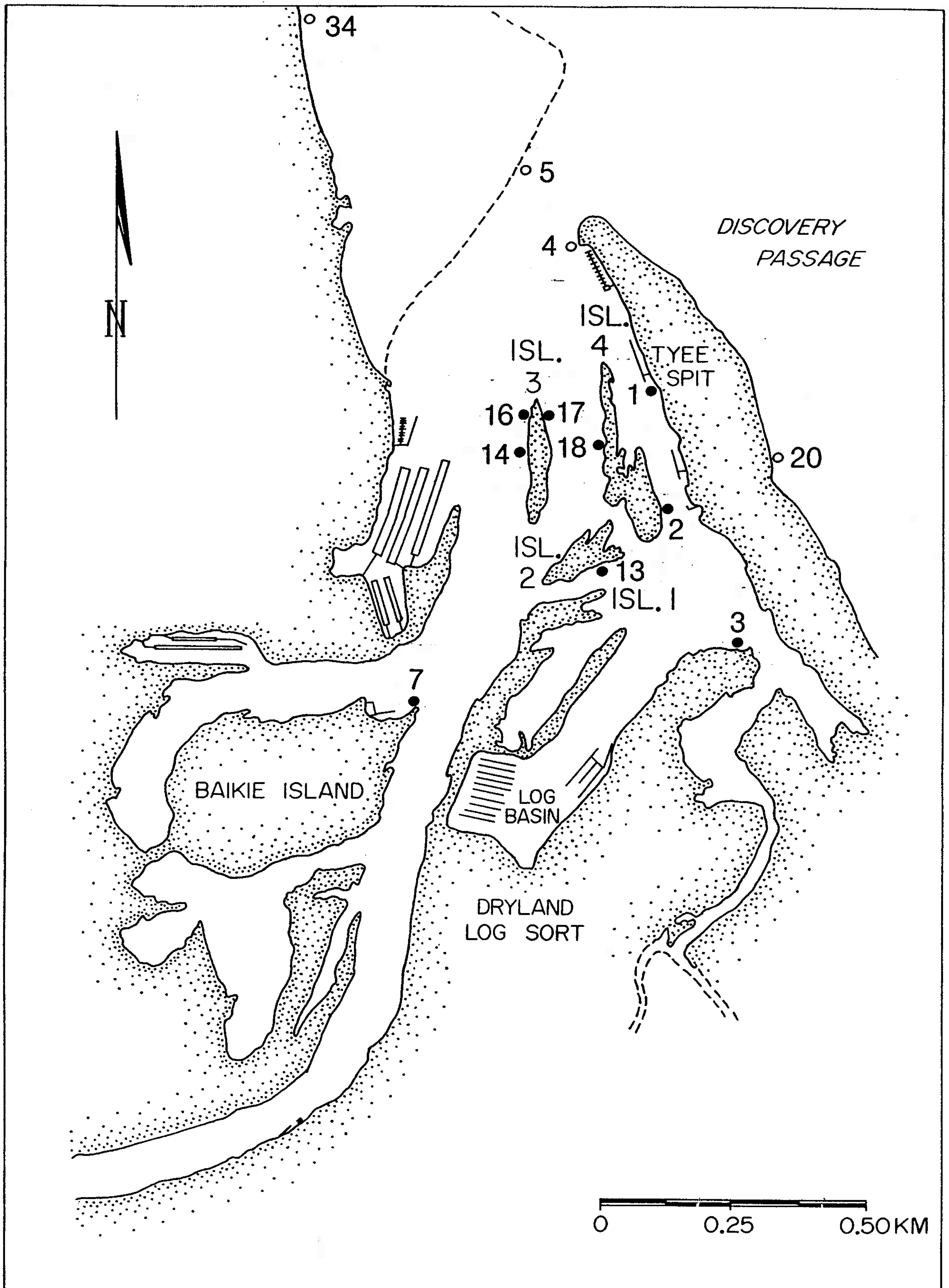
Category	Estuarine	Transition	Marine
Copepod nauplii	199.3 ± 44.1	740.5 ± 222.7	3792.2 ± 1206.1
Nematodes	175.2 ± 33.3	474.3 ± 254.2	165.0 ± 37.0
Harpacticoid copepods	96.0 ± 22.4	456.0 ± 166.1	3836.6 ± 1258.0
Calanoid copepods	14.7 ± 2.9	218.8 ± 119.4	351.0 ± 41.8
Eggs	14.4 ± 3.6	69.8 ± 20.8	175.3 ± 39.7
Worms	12.0 ± 1.7	27.0 ± 7.6	88.5 ± 18.3
Ostracods	10.7 ± 2.6	36.7 ± 17.3	50.1 ± 25.5
Amphipods	8.6 ± 1.7	20.8 ± 7.6	886.1 ± 311.7
Cladocerans	4.9 ± 1.4	<1.0	9.6 ± 4.3
Isopods	4.7 ± 1.4	1.5 ± 1.0	2.4 ± 0.9
Barnacle nauplii	4.5 ± 1.4	53.2 ± 28.9	136.3 ± 73.6
Ectoprocts	1.0 ± 0.3	35.8 ± 22.1	8.4 ± 1.8
Gastropod eggs	1.9 ± 0.5	22.8 ± 7.3	130.0 ± 30.9
Rotifers	2.9 ± 1.7	19.2 ± 13.0	-
Polychaetes	<1.0	17.8 ± 12.0	16.4 ± 8.0
Tunicates	<1.0	17.2 ± 6.0	167.5 ± 71.6
Gastropods	<1.0	14.8 ± 8.3	9.8 ± 1.8
Cumaceans	<1.0	14.7 ± 7.2	10.8 ± 4.8
Barnacle cypris	1.3 ± 0.4	7.7 ± 4.5	21.0 ± 4.8
Echinoderm larvae	<1.0	6.0 ± 2.9	1.0 ± 0.3
Bivalves	<1.0	4.5 ± 2.3	2.6 ± 0.8
Acarinans	4.1 ± 0.6	4.2 ± 2.6	4.1 ± 0.7
Euphausiids	-	3.8 ± 2.6	1.1 ± 0.4
Crab zoea	<1.0	3.2 ± 2.3	<1.0
Mysids	<1.0	1.7 ± 0.9	<1.0
Tanaidaceans	<1.0	-	6.0 ± 2.4
Medusae	<1.0	<1.0	1.5 ± 0.6
Insects	1.7 ± 0.6	-	<1.0
Zone totals	561.1 ± 92.4	2273.7 ± 610.1	9876.2 ± 2691.0

Table 14. Comparison of dominant harpacticoid species between zones. Mean numbers of each species m-2 ± 1SE averaged over all samples for all stations.

Category	Estuarine	Transition	Marine
Unidentified copepodites	44.2 ± 10.5	247.7 ± 88.3	1313.0 ± 440.8
Huntemannia jadensis	21.3 ± 7.9	<1.0	6.4 ± 1.6
Family Ectinosomatidae	9.3 ± 2.7	27.0 ± 11.8	183.4 ± 54.3
Tisbe species	5.6 ± 2.2	36.2 ± 13.3	1915.8 ± 814.0
Microarthridion littorale	3.6 ± 1.7	-	<1.0
Zaus species	2.7 ± 1.9	5.5 ± 2.0	88.5 ± 33.2
Mesochra alaskana	1.8 ± 0.6	<1.0	-
Harpacticus species	1.5 ± 0.7	111.7 ± 65.8	70.0 ± 20.5
Heterolaophonte longisetigera	<1.0	19.8 ± 12.1	14.1 ± 7.0
Dactylopodia species	<1.0	2.0 ± 1.2	41.9 ± 13.6
Laophontid sp. "C"	<1.0	1.8 ± 1.8	-
Robertsonia propinqua	-	<1.0	1.4 ± 0.9
Nitocra spinipes	<1.0	<1.0	5.4 ± 2.2
Diosaccus spinatus	<1.0	-	55.2 ± 34.5
Mesochra pygmaea	<1.0	-	35.6 ± 14.7
Amphiascopsis cinctus	-	-	21.0 ± 13.0
Ameira longipes	<1.0	<1.0	16.7 ± 7.8
Diarthrodes unisetosus	<1.0	<1.0	14.3 ± 3.8
Paralaophonte perplexa	-	-	9.1 ± 5.4
Amphiascus undosus	-	-	6.2 ± 3.7
Typhlamphiascus sp. "A"	-	-	4.0 ± 3.7
Laophonte inopinata	-	-	4.0 ± 4.0
Ameira parvuloides	-	-	3.9 ± 2.2
Amphiascoides species	<1.0	-	3.9 ± 1.4
Parastenhelia spinosa	-	-	3.2 ± 2.0
Paralaophonte pacifica	-	-	3.0 ± 1.9
Scutellidium arthuri	-	-	2.6 ± 1.9
Proameira simplex	-	-	2.3 ± 1.4
Microsetella species	<1.0	-	2.1 ± 0.9
Tachidius (Neotachidius) triangularis	-	-	1.8 ± 1.6
Mesocletodes arenicola	<1.0	-	1.0 ± 0.8
Zone totals	96.0 ± 22.4	456.0 ± 166.1	3836.6 ± 1258.0

FIGURES

Fig. 1. Map of the Campbell River estuary and surrounding area showing the location of the estuarine zone stations (solid circles) and transition zone stations (open circles) in 1982.


34
5
DISCOVERY
PASSAGE
4
N
ISL.
4
TYEE
SPIT
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3
1
16
17
18
14
20
2
ISL.
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ISL. I
3
7
BAIKIE ISLAND
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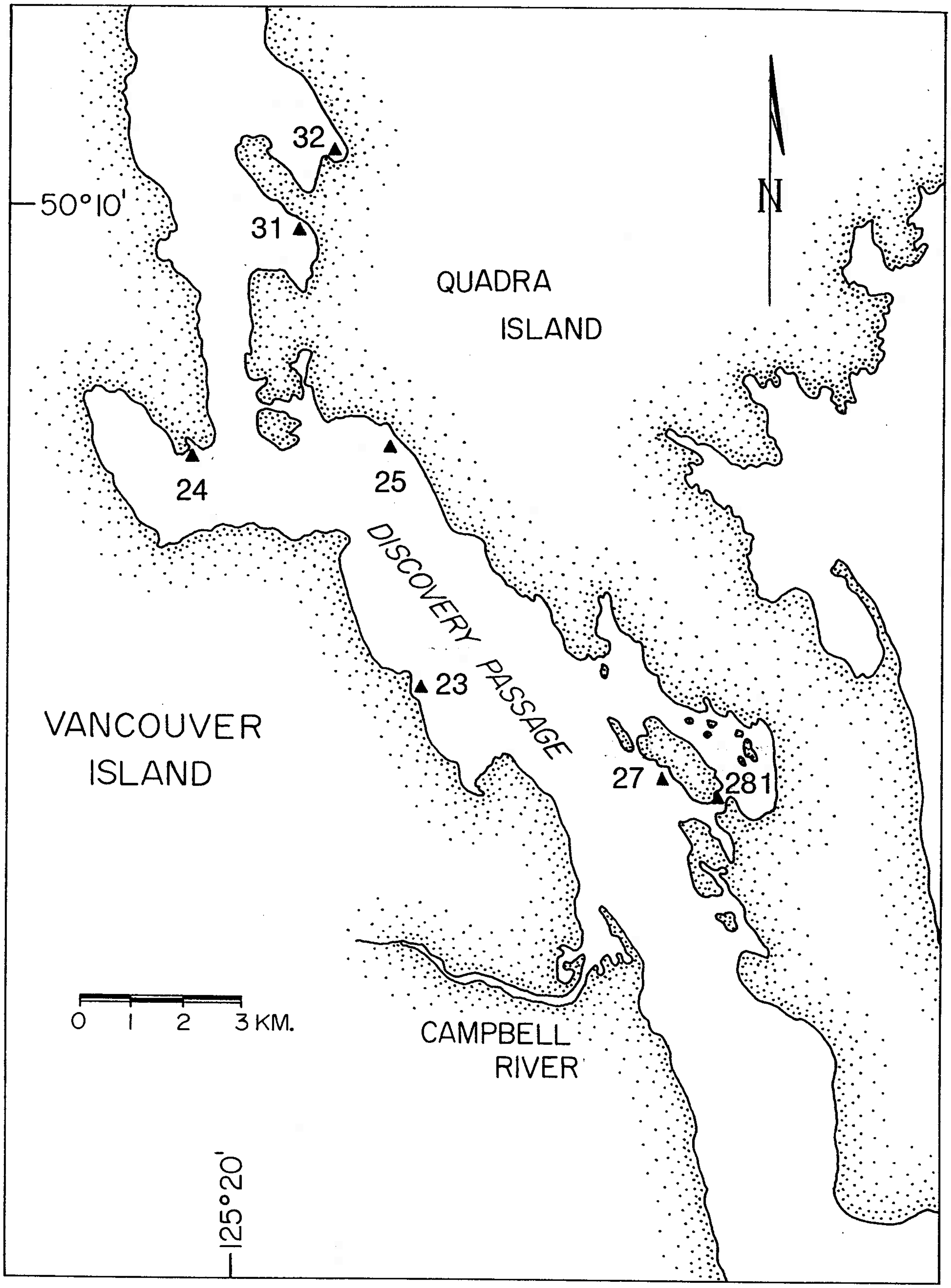
BASIN
DRYLAND
LOG SORT
0
0.25
0.50 KM

Fig. 2. Map of Discovery Passage showing the location of the marine zone stations (solid triangles) in 1982.


50°10'
32
31
QUADRA
ISLAND
N
24
25
DISCOVERY PASSAGE
23
VANCOUVER
ISLAND
27
281
0 1 2 3 KM.
CAMPBELL
RIVER
125°20'

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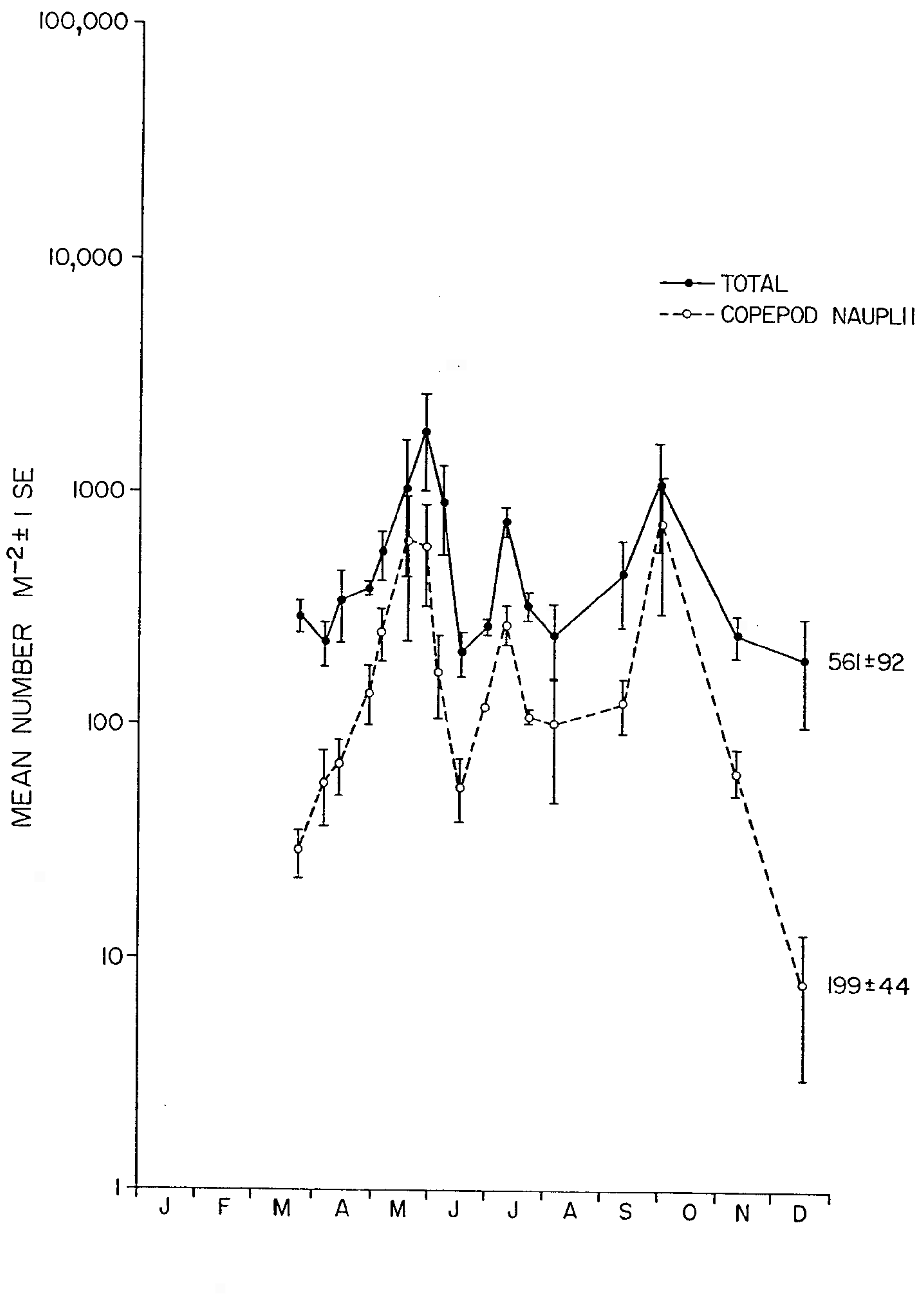

Fig. 3. Copepod nauplii $m^{-2}(\bar{x} \pm 1SE)$ compared to total epibenthos for all estuarine zone stations sampled on each date and overall yearly means ($\pm$ 1SE).

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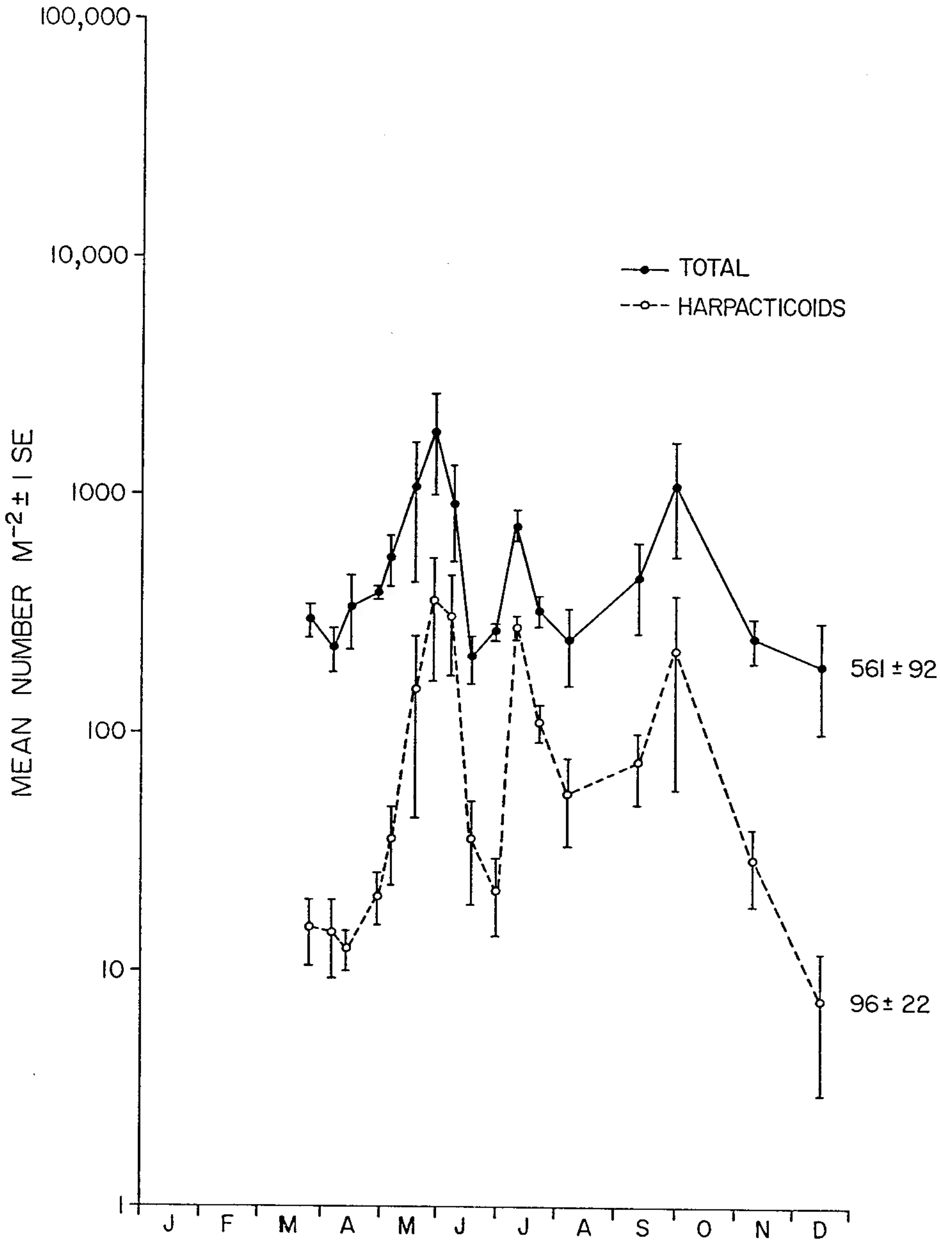

Fig. 4. Harpacticoid copepods m^{-2} ($\bar{x} \pm$ 1SE) compared to total epibenthos for all estuarine zone stations sampled on each date and overall yearly means ($\pm$ 1SE).

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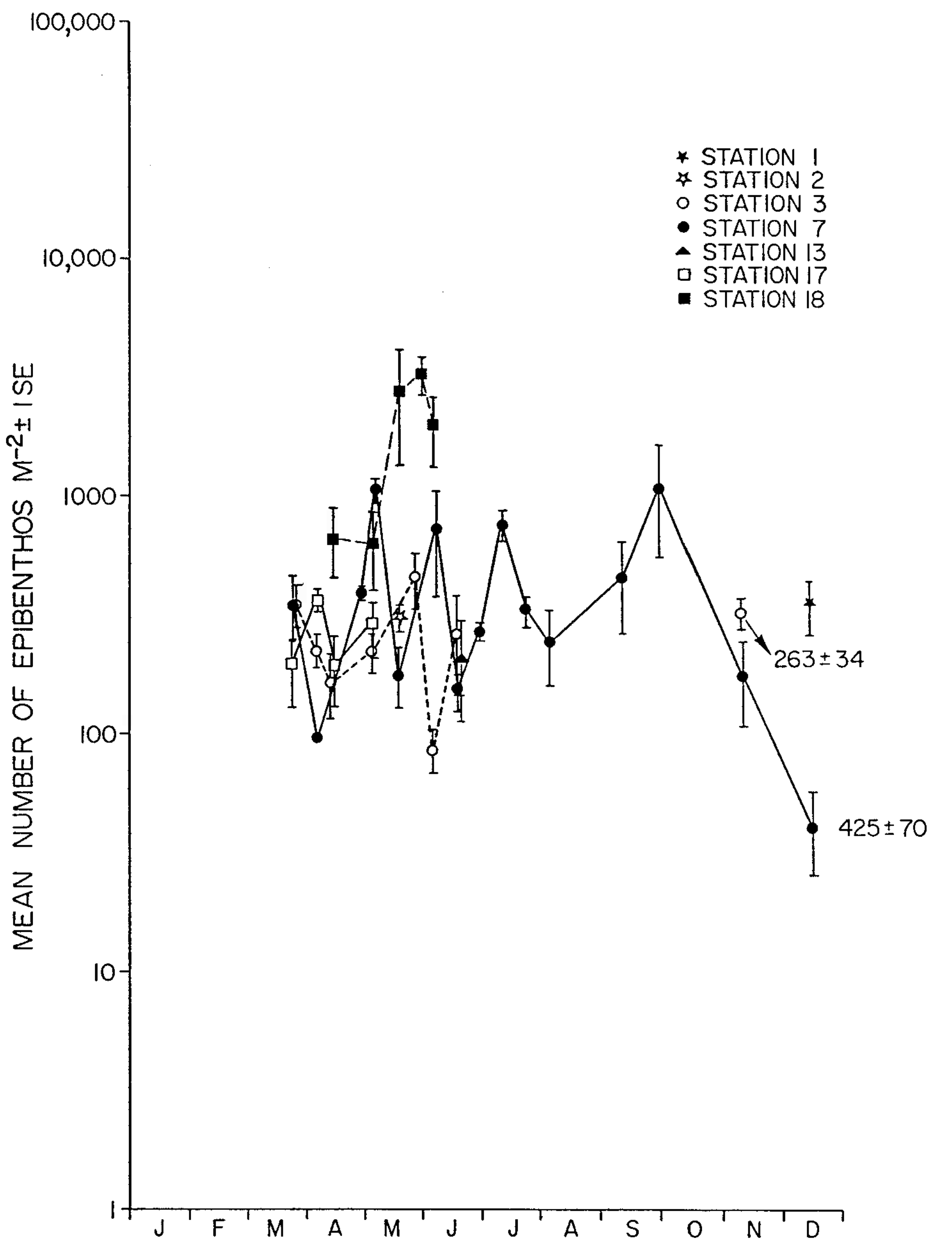

Fig. 5. Total epibenthos m^{-2}($\bar{x}$ ± 1SE) at each estuarine zone station by sampling date. Overall yearly means (± 1SE) are indicated for stations 3 and 7.

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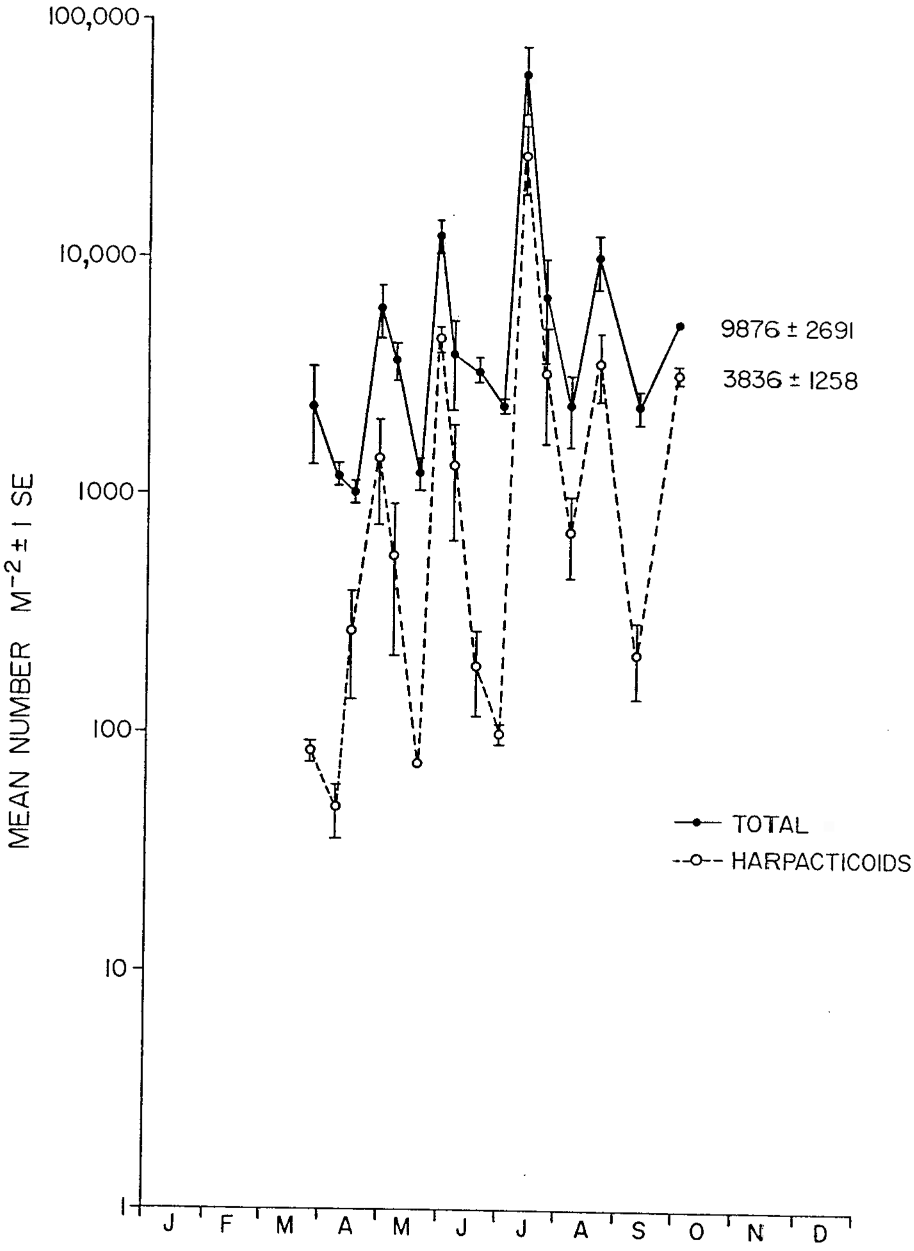

Fig. 6. Harpacticoid copepods m^{-2}($\bar{x}$ + 1SE) compared to total epibenthos for all marine zone stations sampled on each date and overall yearly means (± 1SE).

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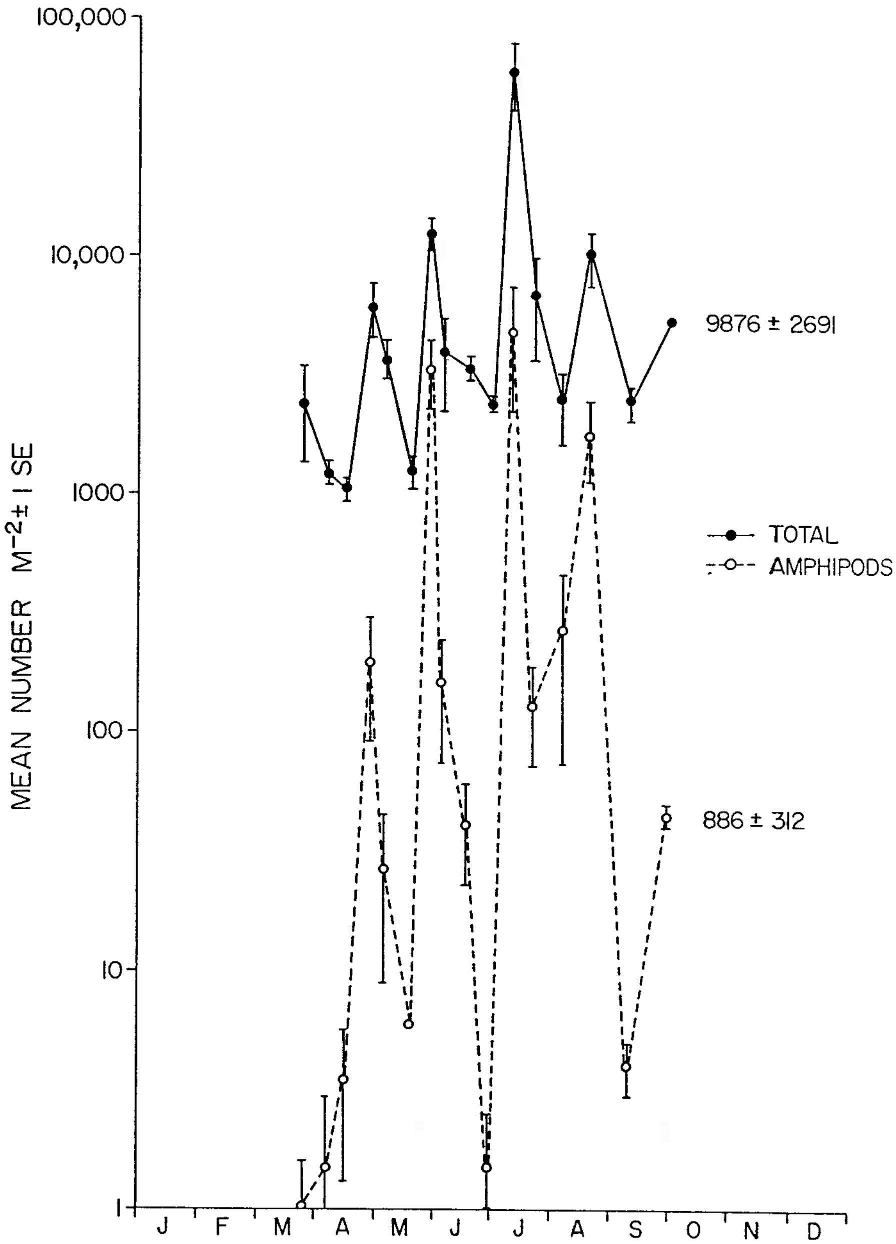

Fig. 7. Amphipods $m^{-2}(\bar{x} + 1SE)$ compared to total epibenthos for all marine zone stations sampled on each date and overall yearly means ($\pm$ 1SE).

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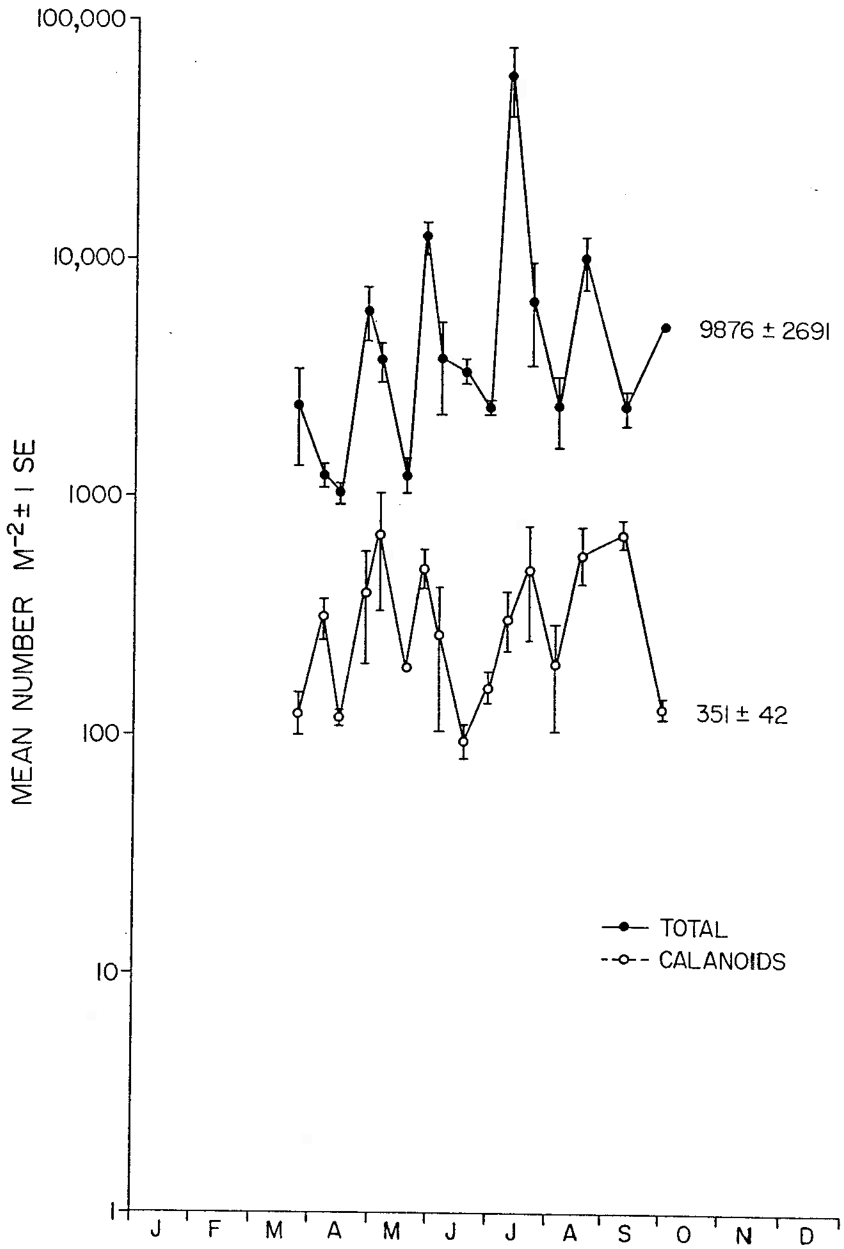

Fig. 8. Calanoid copepods m^{-2}($\bar{x}$ + 1SE) compared to total epibenthos for all marine zone stations sampled on each date and overall yearly means (± 1SE).

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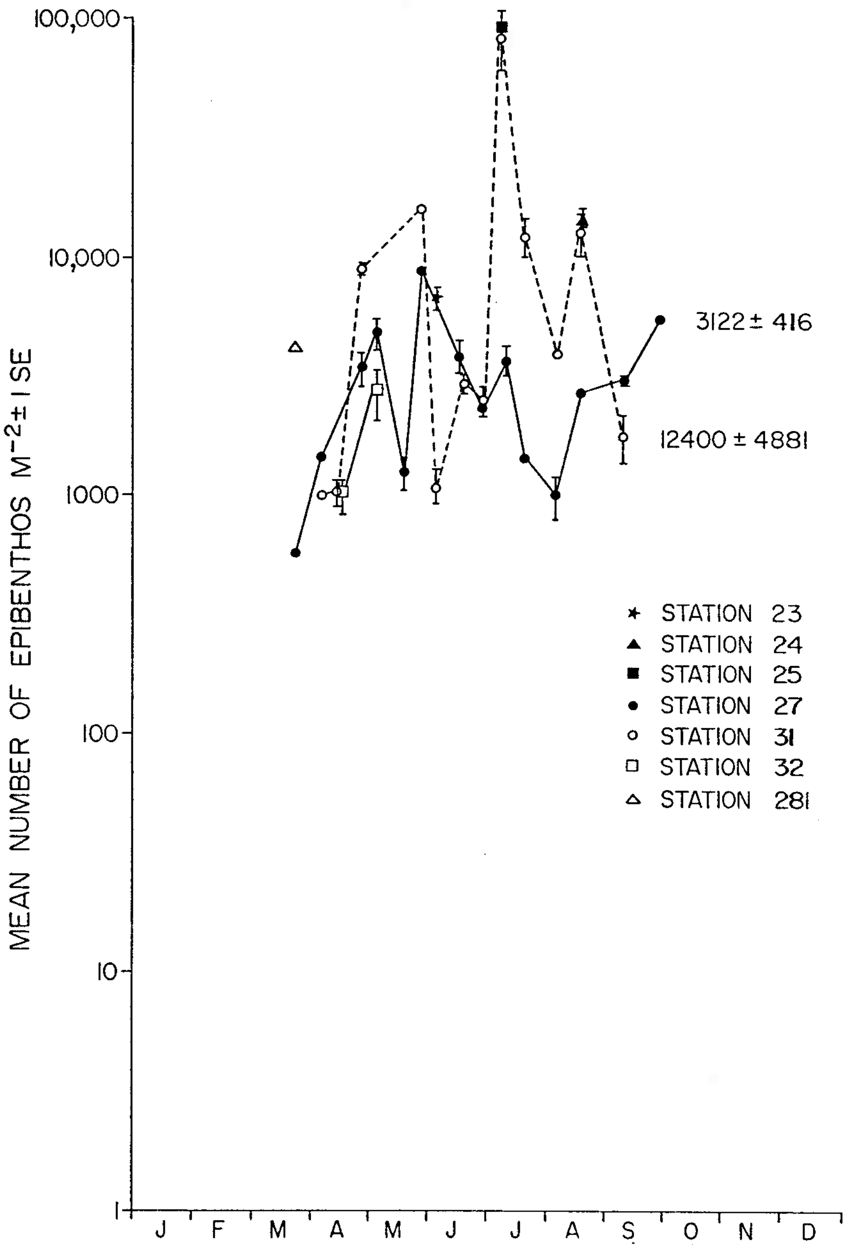

Fig. 9. Total epibenthos $m^{-2}(\bar{x} \pm 1SE)$ at each marine zone station by sampling date. Overall yearly means (± 1SE) are indicated for stations 27 and 31.

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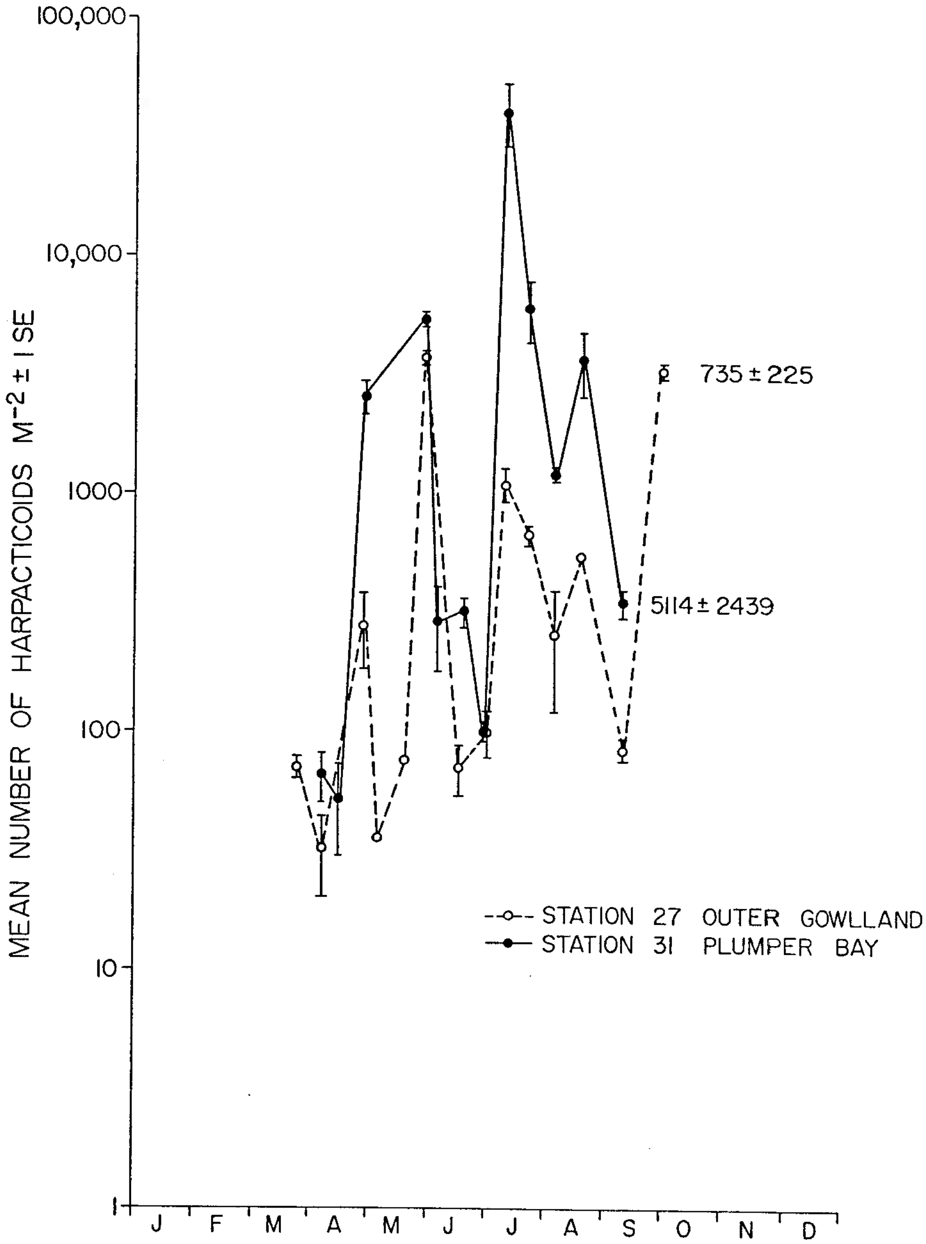

Fig. 10. Harpacticoid copepods m^{-2}($\bar{x}$ + 1SE) at stations 27 and 31 by sampling date and overall yearly means ($\pm$ 1SE).

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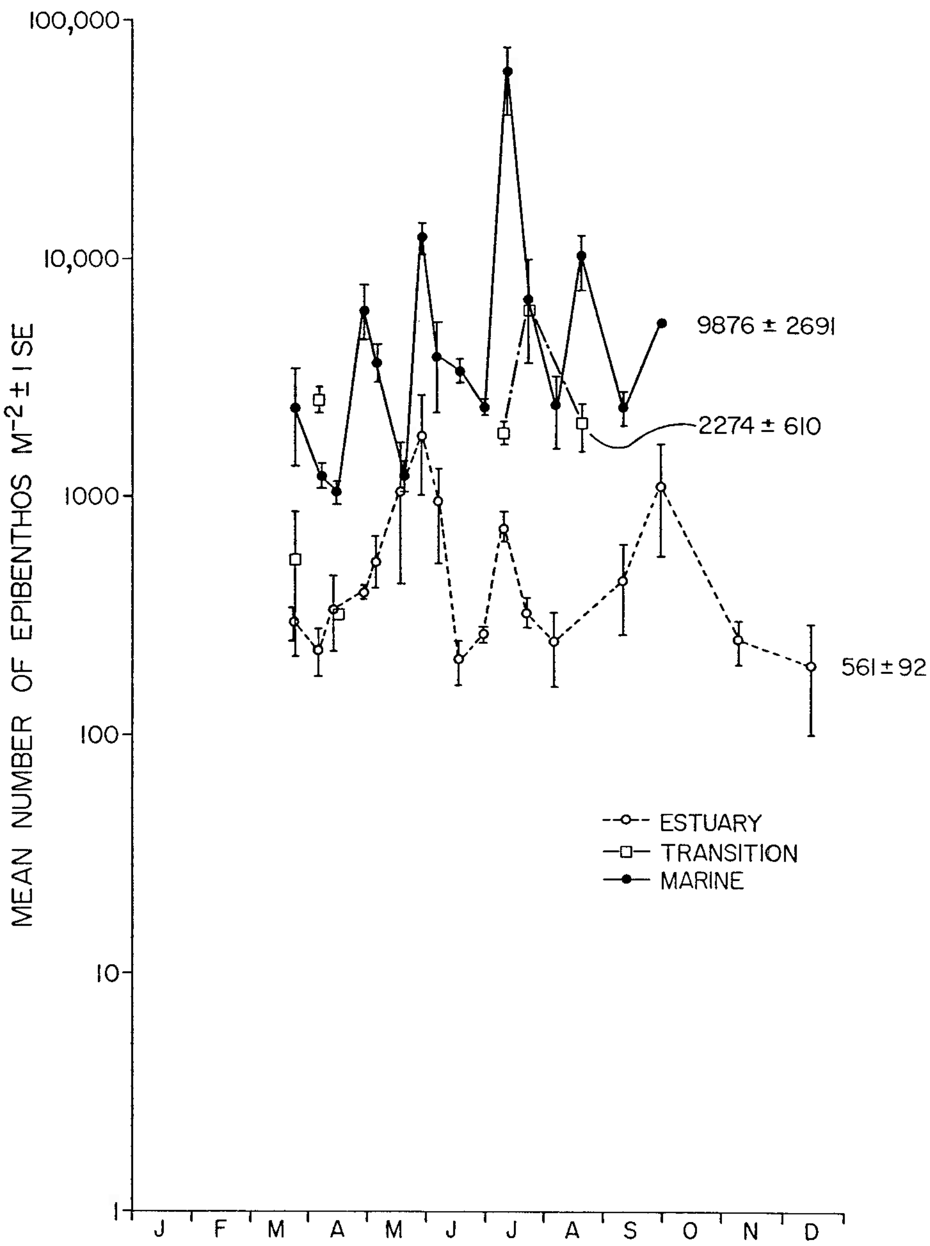

Fig. 11. Zonal comparison of total epibenthos m^{-2}($\bar{x}$ + 1SE) for all stations sampled on each date and overall yearly means (± 1SE).

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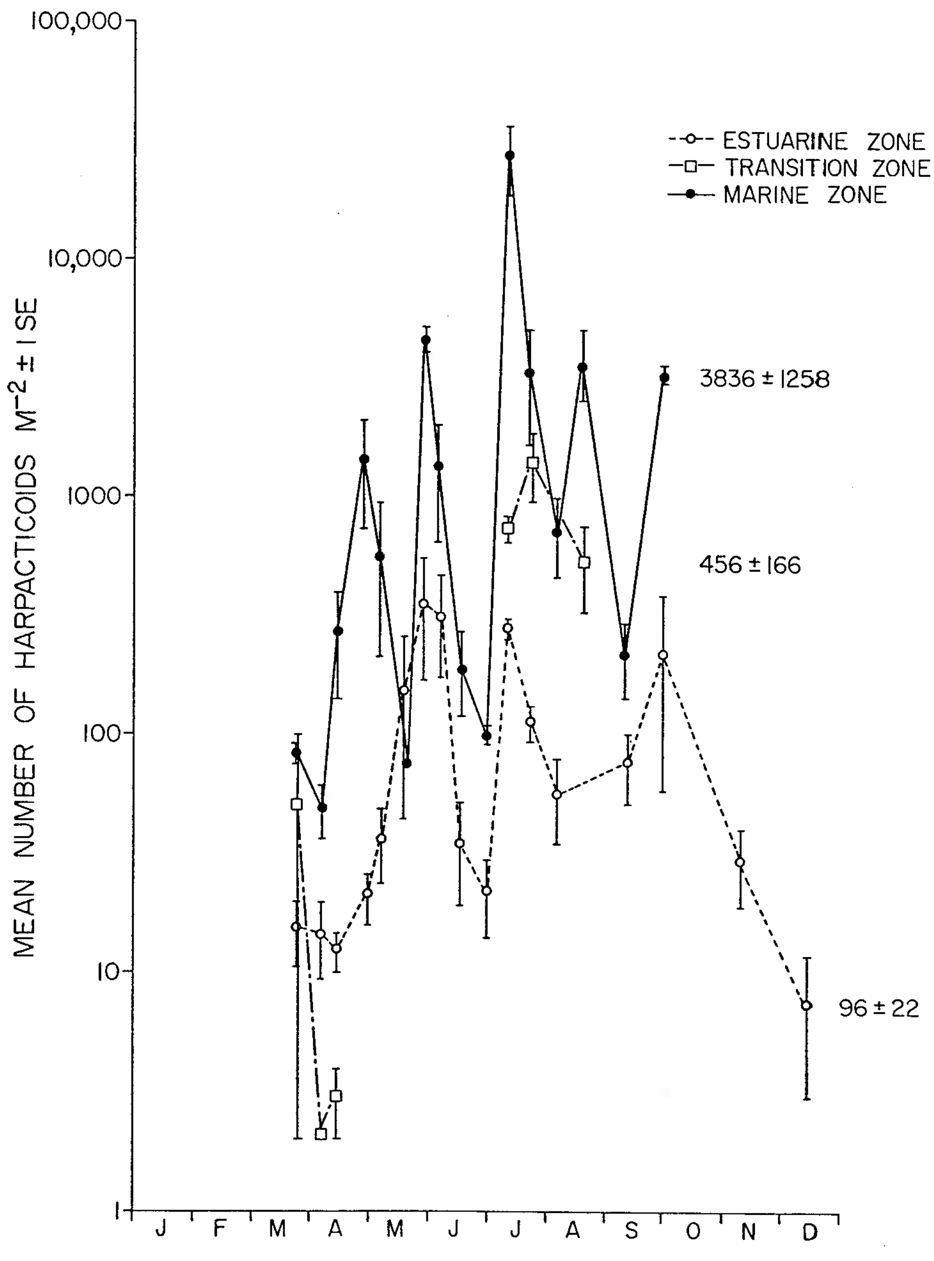

Fig. 12. Zonal comparison of harpacticoid copepods m^{-2}($\bar{x}$ + 1SE) for all stations sampled on each date and overall yearly means ($\pm$ 1SE).