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A Comparison of Meiofauna Available as Fish Food on Sturgeon and Roberts Banks, Fraser River Estuary, British Columbia

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A COMPARISON OF MEIOFAUNA AVAILABLE AS FISH FOOD ON STURGEON AND ROBERTS BANKS, FRASER RIVER ESTUARY, BRITISH COLUMBIA

by

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During 1980-81 the communities of fish present at three different sites on the Fraser River estuary were sampled each month using a beach seine. In conjunction with this work, in order to assess the food available to the fish community in each area, the meiofauna and epifauna were also sampled with core samplers and an epibenthic sled.

Analysis of the core samples showed the mean densities of total meiofauna to be the greatest at Iona Island (1,937 ± 170 10 cm^{-2}) followed by Roberts Bank (1,036 ± 118 10 cm^{-2}) and Steveston (335 ± 41 10 cm^{-2}). Nematodes formed the highest percentage of the population at all three sites - Iona Island (19.5-78.0%), Steveston (5.4-73.3%) and Roberts Bank (11.4-94.6%).

The results of the sled sampling indicated the total mean epifaunal densities were highest at Roberts Bank (51,656 ± 10,310 m^{-2}) second greatest at Steveston (16,622 ± 6,325 m^{-2}) and lowest at Iona Island (13,324 ± 2,520 m^{-2}). Numerically, copepod nauplii comprised the most of the population at Iona Island (4.9-80.7%) and Steveston (3.0-94.6%) while the harpacticoid copepods were dominant at Roberts Bank (9.6-84.3%). Based on the potential food available, Roberts Bank was the most suitable area for the rearing of juvenile salmonids.

RÈSUMÈ

Bravender, B.A., C.D. Levings and T.J. Brown. 1993. A comparison of meiofauna available as fish food on Sturgeon and Roberts Banks, Fraser River estuary, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1904: 40 p.

Au cours de 1980 et 1981, les communautés de poissons présentes à trois endroits différents de l'estuaire du fleuve Fraser ont été échantillonnées chaque mois à l'aide d'une senne de rivage. Conjointement à ces travaux, afin d'évaluer le nourriture disponible pour les communautés de poissons de chaque

secteur, on a également échantillonné la meiofaune et l'épifaune à l'aide de carottiers et d'un traineau épibenthique.

L'analyse des carottes a indiqué que les densités meiofauniques moyennes totales étaient les plus fortes à Iona Island (1,937 ± 170 10 cm^{-2}), puis à Roberts Bank (1,036 ± 118 10 cm^{-2}) et à Steveston (335 ± 41 10 cm^{-2}. Les nématodes ont le pourcentage le plus élevé de population d'organismes aux trois emplacements: Iona Island (19.5-78.0%), Steveston (5.4-73.3%) et Roberts Bank (11.4-94.6%).

Les résultats de l'échantillonnage effectué à l'aide du traineau indiquaient que les densités epifauniques moyennes totales étaient les plus fortes à Roberts Bank (51,656 ± 10,310 m^{-2}), puis à Steveston (16,622 ± 6,325 m^{-2}), et les plus faibles à Iona Island (1,324 ± 2,520 m^{-2}). Numériquement, ce sont les copépodes Nauplii qui étaient les plus importants à Iona Island (4.9-80.7%) et à Steveston (3.0-94.6%), alors que ce sont les copépodes harpacticoides qui dominaient à Roberts Bank (9.6-84.3%). En se basant sur la quantité de nourriture potentielle disponsible, on peut conclure que Roberts Bank est l'endroit le plus adapté à l'élevage de saumon juvénile.

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INTRODUCTION

For some time, the estuary of the Fraser River has been under pressure from industrial development along its shoreline and the increasing population in the region. In spite of this fact, studies conducted in the estuary in the late 1970's showed extensive use of both the sedge marshes (Carex lyngbyei) (Levy et al. 1982a,b) and mudflat areas (Goodman 1975; Greer et al. 1980) as a rearing site by juvenile salmonids and other species of fish.

In early 1980, three sites were chosen on Sturgeon and Roberts Banks for further study of the food available to the fish populations (Fig. 1). These sites were representative of some of the different habitats available on the banks and varied in sediment type, exposure, vegetative cover, salinity and temperature regimes. Table 1 provides a brief description of the stations. The station at Iona Island was located approximately five km from the sewage outfall. The site at Steveston was positioned in a highly exposed area, subjected to strong current action. The site on Roberts Bank was located on a manmade beach, namely the coal loading facility built in 1969 (Levings 1985), and beds of eelgrass (Zostera marina) were present on the surrounding mudflat. Sample sites were characterized by fine mud at Iona Island, sand at Steveston and a mud-sand mixture at Roberts Bank. At Iona Island, temperature and salinity ranged from 7-24°C and 2-22‰, at Steveston from 5-22°C and 2-20‰ and at Roberts Bank between 2-22°C and 14-28‰ (Gordon and Levings 1984). A more detailed discussion of the site locations and listing of physical data may be found in Conlin et al. (1982) and Gordon and Levings (1984).

Between April 15, 1980 and June 3, 1981, fourteen trips were made to the estuary. In conjunction with beach seine collections of the fish community (Gordon and Levings 1984) two sampling methods were used to sample the meiofauna in the sediment and the epifauna immediately above the bottom. The samples were all obtained at low tide and are from an elevation of approximately 0.5 m above chart datum.

MATERIALS AND METHODS

Two hundred and thirty-four samples of the meiofauna present in the top 1 cm of sediment were collected using small cores which sampled an area of 6.16 cm^2 (Sibert et al. 1982b). Fifty cm^3 syringes, with the bottom end removed, were fitted with rubber stoppers, top and bottom, and inserted into the sediment at the water's edge on dry land. Six replicate cores were collected at each site and the top 1 cm was extruded from the core and preserved in 4% v/v formalin and rose bengal. In the laboratory, the meiofauna present in the core samples were separated from the sediment and debris by repeated decantation through a

44 μm sieve and were then counted using a dissecting microscope. If required, the samples were split with a Folsom splitter and 100 of the dominant organisms counted. The sample total was then calculated and recorded. The first 100 harpacticoids found were preserved and identified to species. Where there were a large number of harpacticoid copepods in the sample, the total number of each species was calculated as a proportion of the number identified.

One hundred and seventeen samples of near-bottom epifauna were collected at the same time as the cores using an epibenthic sled (Sibert et al. 1982a). The sled had a 10 cm x 10 cm mouth opening, adjustable to differing heights above the bottom, and was fitted with a 44 μm net (Sibert et al. 1977). Three replicate samples were taken at each site in water approximately 30 cm deep. The sled was towed for five metres, sampling an area of 0.5 m^2 each time. These samples were also preserved in 4% formalin and rose bengal and analyzed in the same manner as the core samples.

RESULTS AND DISCUSSION

A. CORE SAMPLES

A-1. Meiofauna densities

Analysis of the core samples showed the meiofauna at the three sites to be distinctly different, with twenty taxonomic categories found at Iona Island, seventeen at Steveston and twenty-six at Roberts Bank (Sibert et al. 1982b). The overall mean density of meiofauna was the highest at Iona Island ($1,937 \pm 170$ 10 cm^{-2}), followed by Roberts Bank ($1,036 \pm 118$ 10 cm^{-2}). In comparison, total mean densities were much lower at Steveston (335 ± 41 10 cm^{-2}) and each site showed its own unique seasonal pattern of abundance (Table 2, Fig. 2). At all three sites nematodes, copepod nauplii and harpacticoid copepods were the most numerous categories in the samples, with nematodes being abundant at all three sites and copepod nauplii and harpacticoids occurring in the highest numbers at Roberts Bank (Table 2, Figs. 3-5). Analysis of the cores by percent composition also indicated that the three sites are unique in their composition and seasonal cycles (Table 3, Fig 6). The variability in density and community structure at the three sites was most likely due to the differences in sediment and vegetation. At Iona Island there was reduced circulation, the site was very muddy and the discharge of domestic sewage into the area has had a profound influence in the form of a deep sludge layer close to the outfall (B.C. Research 1975; Otte and Levings 1975). At Steveston, there was good water circulation (Levings 1982) and the area was characterized by clean, well washed sand. At Roberts Bank, the sample site was on a man-made shoreline, namely the south shore of the coal port island. The sediment was a cobble-mud-sand mixture and eelgrass (Zostera marina) was

present.

A-2. Harpacticoid copepod species

Analysis of the harpacticoid copepods from the core samples showed only twenty-one species present at Iona Island, fourteen species at Steveston and forty-five at Roberts Bank (Sibert et al. 1982b). The unidentified copepodites (all the young stages of all harpacticoid species combined) were the dominant category at Iona Island and Roberts Bank and third in importance at Steveston (Table 4, Fig. 7). The Family Ectinosomatidae, which includes a number of genera which are difficult to separate, were also important at all three sites and were found throughout most of the year (Fig. 8). The remainder of the species occurred sporadically and suddenly, appearing only during certain months of the year. At Iona Island the abundance of Huntemannia jadensis varied throughout the sampling period and Microarthridion littorale was numerous in both the spring of 1980 and 1981. Two interstitial species, Leptastacus constrictus and Paraleptastacus spinicauda, showed peaks of abundance during the summer months at Steveston. At Roberts Bank several small epibenthic species, Amphiascoides sp., Dactylopodia sp. and Mesochra pygmaea were collected randomly throughout the sampling.

B. SLED SAMPLES

B-1. Epifauna densities

Analysis of the sled samples showed the richest epifaunal community to be at Roberts Bank where thirty categories of epifauna were found. There were twenty-nine categories at Iona Island and thirty-one at Steveston (Sibert et al. 1982a). The highest density of epifauna in any sample was found in May 1980 ($22,9291 \pm 27,947$ m^{-2}) at Roberts Bank where the overall mean density was $51,656 \pm 10,310$ m^{-2}. At Steveston, the epifauna reached a maximum of $96,047 \pm 53,641$ m^{-2} in September, 1980 with an overall mean density of $16,622 \pm 6,325$ m^{-2}. The highest total density at Iona Island was $50,467 \pm 9,272$ m^{-2} in May, 1981 and the mean density for all samples was $13,324 \pm 2,520$ m^{-2} (Table 5, Fig. 9). At all three sites the copepod nauplii reached high densities at least once during the year, showing a strong seasonal cycle (Fig. 10). The harpacticoid copepods reached very high numbers m^{-2} in spring 1980 at Roberts Bank and showed several yearly peaks at the other two sites (Fig. 11). At all three sites calanoids, worms, eggs and rotifers made up a large proportion of the epibenthic community at some time, usually exhibiting one or two peaks in abundance during the year. At Roberts Bank, amphipods were also very numerous in the early spring.

The patterns of change in the total epifaunal community as well as the

dominant categories were different between the three sites. The percent composition of the sleds for harpacticoid copepods, copepod nauplii and nematodes changed from month to month at each station (Table 6, Fig. 12).

B-2. Harpacticoid copepod species

The highest number of harpacticoid copepod species found was fifty-six from Roberts Bank, followed by Iona Island and Steveston with thirty-six species each (Sibert et al. 1982a). The unidentified copepodites reached very high densities at Roberts Bank and showed an early spring peak at all three sites (Table 7, Fig. 13). Three typical mud dwelling species were the most numerous at Iona Island, Tachidius (Neotachidius) triangularis, Leimia vaga and Microarthridion littorale (Fig. 14). At Steveston, the Family Ectinosomatidae, Tachidius (Neotachidius) triangularis and Mesochra pygmaea occurred sporadically and in low numbers (Fig. 15). Samples from Roberts Bank showed very high densities of Tisbe sp. in the spring of 1980 while Harpacticus sp. and the Family Ectinosomatidae occurred year round (Fig. 16). At each of the stations, there were large seasonal variations in other species as well.

C. STATISTICAL ANALYSIS

To test whether the differences in meiofauna and epifauna at the three stations were significantly different, analysis of variance (ANOVA) was carried out after the sample data were transformed ($\log_{10}(X+1)$). Where significant differences occurred, Bonferroni t-tests were used to separate or group the stations. The dominant categories and the most abundant species of harpacticoid copepod from both the core and sled samples were included in the analysis.

C-1. Core samples

The numerical abundance of the fifteen most common groups of meiofauna and the total counts at each site were tested between the three habitats. The ANOVAs indicated that thirteen groups and the total counts were highly significantly different ($P \leq 0.01$) between the three sites (Table 8). Using the Bonferroni t-test, the three stations were all grouped separately for nematodes, worms, amphipods, bivalves, ostracods and total abundance. Samples from Iona Island and Roberts Bank were grouped together for eggs, ectoprocts, cumaceans and hydroids. Samples from Steveston and Roberts Bank were grouped for harpacticoids and ciliates and those from Iona Island and Steveston were grouped for foraminiferans and rotifers. There was no significant difference between sites for copepod nauplii (all three sites were grouped together) and there was some overlap for turbellarians.

The same analysis carried out on the seven most common harpacticoid copepod species from the core samples showed the distribution of five of them to be significantly different between sites. The numbers of Huntemannia jadensis and Microarthridion littorale at Iona Island were significantly higher than at Steveston and Roberts Bank. Leptastacus constrictus was significantly higher and the unidentified copepodites were significantly lower at Steveston in comparison to the other two sites, while Amphiascoides sp. was significantly higher at Roberts Bank. All the stations were grouped together for Tachidius (Neotachidius) triangularis and there was some overlap between all three stations for the Family Ectinosomatidae (Table 9).

C-2. Sled samples

ANOVAs performed with data from the thirty most common epifaunal groups collected in the sled samples showed a significant difference between the three sites for eighteen of the categories (Table 10). The results of the t-tests showed that for twelve of these eighteen categories, samples from Iona Island were grouped with Steveston and those from Roberts Bank were separate. The harpacticoid copepods were the only group where all three stations were separated. Only the bivalves and ectoprocts showed some overlap between all three sites. The ANOVA on the total counts indicated a significant difference ($P \leq 0.01$), with the t-test showing samples from Iona Island and Steveston grouped separately from Roberts Bank. There was no significant difference between sites for worms, foraminiferans, barnacle cypris, hydroids, acarinans, rotifers, insects, cladocerans, decapods, ciliates, turbellarians and fish.

The harpacticoid species were identified from one hundred and sixteen sled samples and thirty-eight species were tested for similarity between the sites. Twenty-three showed a significant difference in distribution between the three stations ($P \leq 0.01$) (Table 11). Samples from Iona Island were grouped together with Steveston for seventeen of the species and Roberts Bank was separate. Iona Island and Roberts Bank were grouped together for only one species, Huntemannia jadensis. There was no significant difference between sites for Schizopera knabeni, Paralaophonte congenera congenera, Heterolaophonte variabilis, Ameira longipes, Parapseudoleptomesochra sp., Laophontid sp., Diosaccus spinatus, Apodopsyllus vermiculiformis, Amphiascopsis cinctus, Mesochra sp., Tegastidae sp. and Stenhelia peniculata. There was some overlap between the three sites for Tachidius (Neotachidius) triangularis, Amphiascus minutus and Paralaophonte pacifica.

D. COMPARISONS BETWEEN HABITATS AND OTHER ESTUARIES

The results of the statistical analysis indicate that the three sites are

representative of a variety of habitat types. The groupings from the core samples show that the meiofauna communities at all three sites are quite different, with Iona Island being somewhat more similar to Roberts Bank than Steveston. This was also evident from the percent composition of the cores, with each site seeming to follow a distinct pattern. The same is true for the occurrence of the harpacticoid copepod species in the cores at the three sites. Steveston was dominated by an interstitial species, Leptastacus constrictus, which could be expected because of the predominantly sandy sediment at this site. Two burrowing types, Huntemannia jadensis and Microarthridion littorale were most common at Iona Island, perhaps due to the prevalence of a surface sludge in the area. At Roberts Bank, the Family Ectinosomatidae was the most numerous in the cores, a group which is commonly found in association with vegetation.

The analysis of the epifauna from the sled samples showed a less clear separation of all three stations than for the cores with all the stations being grouped together for many of the categories. Where the stations were differentiated, Iona Island was most often grouped with Steveston and Roberts Bank was usually alone. Here the highest density of epifauna was observed, probably due to the presence of eelgrass. At this site, there were much higher numbers of truly epibenthic harpacticoids in the sleds which are normally found in association with eelgrass (e.g., Harpacticus sp., Zaus sp.). Comparisons between years showed the total harpacticoid abundances in 1981 to be much lower than in 1980 at both Roberts Bank and Steveston.

There have only been a few studies carried out previously on the meiofauna of the Iona Island - Sturgeon Banks area. Harrison (1981) sampled the meiofauna of the Iona Island area over a one year period in 1978 at two sites to the north of the jetty. She collected cores from a mud and a nearby sand site and found nematodes and harpacticoids to be dominant in the mud community, although in lower densities than were found in this study. An investigation of the nematodes at one site at Iona Island by Sharma and Webster (1983) found 24 species present in the sediments, but in much lower total numbers than reported here. A study carried out by Webb (1989,1991a,b) on the harpacticoids in an eelgrass bed on Roberts Bank detected 55 species in the sediments and on the eelgrass. However this author sampled the blades of eelgrass and therefore sampled a different harpacticoid microhabitat than the present study.

A similar study has been carried out at the Campbell River estuary where, between 1982-1984, nine sites were sampled throughout the estuarine area with the same epibenthic sled (Kask and Brown 1984, 1985, 1986). In conjunction, samples of the juvenile salmon were also collected at the same sites. At the time of sampling, many of these sites were located in newly constructed marsh sites, and the overall mean total density was much lower (562-1148 m^{-2}) over the three years of sampling than at any of the Fraser estuary sites (Kask et al.

1988a, 1988b).

It is accepted that harpacticoid copepods are an important food source for juvenile salmon rearing in the Fraser River estuary (Levings et al. 1991; Levy et al. 1982b; Webb 1991 a,b). During 1986, sampling of an eelgrass bed on Roberts Bank was carried out by D'Amours (1987). He sampled the entire harpacticoid copepod community and focused on Tisbe spp., Harpacticus uniremis and Zaus aurelii as the most available and preferred food sources for juvenile salmon. The results of the sampling of the epibenthic communities at the three sites showed these harpacticoids to reach their highest densities at Roberts Bank where they were dominant in the spring samples. Levings (1985) found extensive use of the low tide area at this site by juvenile pink, chum and chinook; harpacticoid copepods formed a substantial portion of their diet. Cordell and Simenstad (1988) have proposed that a complex consisting of Harpacticus sp., Zaus sp. and Tisbe sp. is indicative of a habitat suitable for the rearing of juvenile salmonids. In studies conducted by D'Amours (1987) and Webb (1989), these three taxa were heavily consumed by juvenile salmon on Roberts Bank. A comparison of this complex at all three sites showed that the highest numbers of Harpacticus sp., Zaus sp., and Tisbe sp. were found at Roberts Bank (Fig. 17). Of the three sites investigated, Roberts Bank was therefore the most suitable for the rearing of young fish.

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Table 1. Descriptions of the three stations sampled on the Fraser River estuary (see Conlin et al. 1982 for exact station locations).

Station No.	Station Name	Habitat type
1	Iona Island	On Sturgeon Bank, on the north side of the sewage channel near the end of the causeway, a man-made trench connected with the Iona Island sewage treatment plant; 90% sand-10% mud; moderate slope.
2	Steveston	On Sturgeon Bank, a relict river channel, on the south-west sand bar at 1 m tidal level; 100% sand; moderate slope.
3	Roberts Bank	On the Westshore Causeway man-made beach; cobble from mid-tide upshore, sand and eelgrass downshore; moderate slope.

Table 2. Mean numbers of meiofauna 10 cm^{-2} ± 1SE for core samples collected at Iona Island, Steveston and Roberts Bank. Only categories with average ≥ 0.1 10 cm^{-2} included.

Category	Station		
	Iona Island	Steveston	Roberts Bank
Harpacticoids	150.6 ± 14.4	84.4 ± 16.6	191.7 ± 40.2
Calanoids	0	0	0.5 ± 0.2
Copepod nauplii	170.1 ± 23.5	107.9 ± 15.4	339.8 ± 56.9
Nematodes	1143.7 ± 143.2	104.1 ± 15.2	385.4 ± 37.6
Worms	119.5 ± 21.6	13.0 ± 2.5	23.4 ± 2.8
Amphipods	2.4 ± 0.6	0	11.1 ± 2.3
Eggs	29.8 ± 3.9	6.2 ± 1.2	45.7 ± 13.9
Bivalves	9.5 ± 1.1	0.1 ± 0	2.8 ± 0.5
Foraminiferans	0.4 ± 0.1	0.2 ± 0.1	3.1 ± 0.5
Ectoprocts	1.1 ± 0.2	0	1.1 ± 0.4
Cumaceans	3.1 ± 0.9	0.1 ± 0.1	1.9 ± 0.4
Gastropod eggs	0	0	1.7 ± 0.4
Ostracods	0.6 ± 0.1	7.6 ± 1.0	5.4 ± 0.9
Hydroids	1.8 ± 0.6	0	0.7 ± 0.1
Acarinans	0	0	0.2 ± 0.1
Gastropods	0	0	0.1 ± 0
Rotifers	16.7 ± 5.4	5.8 ± 1.5	0.8 ± 0.2
Ciliates	283.0 ± 38.5	2.4 ± 0.7	10.0 ± 3.5
Turbellarians	4.9 ± 0.9	2.7 ± 0.7	7.2 ± 1.7
Nemerteans	0	0	2.9 ± 1.5
Total	1937.4 ± 170.1	334.5 ± 41.2	1035.5 ± 118.2
	N = 78	N = 72	N = 84

Table 3. Percent composition of harpacticoid copepods, copepod nauplii and nematodes in core samples collected at Iona Island, Steveston and Roberts Bank.

	Iona Island			Steveston			Roberts Bank		
	Harp	Cope Naup	Nema	Harp	Cope Naup	Nema	Harp	Cope Naup	Nema
April/80	3.4	15.0	74.0	14.5	2.4	73.3	17.0	19.0	39.6
May/80	6.0	9.2	76.0	12.6	17.0	62.6	21.6	49.0	19.3
June/80	10.0	4.6	78.0	18.8	70.6	5.4	26.9	55.9	11.4
Sept 4/80	13.3	7.2	48.2	34.6	23.0	36.7	8.4	41.9	40.2
Sept 22/80	4.1	3.4	60.7	40.3	30.4	17.0	31.5	38.2	24.9
Oct/80	8.5	14.0	32.3	33.3	18.0	23.1	1.2	3.3	94.6
Nov/80	8.0	1.6	21.6	-	-	-	1.8	2.5	93.1
Dec/80	5.8	1.3	61.6	20.6	20.4	33.7	11.8	1.8	81.7
Jan/81	5.0	2.6	59.0	28.2	29.1	31.6	13.6	7.8	67.1
Feb/81	-	-	-	10.0	25.1	49.7	2.2	5.3	49.0
March/81	2.7	12.8	50.2	22.9	32.4	22.7	2.8	21.5	28.1
April/81	2.9	4.5	30.3	-	-	-	2.4	16.4	49.8
May/81	14.3	4.1	28.8	11.7	44.7	28.9	5.2	16.4	59.1
June/81	29.0	29.4	19.5	8.2	37.9	44.8	18.7	39.9	30.8

Table 4. Mean numbers of harpacticoid copepod species 10 cm^{-2} ± 1SE for core samples collected at Iona Island, Steveston and Roberts Bank. Only species with average ≥ 0.1 10 cm^{-2} included.

Species	Station		
	Iona Island	Steveston	Roberts Bank
Unidentified copepodite	46.0 ± 8.1	7.2 ± 1.3	75.7 ± 18.5
Huntemannia jadensis	26.5 ± 3.0	0.8 ± 0.2	1.2 ± 0.2
Microarthridion littorale	22.6 ± 3.7	0.1 ± 0.1	1.7 ± 1.2
Family Ectinosomatidae	17.6 ± 2.9	6.4 ± 1.1	28.7 ± 5.6
Scottolana canadensis	9.8 ± 1.7	0	0
Leimia vaga	9.5 ± 1.9	0	0
Tachidius (Neotachidius) triangularis	7.6 ± 1.8	3.6 ± 1.1	8.2 ± 3.1
Leptastacus constrictus	3.6 ± 1.4	46.2 ± 14.0	1.5 ± 0.5
Schizopera knabeni	3.3 ± 1.1	0	0
Sarsameira species	2.6 ± 1.0	0	0
Paraleptastacus spinicauda	0.9 ± 0.5	12.9 ± 2.5	0
Amphiascoides species	0.5 ± 0.2	0.2 ± 0.1	10.5 ± 3.6
Heterolaophonte hamondi	0.1 ± 0	0	0
Limnocletodes behningi	0.1 ± 0	0	0
Paraleptastacus vermicularis	0.1 ± 0	0	0
Kliopsyllus species	0	6.9 ± 1.4	0
Mesochra pygmaea	0	0	12.9 ± 5.9
Amphiascus undosus	0	0	9.2 ± 3.5
Dactylopodia species	0	0	7.1 ± 1.7
Danielsennia typica	0	0	6.1 ± 1.1
Harpacticus species	0	0	5.1 ± 2.1
Ameira parvuloides	0	0	4.7 ± 1.6
Diarthrodes species	0	0	4.6 ± 1.7
Laophontid species	0	0	3.4 ± 0.8
Longipedia americana	0	0	1.4 ± 0.4
Parastenhelia hornelli	0	0	1.4 ± 0.6
Heterolaophonte variabilis	0	0	1.3 ± 0.8
Amonardia normani	0	0	1.1 ± 0.5
Zaus species	0	0	1.1 ± 0.6
Robertgurneya hopkinsi	0	0	0.8 ± 0.2
Paralaophonte pacifica	0	0	0.7 ± 0.2
Tisbe species	0	0	0.7 ± 0.2
Paralaophonte congenera congenera	0	0	0.4 ± 0.2
Stenhelia (Stenhelia) peniculata	0	0	0.3 ± 0.1
Enhydrosoma hopkinsi	0	0	0.3 ± 0.1
Apodopsyllus vermiculiformis	0	0	0.2 ± 0.1
Amonardia perturbata	0	0	0.2 ± 0.2
Proameira simplex	0	0	0.2 ± 0.1
Unidentified cyclopoid	0	0	0.2 ± 0.1
Amphiascus minutus	0	0	0.1 ± 0.1
Psyllocamptus minutus	0	0	0.1 ± 0.1

Table 4. (cont'd).

Species	Station Iona Island	Steveston	Roberts Bank
Stenhelia (Delavalia) oblonga	0	0	0.1 ± 0.1
Stenhelia (Delavalia) species	0	0	0.1 ± 0
Heterolaophonte discophora	0	0	0.1 ± 0
Tegastidae species	0	0	0.1 ± 0
Alteutha langi	0	0	0.1 ± 0.1
Total	150.6 ± 14.4	84.4 ± 16.6	191.7 ± 40.2
	N = 77	N = 72	N = 84

Table 5. Mean numbers of epifauna m^{-2} ± 1SE for sled samples collected at Iona Island, Steveston and Roberts Bank. Only categories with average ≥ 0.1 m^{-2} included.

Category	Station		
	Iona Island	Steveston	Roberts Bank
Harpacticoids	2282.4 ± 729.2	620.0 ± 176.7	26403.7 ± 7189.6
Calanoids	183.3 ± 38.0	148.8 ± 42.3	1179.9 ± 279.7
Copepod nauplii	5782.3 ± 1780.0	9811.3 ± 5486.8	15645.7 ± 3356.8
Nematodes	2726.2 ± 1142.6	99.7 ± 18.0	1146.4 ± 311.7
Worms	268.9 ± 95.8	177.6 ± 70.4	204.3 ± 42.9
Amphipods	13.4 ± 3.8	7.5 ± 3.2	562.0 ± 171.3
Eggs	1651.5 ± 726.3	243.7 ± 51.3	2558.6 ± 983.4
Bivalves	10.7 ± 8.6	0.6 ± 0.4	58.5 ± 24.8
Foraminiferans	0.3 ± 0.2	1.2 ± 0.6	4.7 ± 2.0
Ectoprocts	21.5 ± 7.2	4.7 ± 1.1	57.2 ± 13.0
Cumaceans	21.1 ± 6.1	4.0 ± 1.3	38.7 ± 9.5
Gastropod eggs	0	0.1 ± 0.1	74.2 ± 20.1
Ostracods	4.4 ± 1.8	11.7 ± 4.7	57.2 ± 13.3
Barnacle cypris	0.6 ± 0.4	1.5 ± 0.9	18.3 ± 15.3
Hydroids	6.0 ± 3.2	1.1 ± 0.5	13.8 ± 7.0
Acarinans	2.1 ± 1.1	1.9 ± 1.1	6.8 ± 3.4
Gastropods	1.2 ± 0.5	2.5 ± 1.4	103.2 ± 25.0
Rotifers	215.9 ± 47.2	5375.5 ± 3068.0	3121.8 ± 1355.5
Insects	0.3 ± 0.2	0.9 ± 0.5	1.6 ± 1.0
Tunicates	3.0 ± 1.1	11.3 ± 5.3	132.4 ± 42.1
Barnacle nauplii	4.4 ± 1.8	0.6 ± 0.3	43.1 ± 9.8
Egg cases	0	0	17.3 ± 13.9
Isopods	0.1 ± 0.1	0	5.1 ± 3.1
Medusae	0.1 ± 0.1	0	29.3 ± 11.9
Mysids	26.1 ± 10.0	4.8 ± 1.9	0
Cladocerans	2.7 ± 1.0	1.5 ± 1.0	1.6 ± 1.5
Decapods	0	1.1 ± 1.1	1.0 ± 0.8
Cyclopoids	0	0	78.7 ± 44.7
Echinoderm larvae	0	0.6 ± 0.5	0
Parasitic copepods	27.3 ± 15.5	42.4 ± 29.0	0
Echinoderms	0	0.1 ± 0.1	0
Crab zoea	0.4 ± 0.3	0	0
Ciliates	62.2 ± 27.3	39.3 ± 21.1	62.5 ± 32.1
Turbellarians	5.0 ± 2.7	5.6 ± 3.1	27.1 ± 10.9
Nemertines	0	0	0.8 ± 0.8
Fish	1.0 ± 0.8	0.2 ± 0.1	0
Tardigrades	0	0.1 ± 0.1	0
Total	13324.3 ± 2519.5	16622.1 ± 6325.0	51655.5 ± 10309.8
	N = 39	N = 36	N = 42

Table 6. Percent composition of harpacticoid copepods, copepod nauplii and nematodes in sled samples collected at Iona Island, Steveston and Roberts Bank.

	Iona Island			Steveston			Roberts Bank		
	Harp	Cope Naup	Nema	Harp	Cope Naup	Nema	Harp	Cope Naup	Nema
April/80	27.5	11.9	48.1	7.1	22.0	2.5	84.3	13.4	0.4
May/80	23.9	57.5	9.9	19.3	69.7	1.8	61.6	34.8	0.2
June/80	36.2	41.3	5.9	0.6	3.0	0.2	21.5	23.9	6.3
Sept 4/80	3.6	87.6	3.1	8.9	43.0	2.5	30.1	18.7	8.2
Sept 22/80	3.9	74.2	6.6	1.8	94.6	0.3	27.8	39.3	3.5
Oct/80	30.5	21.7	33.0	17.0	49.7	7.5	57.9	23.3	4.1
Nov/80	12.3	36.3	19.1	-	-	-	9.6	57.5	10.5
Dec/80	4.5	4.9	84.3	16.6	60.4	2.9	49.1	21.6	4.8
Jan/81	7.6	23.4	57.2	4.1	7.6	1.2	34.7	17.3	16.8
Feb/81	-	-	-	5.9	63.7	5.6	17.7	20.8	16.4
March/81	3.0	4.9	5.5	17.7	46.6	7.2	33.4	52.5	2.4
April/81	24.0	30.0	15.1	-	-	-	36.3	38.0	2.5
May/81	13.6	80.7	2.0	5.4	79.8	0.9	12.9	54.6	0.3
June/81	22.8	41.6	11.8	17.6	72.7	2.1	59.6	26.7	0.5

Table 7. Mean numbers of harpacticoid copepod species m^{-2} ± 1SE for sled samples collected at Iona Island, Steveston and Roberts Bank. Only species with average ≥ 0.1 m^{-2} included.

Species	Station		
	Iona Island	Steveston	Roberts Bank
Unidentified copepodite	777.9 ± 339.1	245.9 ± 78.5	13188.2 ± 4218.8
Tachidius (Neotachidius) triangularis	379.5 ± 148.5	55.8 ± 27.6	95.8 ± 29.3
Tisbe species	361.2 ± 274.4	102.1 ± 62.5	7837.3 ± 2707.3
Leimia vaga	244.2 ± 80.2	14.2 ± 5.1	0
Family Ectinosomatidae	144.1 ± 42.9	124.7 ± 57.2	904.6 ± 163.9
Microarthridion littorale	115.8 ± 49.4	6.3 ± 3.8	21.9 ± 9.4
Scottolana canadensis	86.7 ± 34.3	0.3 ± 0.2	0
Mesochra pygmaea	40.6 ± 15.3	36.3 ± 14.2	1330.2 ± 510.5
Huntemannia species	21.7 ± 9.1	0	0
Harpacticus species	16.4 ± 7.2	3.9 ± 2.6	337.9 ± 90.2
Diarthrodes unisetosus	14.6 ± 10.5	0	0
Dactylopodia species	13.4 ± 10.3	2.3 ± 0.8	298.9 ± 80.3
Schizopera knabeni	11.9 ± 6.9	0.2 ± 0.1	1.6 ± 1.6
Zaus species	11.9 ± 7.6	16.1 ± 10.2	1354.3 ± 483.6
Sarsameira species	8.7 ± 5.5	0.1 ± 0.1	0
Microsetella species	7.3 ± 5.2	0	0.2 ± 0.2
Pseudonychocamptus spinifer	5.2 ± 5.2	0	0
Amphiascoides species	5.2 ± 3.5	0.9 ± 0.4	84.1 ± 28.7
Paraleptastacus spinicauda	5.0 ± 2.1	9.8 ± 5.9	0
Paraleptastacus species	3.2 ± 1.8	0	0
Ameira species	2.3 ± 2.1	0	9.6 ± 3.9
Paralaophonte congenera congenera	1.4 ± 1.4	0.1 ± 0.1	0.8 ± 0.7
Heterolaophonte littoralis longisetigera	1.1 ± 1.0	0	0
Amphiascus undosus	0.7 ± 0.6	0.6 ± 0.3	105.5 ± 28.7
Heterolaophonte variabilis	0.6 ± 0.4	2.1 ± 1.5	34.2 ± 16.2
Amonardia normani	0.5 ± 0.4	0.8 ± 0.6	144.5 ± 68.3
Ameira longipes	0.2 ± 0.1	0	2.9 ± 2.0
Danielsennia typica	0.2 ± 0.2	0.1 ± 0.1	167.9 ± 68.2
Ameira parvuloides	0.2 ± 0.2	0.2 ± 0.1	8.0 ± 3.1
Parapseudoleptomesochra species	0.2 ± 0.2	0.1 ± 0.1	0
Laophontid species	0.2 ± 0.2	0	0.3 ± 0.3
Parastenhelia hornelli	0.2 ± 0.2	0	4.1 ± 1.7
Amphiascoides dimorphus	0.1 ± 0.1	0	0
Cletocamptus species	0.1 ± 0.1	0	0
Enhydrosoma hopkinsi	0.1 ± 0.1	0	0
Amphiascus minutus	0.1 ± 0.1	0	1.3 ± 0.6
Huntemannia jadensis	0	4.0 ± 1.7	2.0 ± 1.5
Diarthrodes species	0	2.6 ± 1.2	233.3 ± 87.5

Table 7. (cont'd).

Species	Station Iona Island	Steveston	Roberts Bank
Leptastacus constrictus	0	1.9 ± 1.6	0
Diosaccus spinatus	0	1.3 ± 1.3	9.2 ± 4.3
Stenhelia (St.) peniculata	0	1.3 ± 1.3	0.9 ± 0.7
Microsetella rosea	0	0.8 ± 0.3	0
Tegastidae species	0	0.3 ± 0.2	11.3 ± 6.4
Mesochra species	0	0.2 ± 0.1	0.7 ± 0.7
Apodopsyllus vermiculiformis	0	0.1 ± 0.1	0.2 ± 0.2
Amphiascopsis cinctus	0	0.1 ± 0.1	2.4 ± 1.8
Longipedia americana	0	0.1 ± 0.1	21.4 ± 13.4
Limnocletodes behningi	0	0.1 ± 0.1	0
Paralaophonte pacifica	0	0.1 ± 0.1	5.9 ± 3.3
Stenhelia (St.) asetosa	0	0.1 ± 0.1	0
Dactylopodia crassipes	0	0	116.5 ± 66.3
Tegastes perforatus	0	0	26.3 ± 9.4
Proameira simplex	0	0	10.0 ± 3.5
Alteutha species	0	0	9.8 ± 6.6
Dactylopodia vulgaris	0	0	7.6 ± 6.6
Stenhelia (D.) species	0	0	5.1 ± 4.3
Robertgurneya hopkinsi	0	0	1.8 ± 1.3
Enhydrosoma species	0	0	1.4 ± 1.4
Harpacticus spinulosus	0	0	0.7 ± 0.7
Robertsonia propinqua	0	0	0.7 ± 0.7
Stenhelia (D.) oblonga	0	0	0.7 ± 0.7
Scutellidium arthuri	0	0	0.6 ± 0.6
Amonardia perturbata	0	0	0.4 ± 0.4
Echinolaophonte armiger	0	0	0.2 ± 0.2
Psyllocamptus minutus	0	0	0.2 ± 0.2
Heterolaophonte discophora	0	0	0.1 ± 0.1
Heterolaophonte hamondi	0	0	0.1 ± 0.1
Nitocra spinipes armata	0	0	0.1 ± 0.1
Scottopsyllus species	0	0	0.1 ± 0.1
Total	2282.6 ± 729.2	635.7 ± 181.1	26403.7 ± 7189.6
	N = 39	N = 35	N = 42

Table 8. Comparisons using ANOVA on data for dominant meiofauna from core samples at Iona Island, Steveston and Roberts Bank (N = 234).

Category	F Value	PR > F	Bon T-Test
Harpacticoids	9.27	0.0001	1, (2 + 3)
Copepod nauplii	2.30	0.1021	(1 + 2 + 3)
Nematodes	91.93	0.0001	1, 2, 3
Worms	60.52	0.0001	1, 2, 3
Amphipods	23.57	0.0001	1, 2, 3
Eggs	44.81	0.0001	(1 + 3), 2
Bivalves	83.74	0.0001	1, 2, 3
Foraminiferans	44.59	0.0001	3, (1 + 2)
Ectoprocts	13.09	0.0001	(1 + 3), 2
Cumaceans	11.38	0.0001	(1 + 3), 2
Ostracods	43.50	0.0001	1, 2, 3
Hydroids	12.82	0.0001	(1 + 3), 2
Rotifers	6.14	0.0025	(1 + 2), 3
Ciliates	132.89	0.0001	1, (2 + 3)
Turbellarians	4.36	0.0139	(1 + 3)(3 + 2)
Total	69.29	0.0001	1, 2, 3

Station 1 = Iona Island
Station 2 = Steveston
Station 3 = Roberts Bank

Table 9. Comparisons using ANOVA on data for dominant harpacticoid copepod species from core samples at Iona Island, Steveston and Roberts Bank (N = 233).

Species	F Value	PR > F	Bon T-Test
Unidentifed copepodites	14.32	0.0001	(1 + 3), 2
Microarthridion littorale	41.62	0.0001	1, (2 + 3)
Huntemannia jadensis	213.82	0.0001	1, (2 + 3)
Family Ectinosomatidae	3.17	0.0438	(1 + 3)(3 + 2)
Tachidius (Neotachidius) triangularis	3.45	0.0334	(1 + 2 + 3)
Leptastacus constrictus	37.79	0.0001	2, (1 + 3)
Amphiascoides species	35.01	0.0001	3, (1 + 2)

Station 1 = Iona Island
Station 2 = Steveston
Station 3 = Roberts Bank

Table 10. Comparisons using ANOVA on data for dominant epifauna from sled samples at Iona Island, Steveston and Roberts Bank (N = 117).

Category	F Value	PR > F	Bon T-Test
Harpacticoids	55.36	0.0001	1, 2, 3
Calanoids	7.96	0.0006	3, (1 + 2)
Copepod nauplii	10.36	0.0001	3, (1 + 2)
Nematodes	66.06	0.0001	(1 + 3), 2
Worms	1.67	0.1934	(1 + 2 + 3)
Amphipods	43.72	0.0001	3, (1 + 2)
Eggs	8.86	0.0003	(1 + 3), 2
Bivalves	4.99	0.0084	(3 + 1)(1 + 2)
Foraminiferans	2.07	0.1313	(1 + 2 + 3)
Ectoprocts	6.54	0.0020	(3 + 1)(1 + 2)
Cumaceans	6.43	0.0023	(1 + 3), 2
Gastropod eggs	20.68	0.0001	3, (1 + 2)
Ostracods	10.24	0.0001	3, (1 + 2)
Barnacle cypris	0.87	0.4205	(1 + 2 + 3)
Hydroids	1.35	0.2633	(1 + 2 + 3)
Acarinans	0.53	0.5873	(1 + 2 + 3)
Gastropods	28.91	0.0001	3, (1 + 2)
Rotifers	0.90	0.4097	(1 + 2 + 3)
Insects	0.72	0.4903	(1 + 2 + 3)
Tunicates	14.55	0.0001	3, (1 + 2)
Barnacle nauplii	14.58	0.0001	3, (1 + 2)
Isopods	6.78	0.0017	3, (1 + 2)
Medusae	10.39	0.0001	3, (1 + 2)
Mysids	13.32	0.0001	(1 + 2), 3
Cladocerans	2.64	0.0754	(1 + 2 + 3)
Decapods	0.77	0.4676	(1 + 2 + 3)
Parasitic copepods	5.05	0.0079	(1 + 2), 3
Ciliates	1.51	0.2244	(1 + 2 + 3)
Turbellarians	1.90	0.1549	(1 + 2 + 3)
Fish	1.24	0.2928	(1 + 2 + 3)
Total	18.03	0.0001	3, (1 + 2)

Station 1 = Iona Island
Station 2 = Steveston
Station 3 = Roberts Bank

Table 11. Comparisons using ANOVA on data for dominant harpacticoid copepod species from sled samples at Iona Island, Steveston and Roberts Bank (N = 116).

Species	F Value	PR > F	Bon T-Test
Unidentified copepodites	38.68	0.0001	3, (1 + 2)
Tachidius (Neotachidius) triangularis	4.64	0.0116	(1 + 2)(2 + 3)
Tisbe species	57.25	0.0001	3, (1 + 2)
Leimia vaga	27.96	0.0001	1, 2, 3
Family Ectinosomatidae	25.57	0.0001	3, (1 + 2)
Microarthridion littorale	5.69	0.0044	1, (2 + 3)
Scottolana canadensis	31.70	0.0001	1, (2 + 3)
Mesochra pygmaea	36.94	0.0001	3, (1 + 2)
Harpacticus species	19.95	0.0001	3, (1 + 2)
Dactylopodia species	35.17	0.0001	3, (1 + 2)
Schizopera knabeni	2.69	0.0725	(1 + 2 + 3)
Zaus species	47.68	0.0001	3, (1 + 2)
Sarsameira species	7.86	0.0006	1, (2 + 3)
Microsetella species	10.10	0.0001	1, (2 + 3)
Amphiascoides species	21.74	0.0001	3, (1 + 2)
Paraleptastacus spinicauda	8.18	0.0005	(1 + 2), 3
Ameira species	7.17	0.0012	3, (1 + 2)
Paralaophonte congenera congenera	0.27	0.7669	(1 + 2 + 3)
Amphiascus undosus	22.22	0.0001	3, (1 + 2)
Heterolaophonte variabilis	2.81	0.0646	(1 + 2 + 3)
Amonardia normani	10.92	0.0001	3, (1 + 2)
Ameira longipes	1.72	0.1839	(1 + 2 + 3)
Danielsennia typica	22.32	0.0001	3, (1 + 2)
Ameira parvuloides	5.74	0.0042	3, (1 + 2)
Parapseudoleptomesochra sp.	1.21	0.3029	(1 + 2 + 3)
Laophontid species	0.43	0.6509	(1 + 2 + 3)
Parastenhelia hornelli	5.73	0.0043	3, (1 + 2)
Amphiascus minutus	3.74	0.0268	(3 + 1)(1 + 2)
Huntemannia jadensis	6.54	0.0021	2, (1 + 3)
Diarthrodes species	43.51	0.0001	3, (1 + 2)
Diosaccus spinatus	3.45	0.0352	(1 + 2 + 3)
Apodopsyllus vermiculiformis	0.50	0.6078	(1 + 2 + 3)
Amphiascopsis cinctus	2.01	0.1385	(1 + 2 + 3)
Longipedia americana	5.76	0.0041	3, (1 + 2)
Mesochra species	0.64	0.5291	(1 + 2 + 3)
Paralaophonte pacifica	4.07	0.0197	(3 + 2)(2 + 1)
Tegastidae species	2.67	0.0740	(1 + 2 + 3)
Stenhelia (Stenhelia) peniculata	0.77	0.4645	(1 + 2 + 3)

Station 1 = Iona Island Station 2 = Steveston Station 3 = Roberts Bank

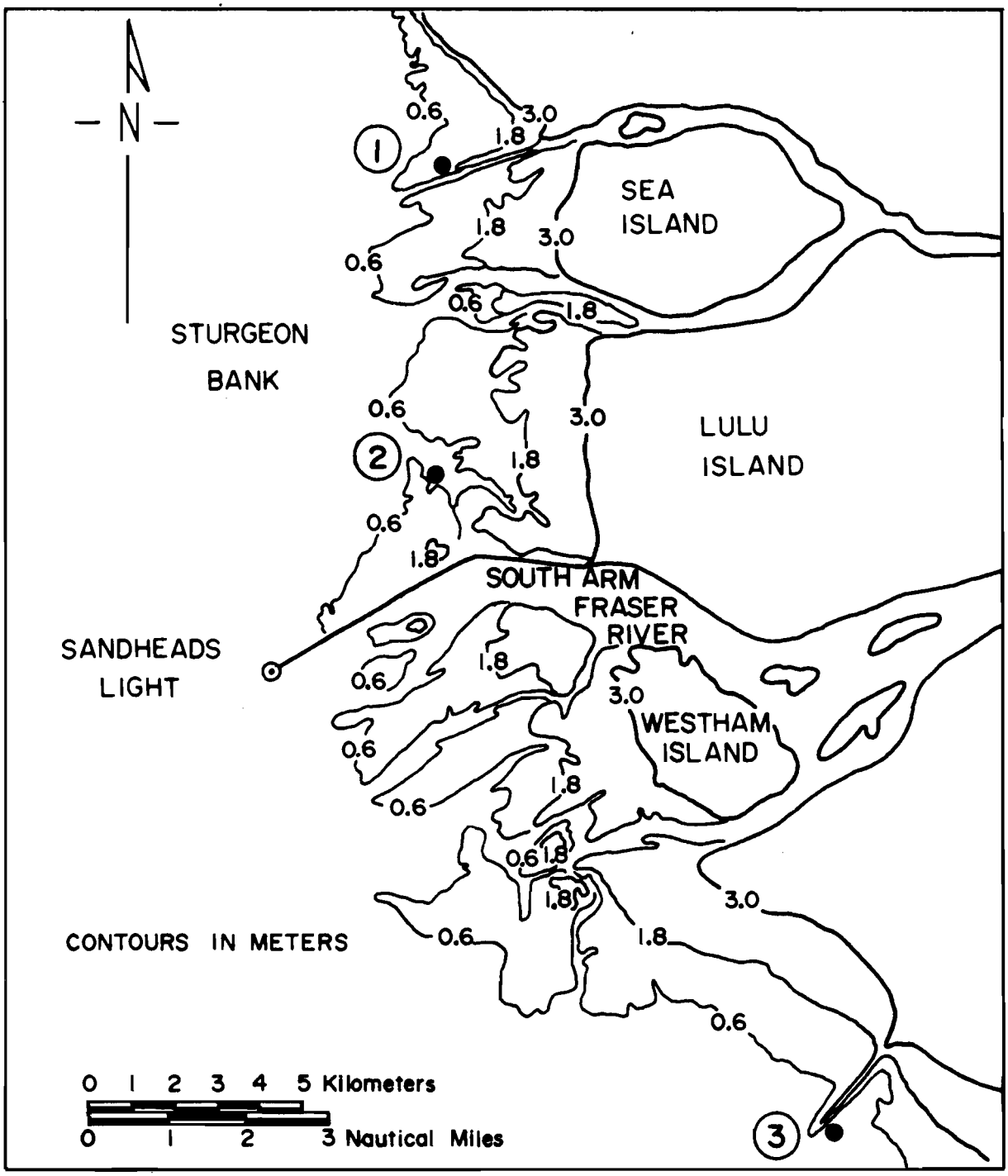

Figure 1. Map of the Fraser River estuary showing the location of Iona Island (1), Steveston (2) and Roberts Bank (3) sampling sites.

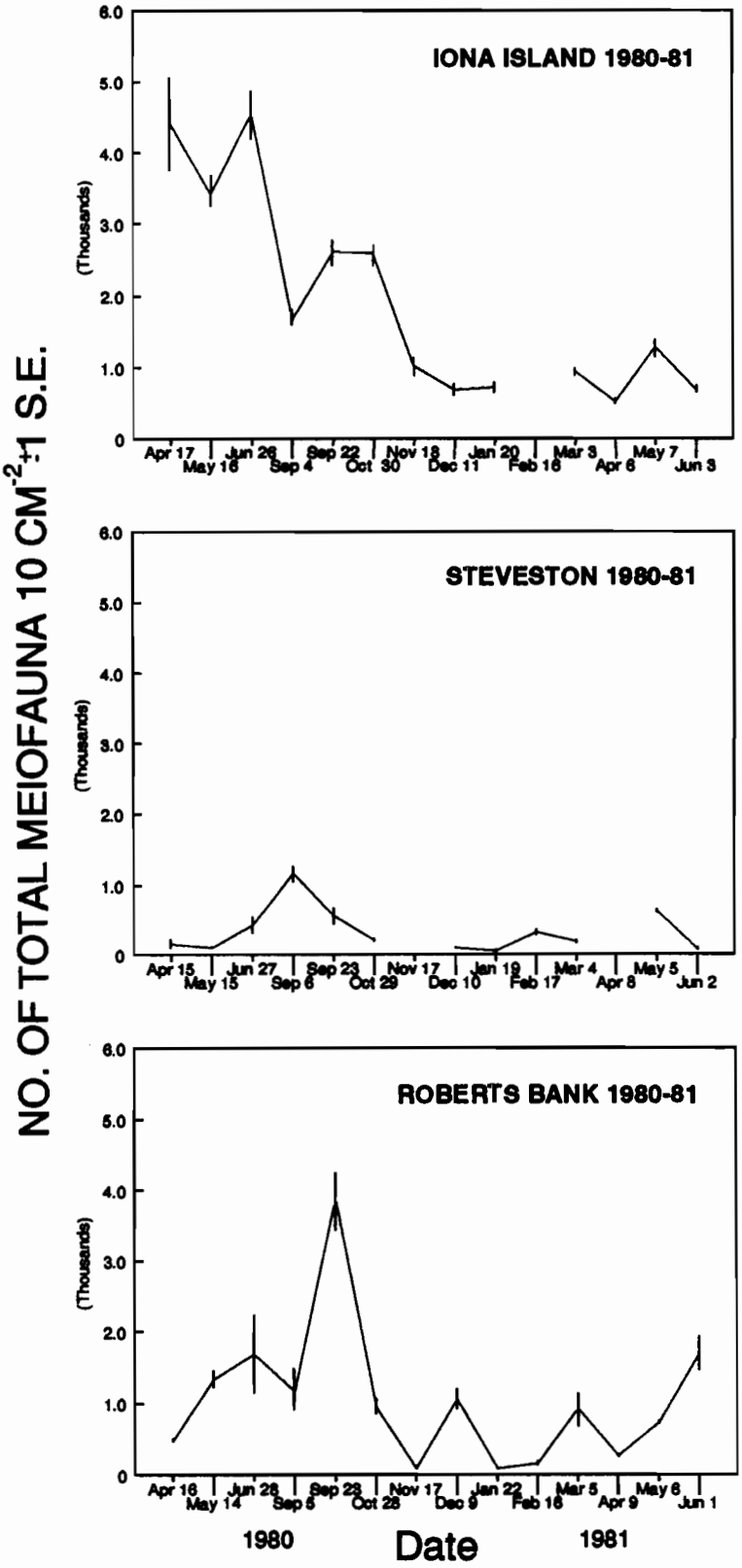

Figure 2. Mean number of total meiofauna obtained in core samples from Iona Island, Steveston and Roberts Bank.

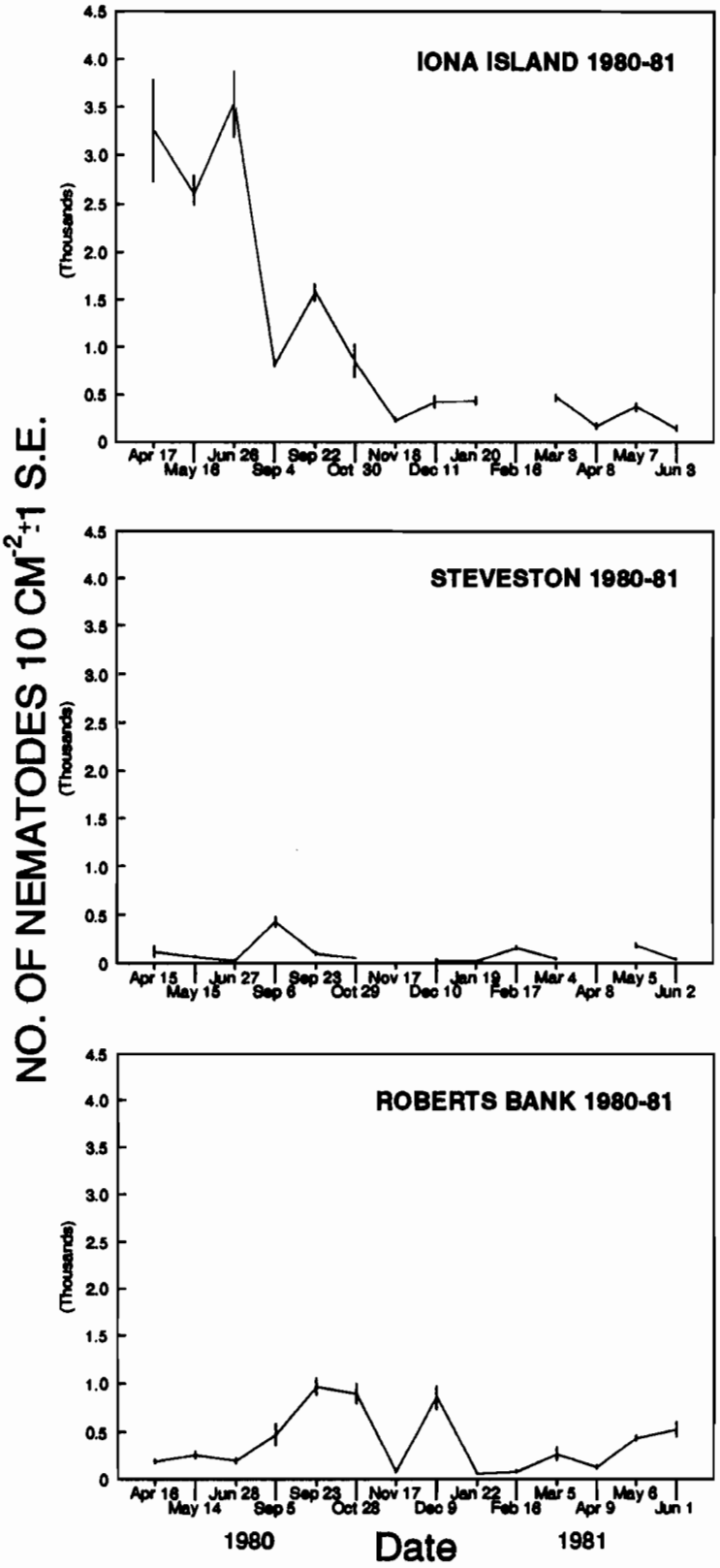

Figure 3. Mean number of nematodes obtained in core samples from Iona Island, Steveston and Roberts Bank.

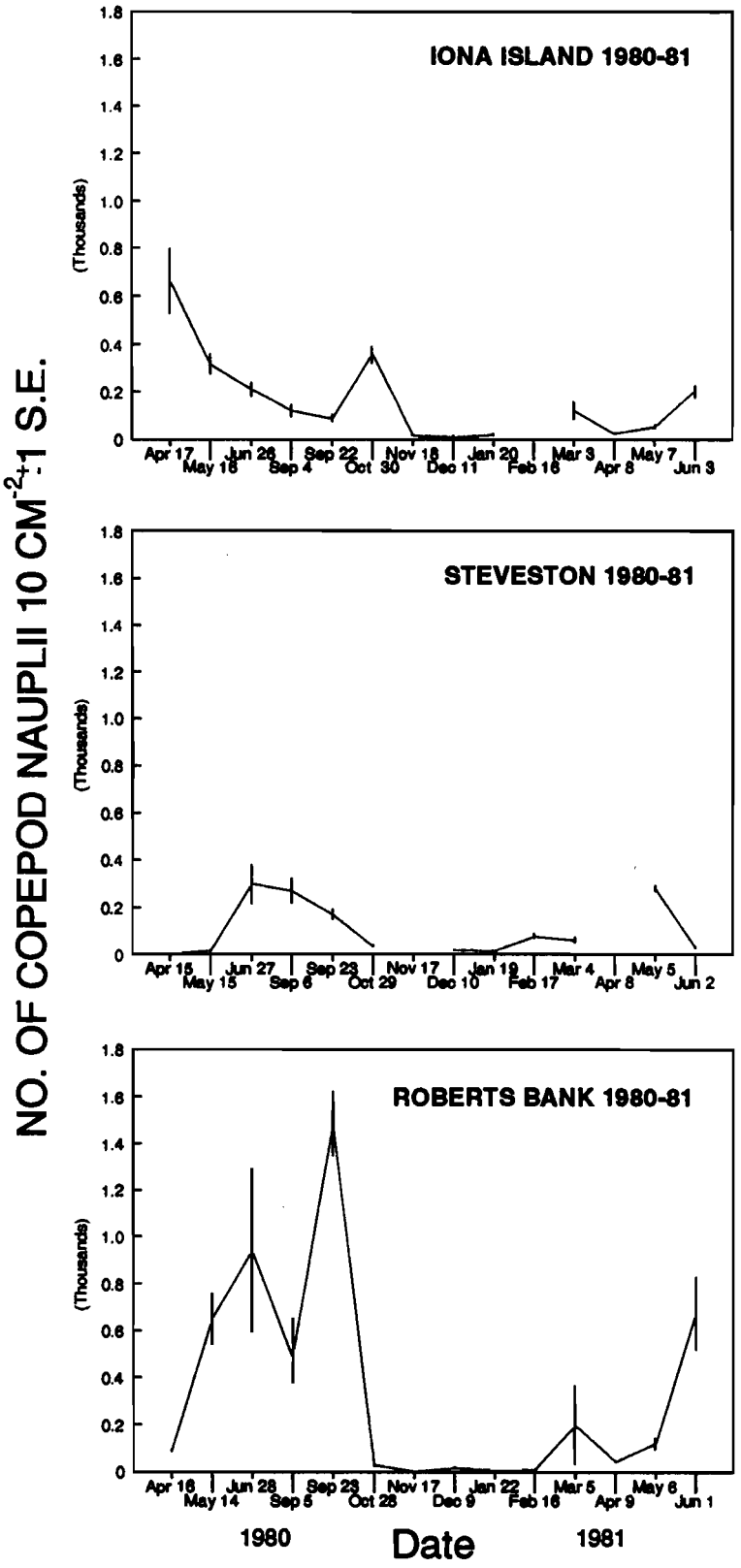

Figure 4. Mean number of copepod nauplii obtained in core samples from Iona Island, Steveston and Roberts Bank.

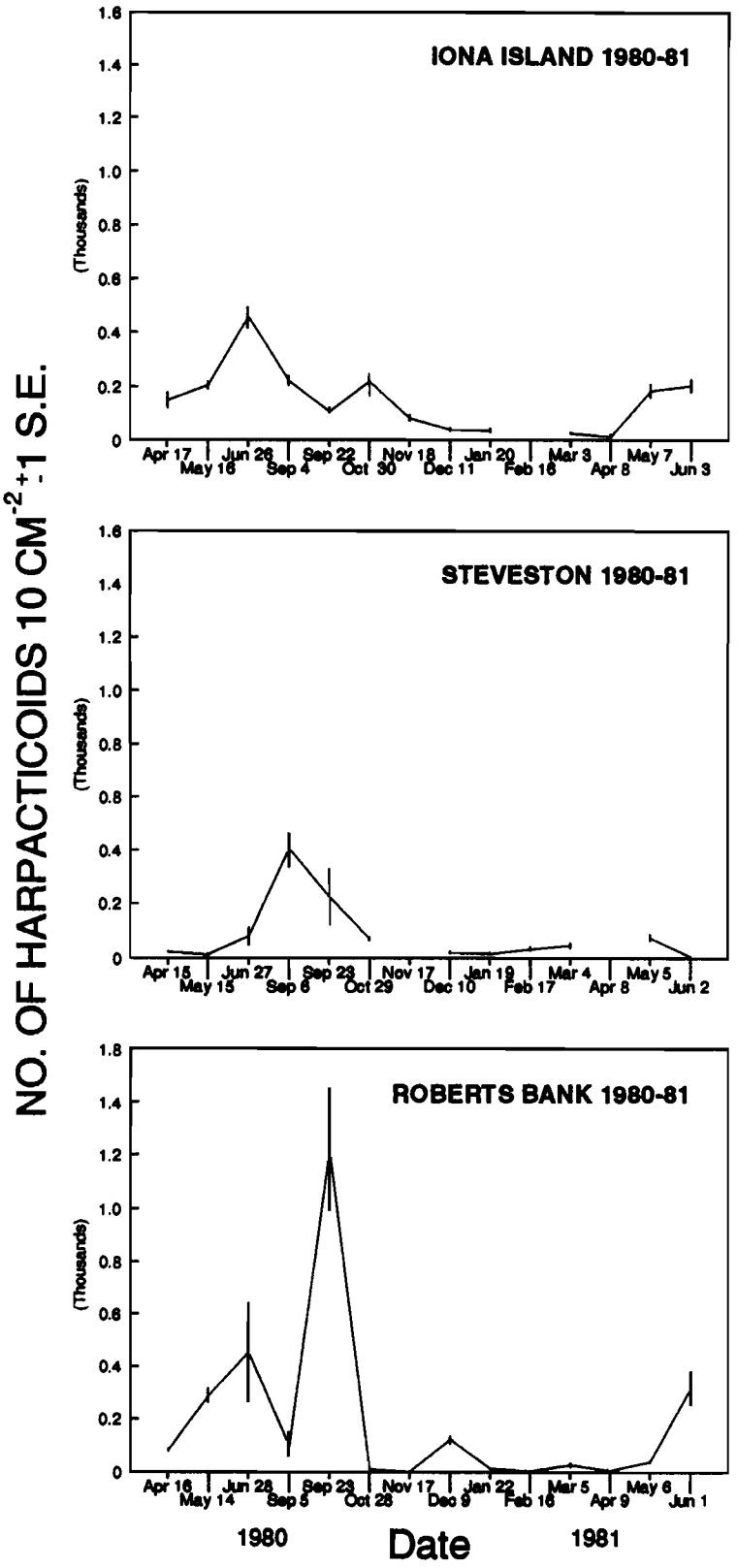

Figure 5. Mean number of harpacticoids obtained in core samples from Iona Island, Steveston and Roberts Bank.

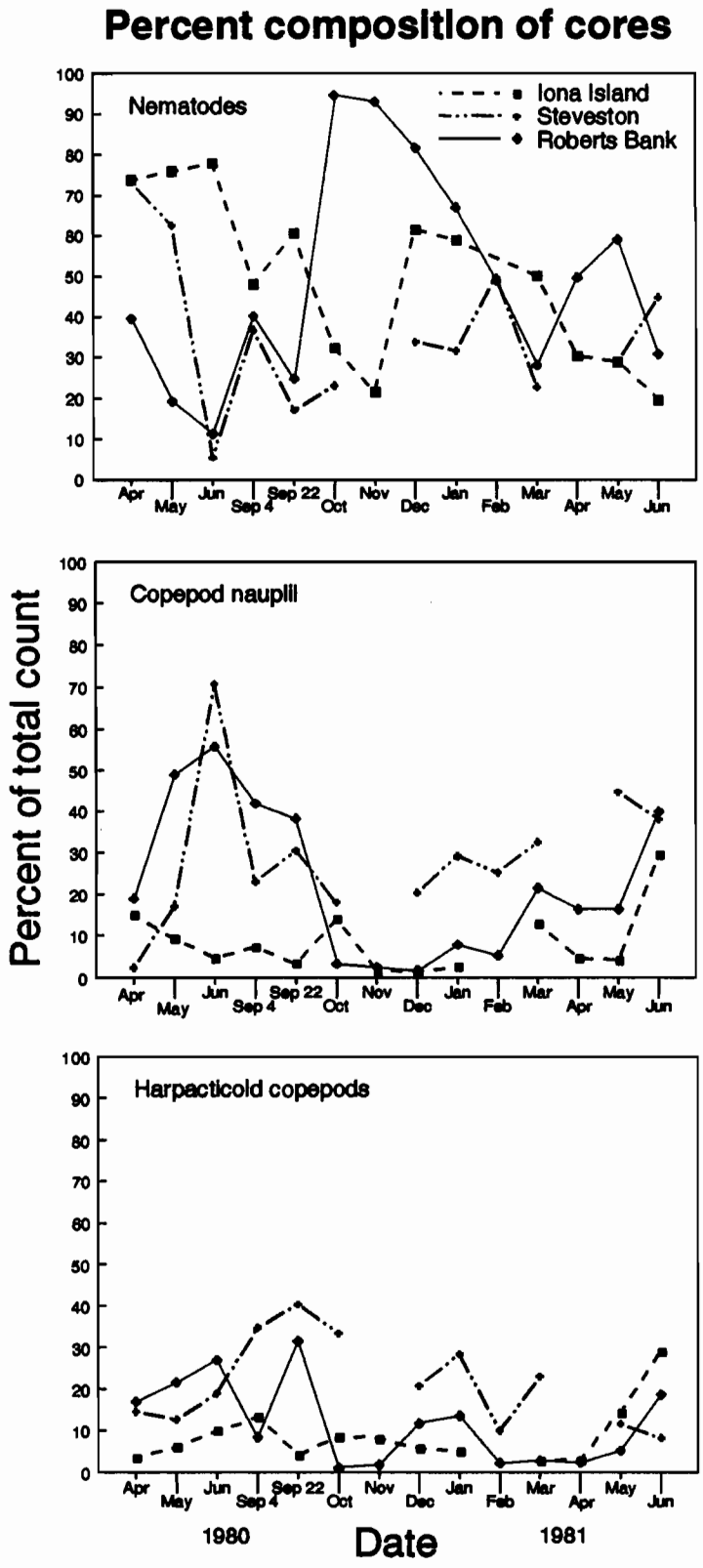

Figure 6. Percent composition of core samples from Iona Island, Steveston and Roberts Bank.

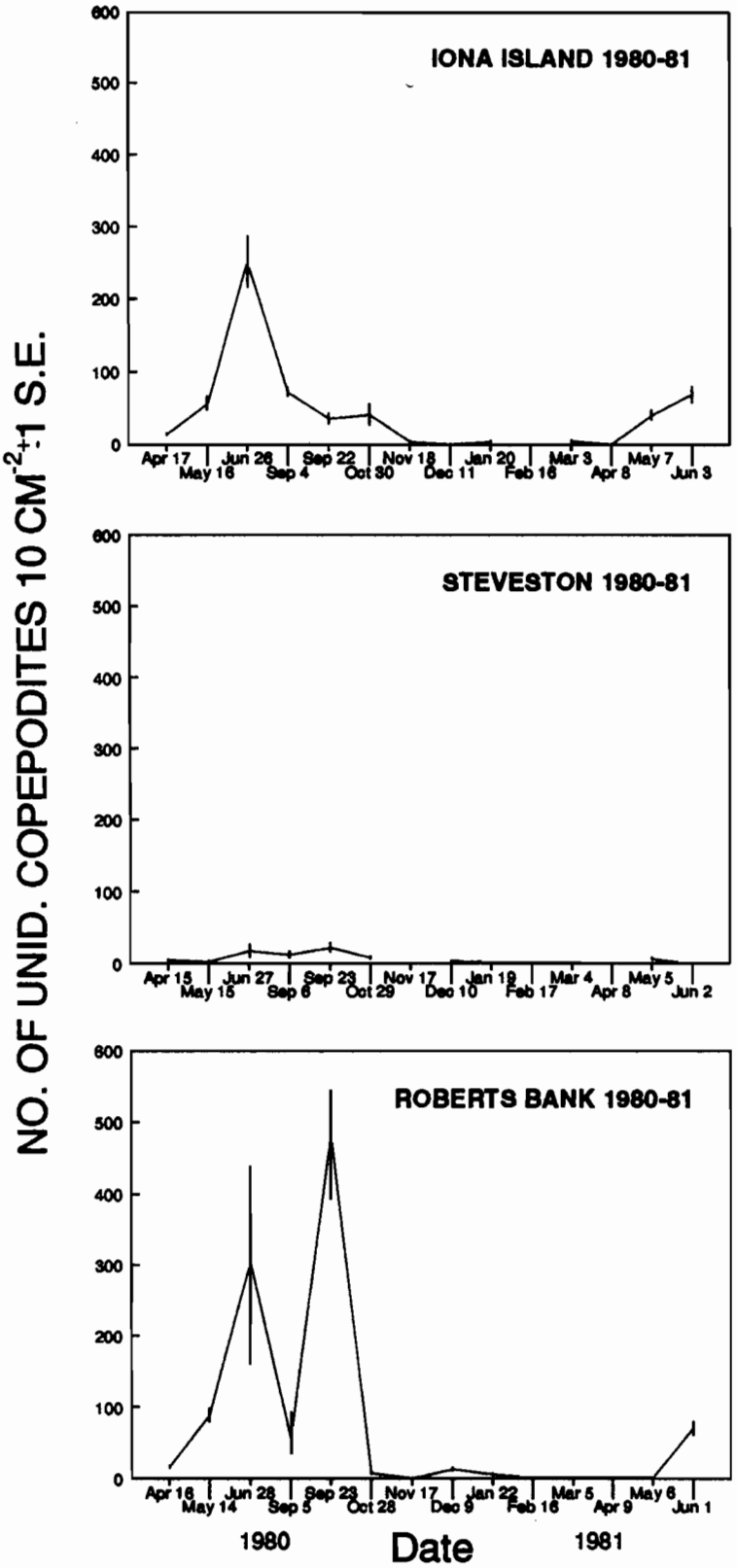

Figure 7. Mean number of unidentified copepodites obtained in core samples from Iona Island, Steveston and Roberts Bank.

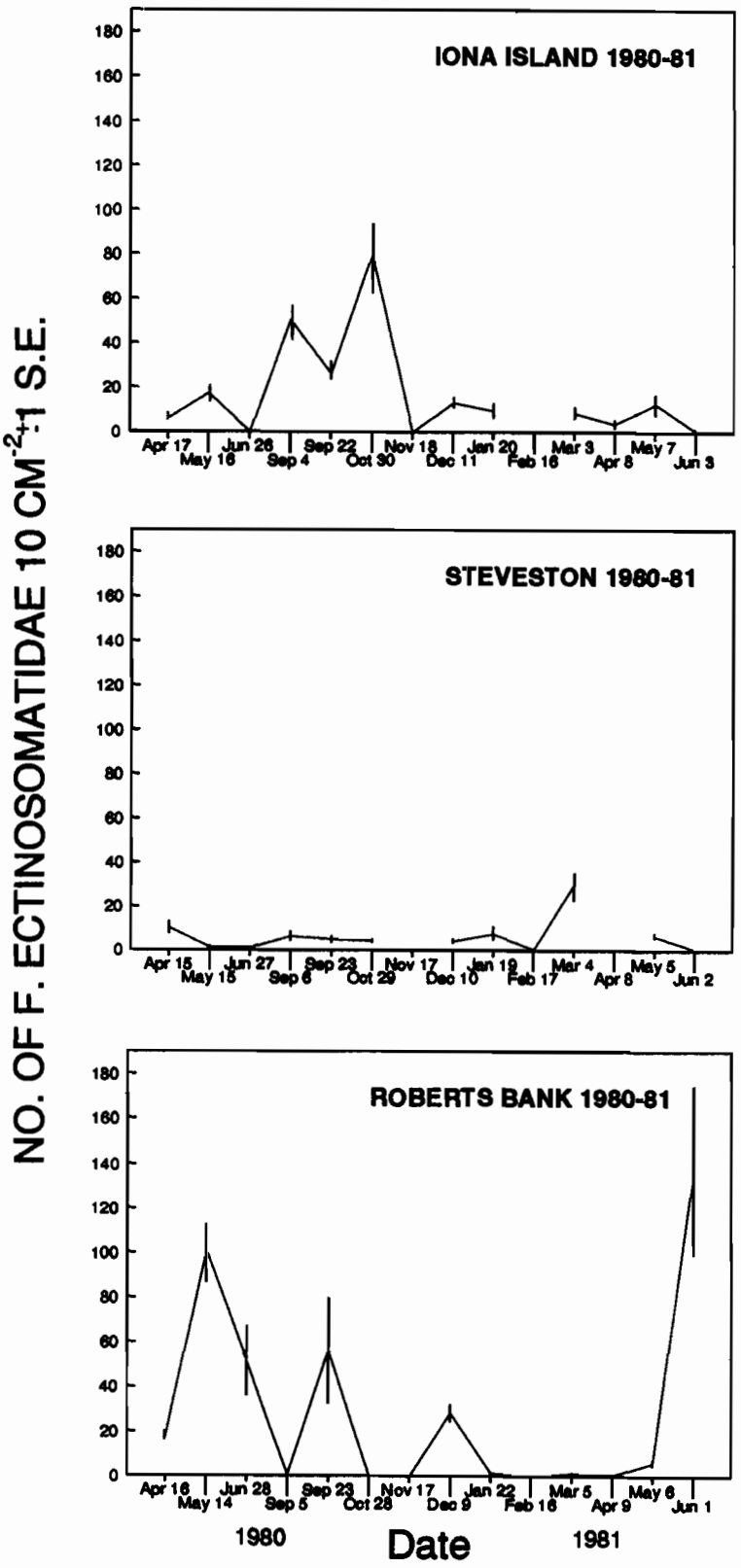

Figure 8. Mean number of Family Ectinosomatidae obtained in core samples from Iona Island, Steveston and Roberts Bank.

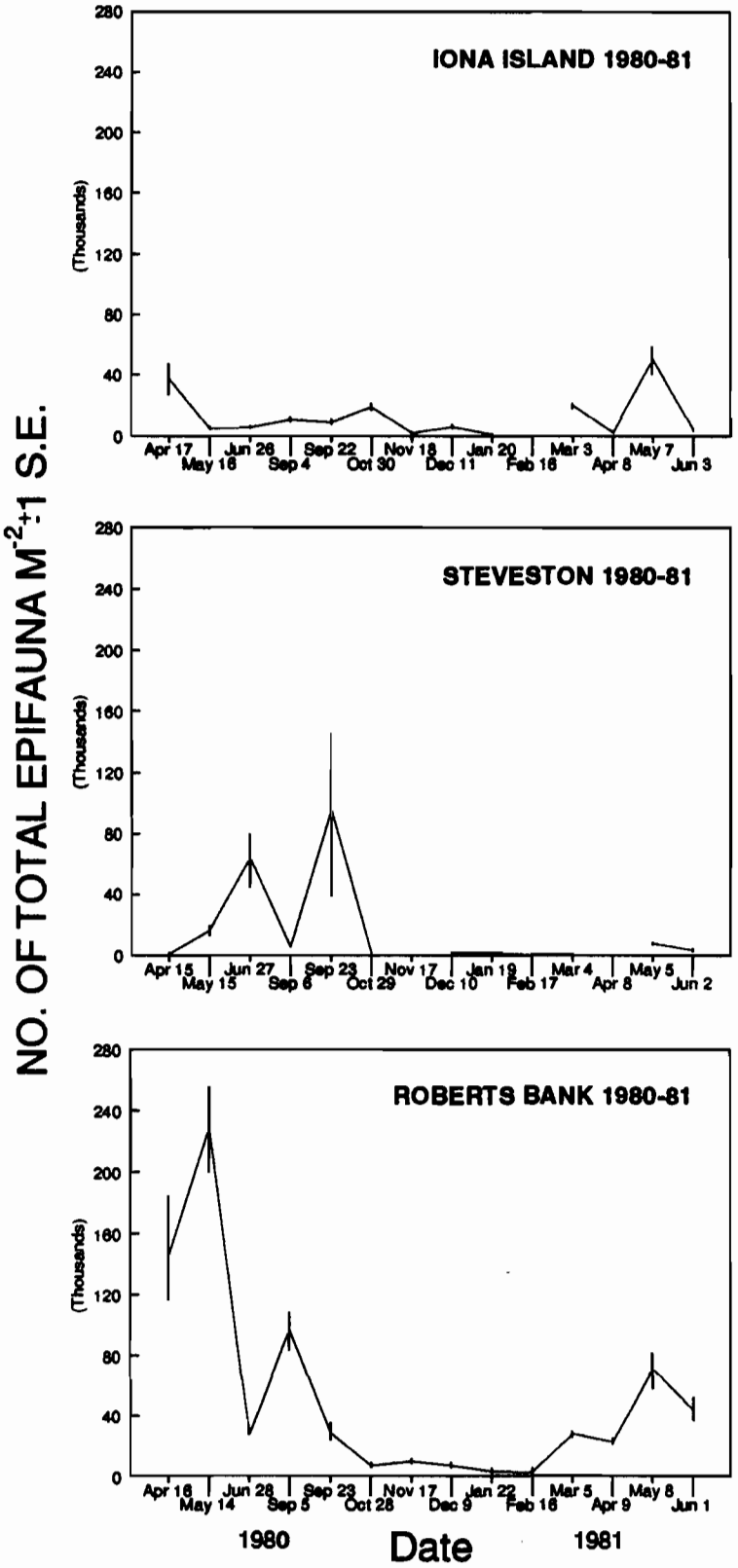

Figure 9. Mean number of total epifauna obtained in sled samples from Iona Island, Steveston and Roberts Bank.

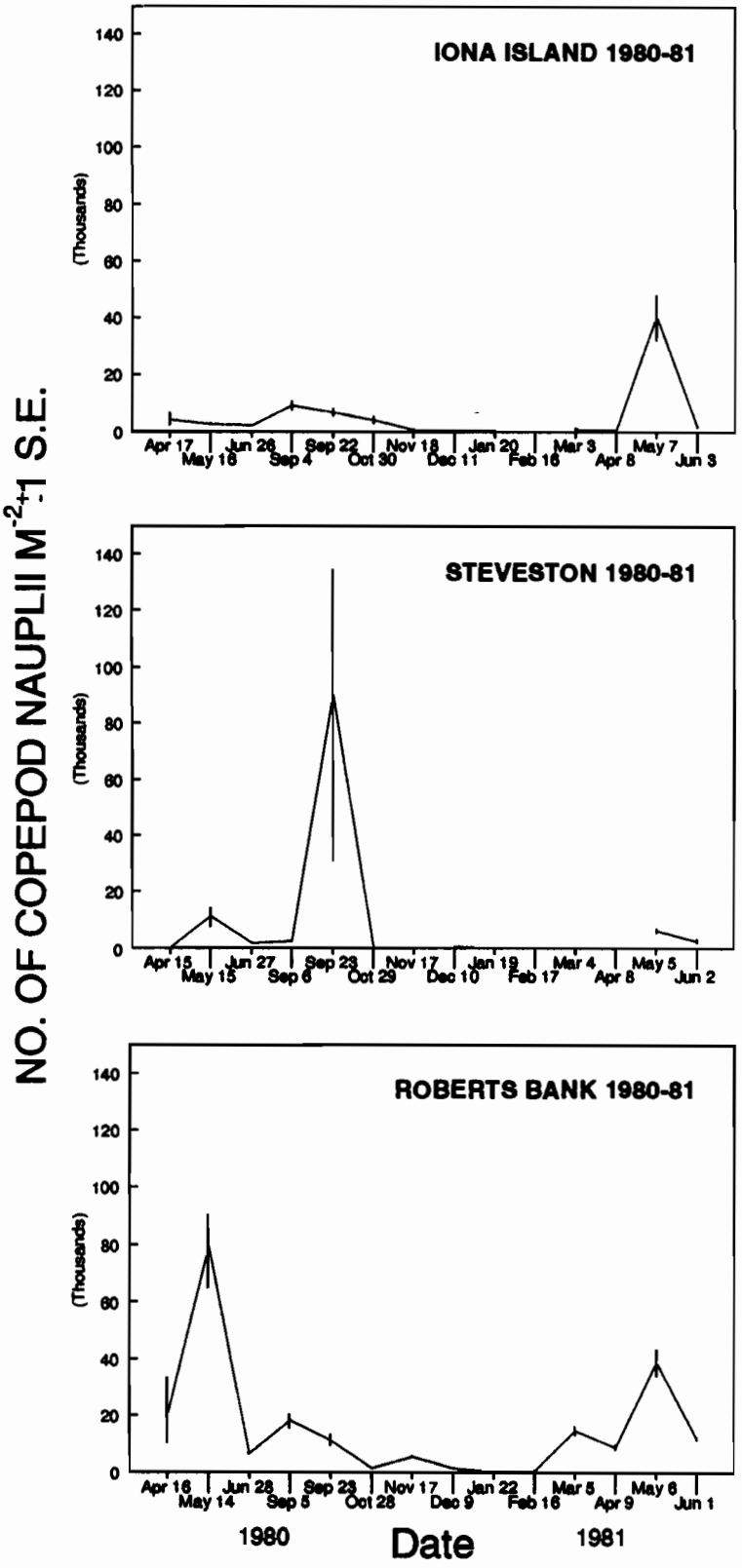

Figure 10. Mean number of copepod nauplii obtained in sled samples from Iona Island, Steveston and Roberts Bank.

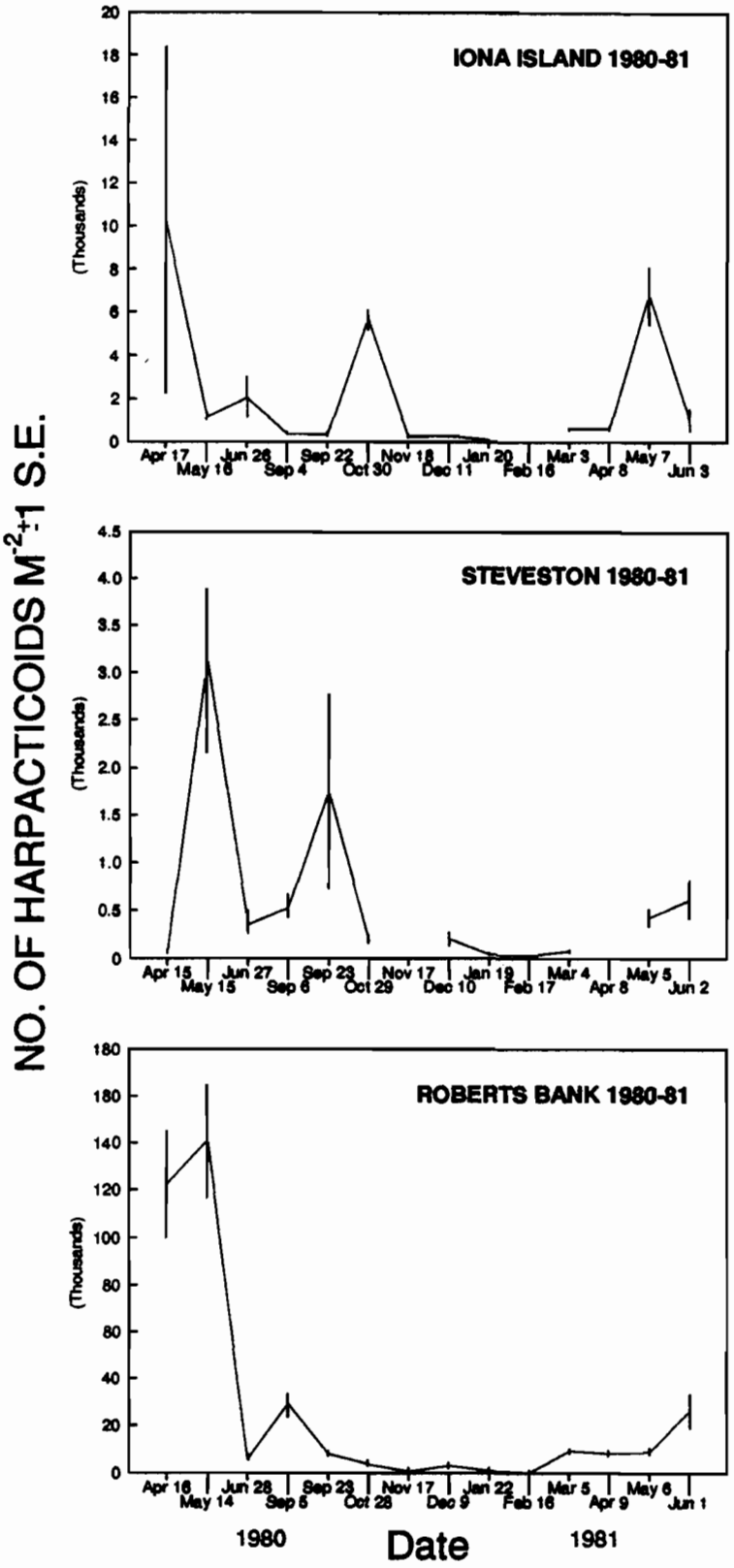

Figure 11. Mean number of harpacticoids obtained in sled samples from Iona Island, Steveston and Roberts Bank.

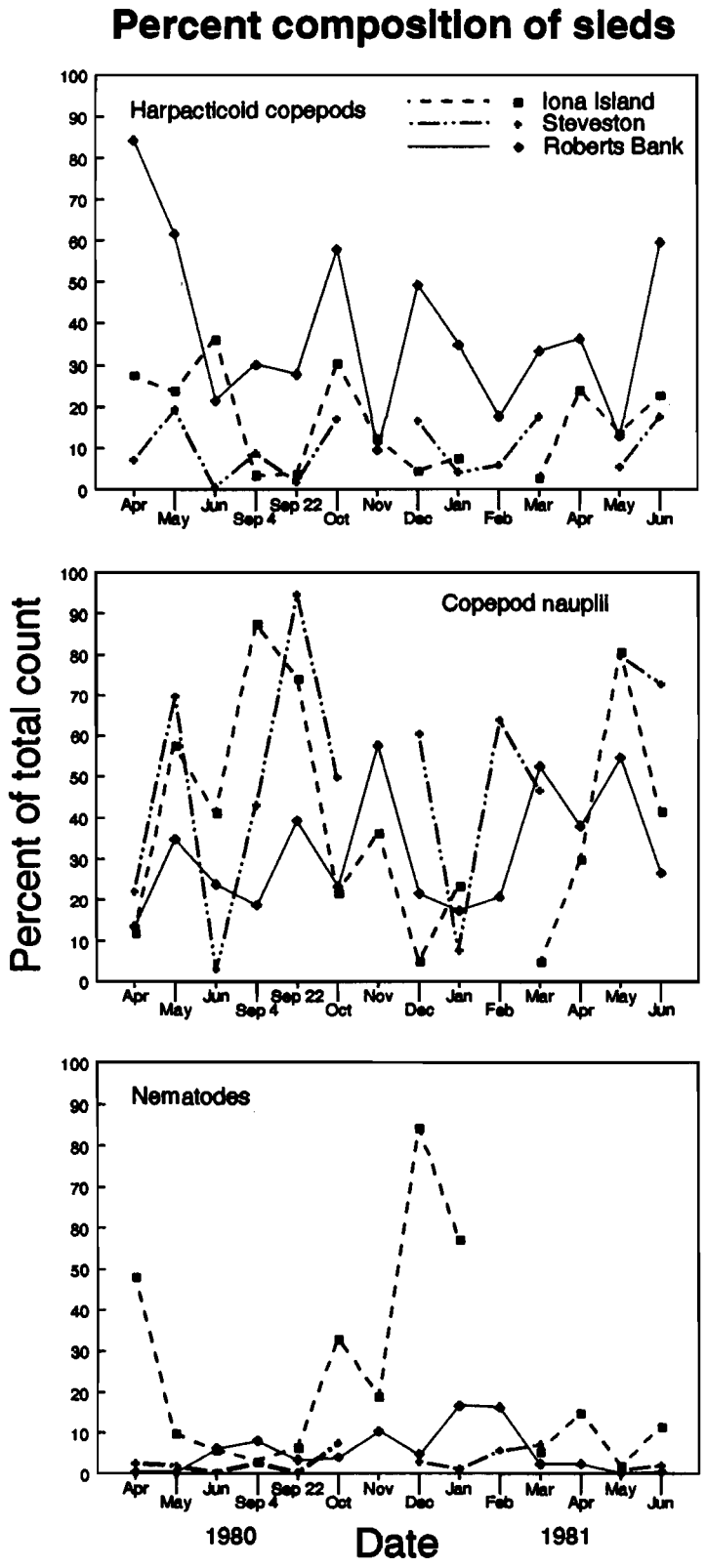

Figure 12. Percent composition of sled samples from Iona Island, Steveston and Roberts Bank.

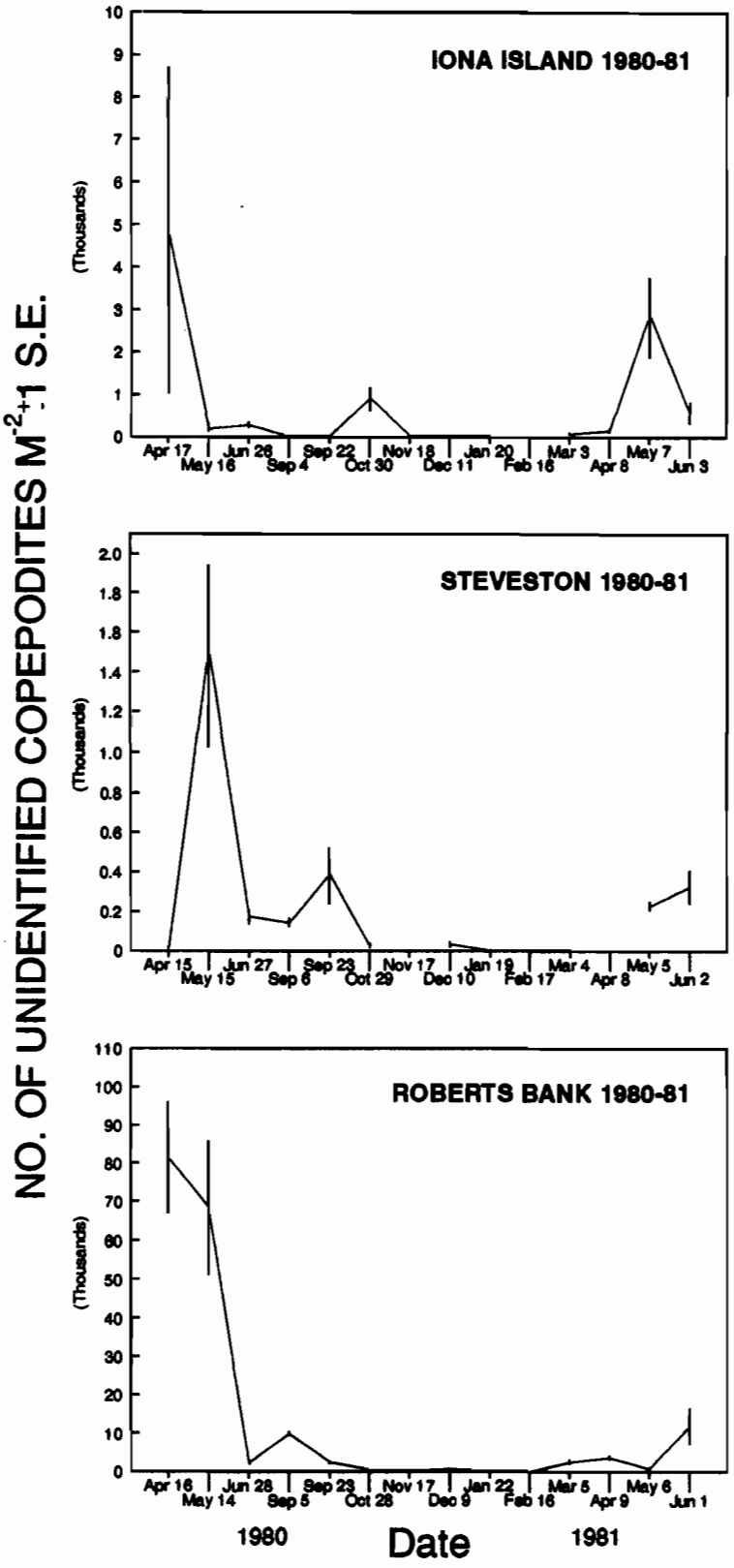

Figure 13. Mean number of unidentified copepodites obtained in sled samples from Iona Island, Steveston and Roberts Bank.

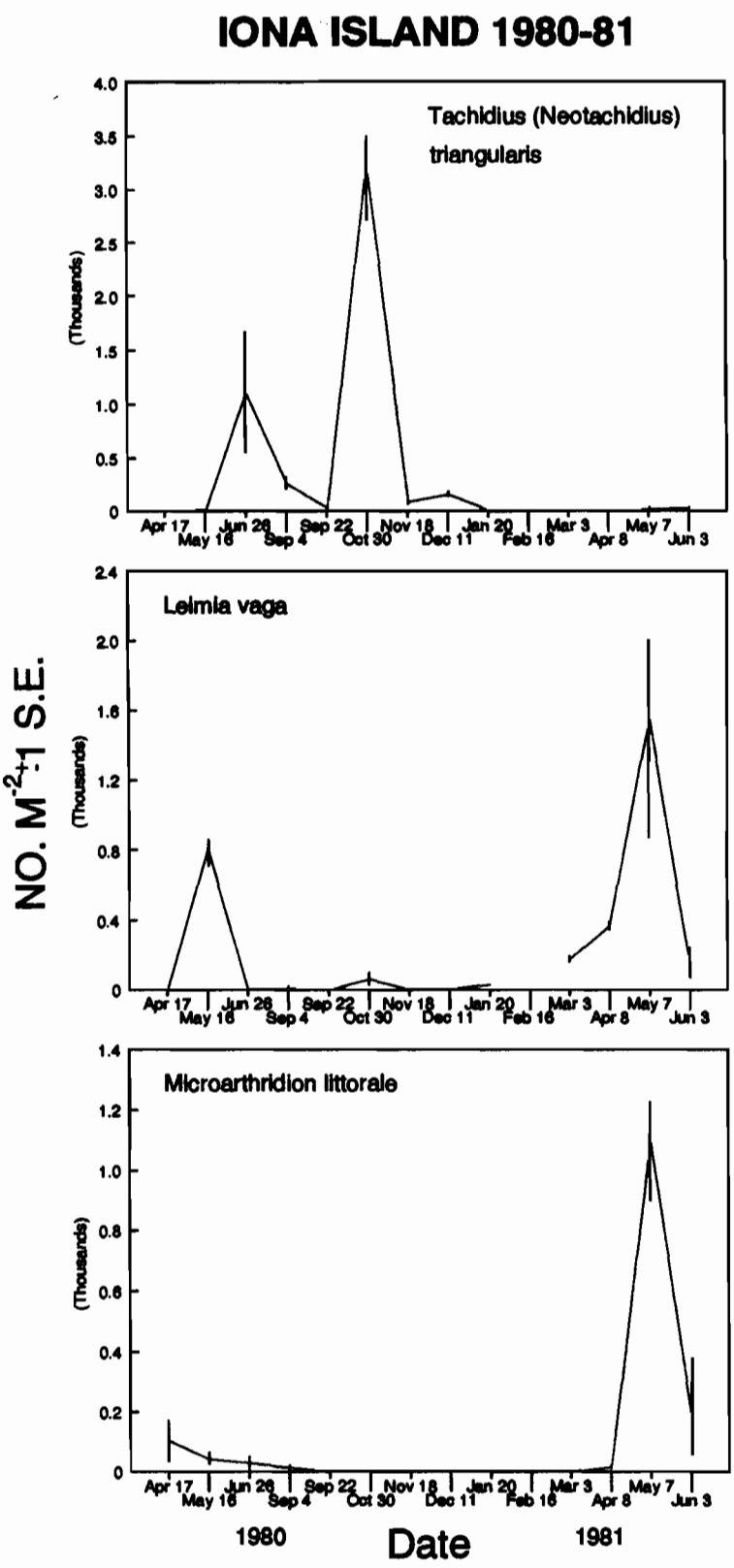

Figure 14. Mean number of dominant harpacticoid copepod species obtained in sled samples from Iona Island 1980-81.

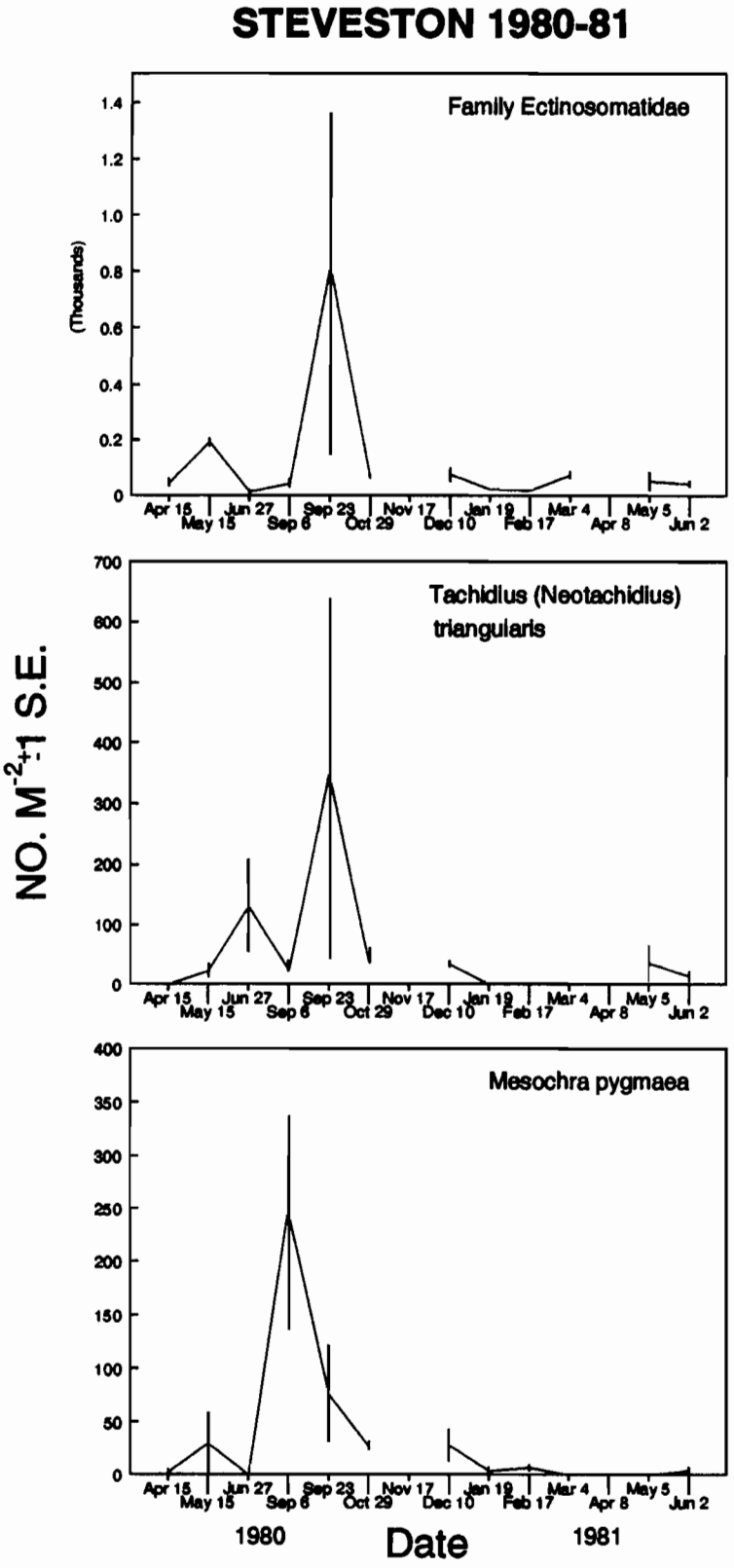

Figure 15. Mean number of dominant harpacticoid copepod species obtained in sled samples from Steveston 1980-81.

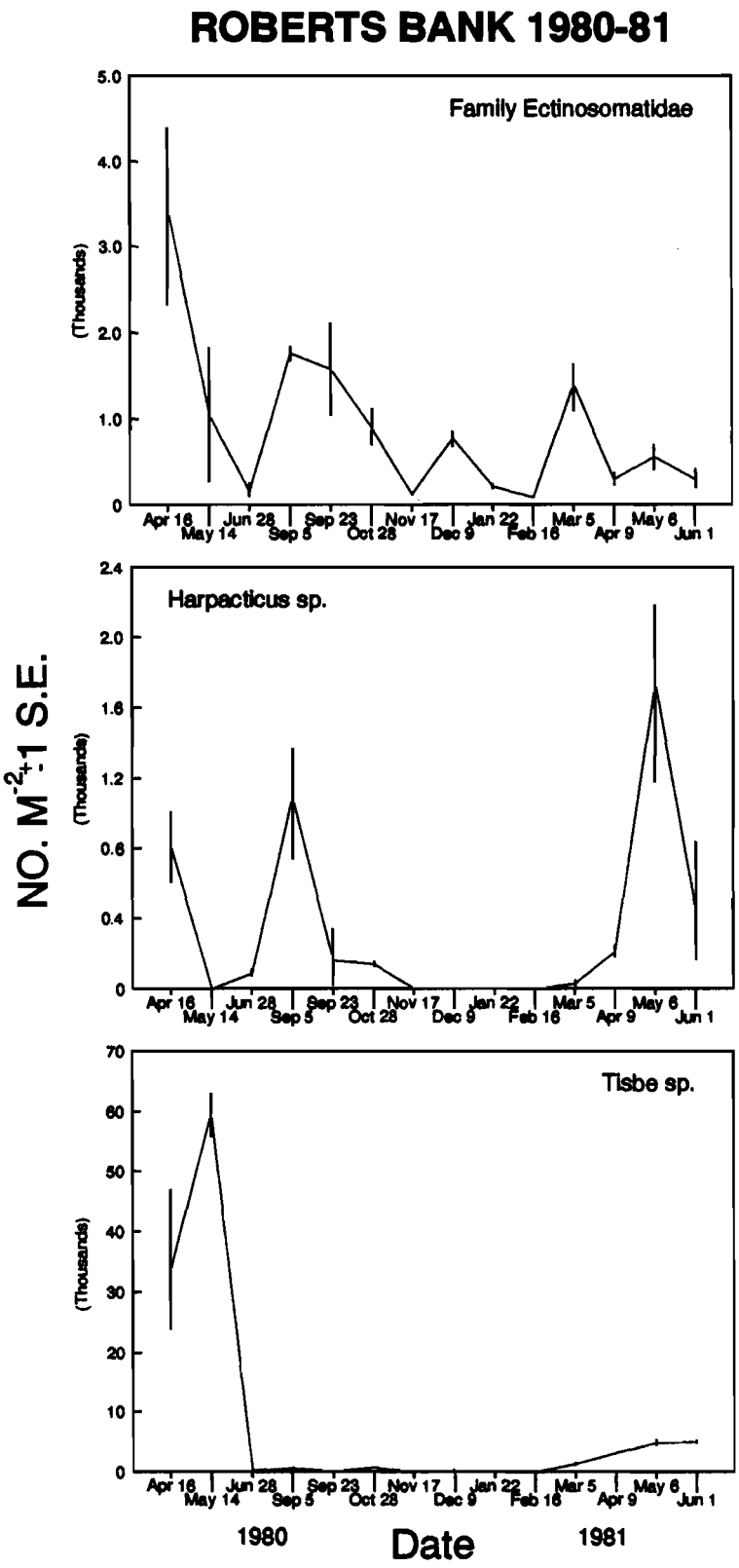

Figure 16. Mean number of dominant harpacticoid copepod species obtained in sled samples from Roberts Bank 1980-81.

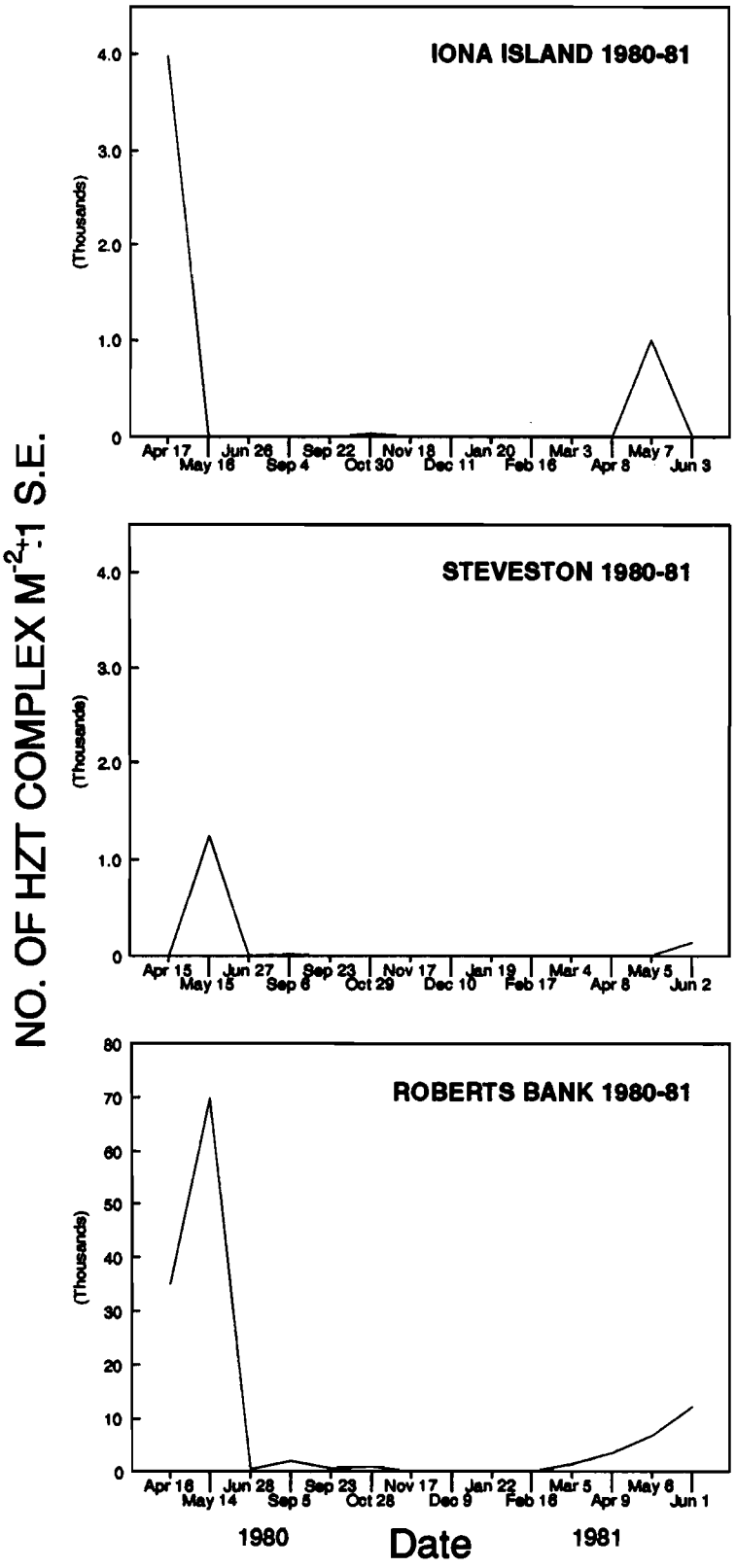

Figure 17. Mean number of Harpacticus sp., Zaus sp. and Tisbe sp. combined in sled samples from Iona Island, Steveston and Roberts Bank.