Results of a Survey of Fish, Juvenile Salmon Diets and Epibenthic Invertebrates in the Englishman River Estuary

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Bravender, B.A., C. Annand, A. Hillaby and J. Naylor. 1996. Results of a survey of fish, juvenile salmon diets and epibenthic invertebrates in the Englishman River estuary. Can. Manuscr. Rep. Fish. Aquat. Sci. 2387: 62 p.

In 1993, following the designation of the Englishman River estuary as a protected preserve, a joint study was undertaken by a number of agencies, including the Department of Fisheries and Oceans. As part of this study, the fish fauna was sampled over a short period in the summer and all species captured were identified. Chinook and chum salmon were found to be present in the area between March and July, rearing in several low tide refuges. Most of the chinook juveniles captured were enhanced juveniles taken from the Big Qualicum River stock and reared in a side channel in the Englishman River by Habitat Enhancement staff in Nanaimo. Samples of the epibenthos collected at sites throughout the estuary showed harpacticoid and calanoid copepods, organisms which are important as fish food, to be dominant at many of the sites. Diet analysis of the juvenile chinook captured and calculation of the Index of Relative Importance (IRI) for each prey category showed that insects dominated the diet. Forage ratios calculated for the juvenile chinook were similar to those recorded in both the Nanaimo River and Campbell River estuaries.

RÉSUMÉ

Bravender, B.A., C. Annand, A. Hillaby and J. Naylor. 1996. Results of a survey of fish, juvenile salmon diets and epibenthic invertebrates in the Englishman River estuary. Can. Manuscr. Rep. Fish. Aquat. Sci. 2387: 62 p.

En 1993, suite à la désignation de l'estuaire de la rivière English comme zone protégée, une étude conjointe a été entreprise par un certain nombre d'organismes, dont le ministère des Pêches et des Océans. Dans le cadre de cette étude, nous avons échantillonné l'ichtyofaune en été pendant une courte période, et toutes les espèces capturées ont été identifiées. Le quinnat et le coho étaient présents dans la région entre mars et juillet, plusieurs refuges de marée basse leur servant de zones de grossissement. La plupart des juvéniles capturés étaient des poissons d'élevage provenant du stock de la Big Qualicum et élevés dans un bras de la rivière English par des membres du service d'aménagement de l'habitat de Nanaimo. Les échantillons d'épibenthos prélevés à divers sites de l'estuaire ont révélé que copépodes harpacticoïdes et calanoïdes, organismes importants dans le régime alimentaire des poissons, dominaient à bon nombre des sites. L'analyse de la nourriture des quinnats juvéniles capturés et le calcul de l'indice d'importance relative de chaque catégorie de proies ont montré que les insectes prédominaient dans l'alimentation. Les taux d'alimentation calculés pour les quinnats juvéniles étaient les mêmes que ceux observés dans les estuaires des rivières Nanaimo et Campbell.

INTRODUCTION

The Englishman River drains into a small estuary on the Strait of Georgia, south of Parksville, B.C. on the east coast of Vancouver Island, British Columbia (49° 19′ 48" latitude, 124° 17′ 30" longitude)(Fig. 1).

The preservation of this estuary has long been the focus of much public interest. Suggestions for the establishment of an Englishman River Riparian Greenbelt, from the estuary to Englishman River Falls Park, and the purchase of the estuary for conservation and recreation were made as long as twenty years ago (Blood, 1976; Le Baron, 1976). At that time, it was noted that the estuary was regularly used by at least twenty-five species of water birds, including rare trumpeter swans (Blood, 1976) and that it was a unique ecosystem. In 1974 the village of Parksville requested that the estuary be purchased by the provincial government and designated as a wildlife and recreational preserve but were unsuccessful in this bid (Le Baron, 1976).

In recent years this estuary was brought to the attention of the Nature Trust of B. C. as a potential preserve. The Department of Fisheries and Oceans identified this estuary as valuable fish habitat and other agencies, including the Canadian Wildlife Service, also endorsed the preservation of this estuary. Between 1981 and 1984, the Nature Trust of B. C. gained title to 11.6 hectares immediately adjacent to the reserve and in 1992, in conjunction with the Pacific Estuary Conservation Program and the Ministry of Environment, Lands and Parks, the Nature Trust of B. C. purchased a further sixty-four hectares on both the east and west sides of the estuary (Fig. 2). These parcels all form part of the 873 hectares designated as the Parksville/Qualicum Wildlife Management Area by the Minister of Environment, Lands and Parks in 1993. This preserve includes seventeen kilometres of foreshore from Qualicum Beach to Madrona Point and is managed by the Vancouver Island Region Wildlife Program of B. C. Environment. Plans are under consideration to expand this Wildlife Management Area to include a riparian strip of Crown land from the estuary to Englishman River falls and an additional 16 acres of foreshore to the south of the existing Management Area (Clermont, 1995).

At the time this estuary was purchased for a protected nature preserve, a joint preliminary biological survey of this area was proposed by a member of a local community group, the Society for the Preservation of the Englishman River Estuary. With financial support from the Department of Fisheries and Oceans, studies were begun in spring 1993 on the fish, epibenthos, benthos, birds, mammals and vegetation of the area. Representatives from a number of different agencies were involved, including the Nature Trust of B. C., Fisheries and Oceans (Science Branch and Habitat Enhancement Branch, both located in Nanaimo), the Canadian Wildlife Service (Qualicum), the University of Victoria and the Provincial Museum in Victoria, and the B. C. Ministry of Environment, Lands, Parks and Ministry Responsible for Human Rights and Multiculturalism (Nanaimo).

Watershed and Hydrology

The Englishman River watershed covers an area of approximately 324 km^2, rising to an elevation of 1819 meters at Mount Arrowsmith. The mean total annual precipitation is 963.9 mm (Boom and Bryden, 1994). Within this watershed are two main tributaries, Morison Creek and the South Englishman River fork. The watershed area of Morison Creek is 48.60 km^2 or 15% of the total Englishman River watershed. The largest tributary, the South Englishman River, has a catchment area of 77.83 km^2 (24% of the total watershed). The boundaries of the watershed extend about twenty-seven kilometres inland from the ocean and the general slope orientation is toward the north and northeast (Blood, 1976). Seven moderate size lakes form part of the watershed, with a combined total area of 6.31 km^2 (Boom and Bryden, 1994).

Hydrology records, available on an intermittent basis since 1916, show that the mean monthly river discharge varies from 1.26 $m^3 s^{-1}$ in August to 29.25 $m^3 s^{-1}$ in December, with an annual mean of 13.70 $m^3 s^{-1}$ (Boom and Bryden, 1994). As the system contains no comparatively large lakes to influence or modify flow characteristics, the river can display large changes in flow and maximum daily discharges can reach three times the highest mean monthly flow. This is a pattern typical of streams on the east coast of Vancouver Island. Water also enters the system from a number of small springs and through lateral seepage into the river itself (Blood, 1976).

About sixteen kilometres from the estuary, on the main river, lies Englishman River Falls, surrounded by a provincial park. These falls, Triple Falls on Morison Creek and South Fork Rapids on the South Englishman River tributary restrict the species of anadromous fish within this river system to the lower reaches.

Fisheries Resources

Six species of Pacific salmon spawn in this system. Between 1953 and 1993, the annual number of chum (Oncorhynchus keta) spawning varied from 250 to 15,000 and coho (Oncorhynchus kisutch) from 65 to 3500. During this same period, annual pink (Oncorhynchus gorbuscha) escapement ranged from 0 to 3500, sockeye (Oncorhynchus nerka) from 0 to 300 and chinook (Oncorhynchus tshawytscha) from 0 to 115 (Fig. 3; Serbic, pers. comm.). Steelhead (Oncorhynchus mykiss) also occur in the system as do resident and sea-run cutthroat trout (Salmo clarki clarki) (Blood, 1976). These stocks all contribute to both the commercial and recreational fisheries of the area.

Since 1988, the Habitat Enhancement Branch of the Department of Fisheries and Oceans has released juvenile salmon into various parts of the Englishman River watershed (Cook, pers. comm.). During this time, a total of 989,000 chum, 1.7

million chinook and 840,000 coho were released into the main river, Kincade, Morison and Whiskey Creeks, and several swamps. Young steelhead and cutthroat trout have also been released in various parts of the watershed.

Study area

The estuary covers an area of approximately sixty-four hectares. Much of its present configuration is the result of the construction and alteration of a number of man-made structures over the past one hundred and twenty-five years (Fig. 1). As early as 1870, dykes were constructed on the west side of the estuary to facilitate farming (Clermont, 1995). The greatest change in the estuary resulted directly from the construction of a dyke in 1969 on the western side of the river to facilitate the booming of logs. This dyke restricted the flow of both fresh and salt water to 8.3 hectares of marsh behind it, resulting in the marsh vegetation gradually being replaced by an upland community (Clermont, 1995).

In the northwest corner of the estuary is a man-made "dogleg" slough, 4.5 metres in depth, which was constructed in the 1950's as part of a proposed development in which the owner planned to build a "little Venice". This project was later abandoned. The elevation and shape of the estuary has also been altered by the removal of gravel from some areas in the past and by filling along the shoreline. Approximately 3.9 hectares adjacent to the western boundary of the estuary has been filled to provide road access to the spit and serve as a winter storage site for recreational vehicles (Clermont, 1995).

The dyke on the western side of the estuary has been altered twice. A ten metre breach was made in the dyke in 1979, under the direction of the Department of Fisheries and Oceans, allowing salt water to once again flow behind the dyke and into the low slough area as it had in the past before the dyke was constructed. This breach was expanded a further ten metres in 1994 by Ducks Unlimited Canada and the Habitat Conservation Fund (Clermont, 1995). It was thought that reclaiming the slough area would likely increase the estuarine rearing habitat available to the juvenile salmon in the system. Fresh-water and possibly pollutants also enter the southwest corner of the estuary through several storm sewers from the city of Parksville.

The central part of the estuary retains very little water at low tide, with only a few shallow pools remaining between several small islands. For the most part, the river flows in a single main channel across the estuary to its' confluence with the ocean. A large sand and gravel bar has formed at the mouth of the river in Parksville Bay.

There is normally little freshwater inflow on the east side of the estuary and this area is dominated by a large salt slough. On an ebb tide, there are usually only a few scattered shallow pools remaining which are largely salt water.

On the gravel spit to the north of the estuary is located a recreational vehicle park, built in 1980, which is the only commercial development close to the new preserve. This development attracts large numbers of visitors in the spring and summer and leases lots to year round residents. Some of the campsites in this development are located within several metres of the dogleg slough allowing unrestricted access to this habitat. Adjoining this are several other private and one municipal campgound at the head of Parksville Bay. On a portion of the south- east boundary of the preserve is a large subdivision, with some lots fronting directly onto the estuary. Behind this is Rathtrevor Beach Provincial Park (Fig. 1).

Within the preserve area, three zones are evident, including an intertidal flat of mud and sand, a salt marsh, and meadow, brush and mixed forest areas in the upper reaches. A detailed description of the plant communities of the estuary and surrounding area may be found in Dawe and McIntosh 1993.

Past Research

Only a few research projects on the Englishman River and estuary had been carried out in this area before 1993. Two studies were carried out in 1979 by the Habitat Managment Division of Fisheries and Oceans. One study monitored the effects of the first breaching of the dyke on the west bank of the river and the subsequent re-flooding of the old slough area (Tutty et al., 1983). The fish populations in the slough and the adjacent area were sampled both before and after the breaching of the dyke. Lengths, weights, ages and diets were determined for chum, chinook and coho salmon both inside and outside the slough. This study included the collection of samples of the epibenthic and benthic fauna at sites within the slough and at the entrance to it. Water temperatures were also recorded.

The second study in 1979 (Hamilton and Kosakoski, 1982), dealt with concerns about the possible effects on the fish stocks in the system of a proposed new diversion of water to increase the supply of domestic water to two local communities. Their report contained a biophysical inventory of the lower eight kilometres of the river including gradient, pool-riffle ratio, wetted width, substrate and spawning distributions for many of the species in the system. They also discussed the historical flow regime and made recommendations concerning the minimum flows necessary for successful rearing of the juvenile salmonids within the system.

Kennedy (1982) carried out a preliminary survey of the vegetation of the Englishman River estuary in 1975-76, using aerial photos and ground truthing, as part of a larger survey of the estuaries of the east coast of Vancouver Island. She found nineteen different communities on the east side of the estuary, dominated by species common in brackish, saline and dry conditions. She also noted the extensive evidence of restricted fresh and salt water flow in many areas of the estuary as reflected in the vegetation.

As part of a survey of the estuaries on the Puget Trough lowlands (which encompasses the Strait of Georgia and Puget Sound), Hutchinson (1988) classified the Englishman River estuary, along with the Chemainus and Nanaimo River estuaries, as a Type C delta. This type is characterized by large areas of Salicornia-Distichlis and Carex-Triglochin communities.

In 1987, the Canadian Wildlife Service published the preliminary results of a study begun in 1979 to document the changes in vegetation following the first breaching of the dyke. After the construction of the dyke in 1969, the newly isolated slough area had changed from an estuarine marsh to an upland ecosystem. Following the removal of a ten metre portion of the dyke in 1979, eighteen species of plants died out within the first year and seven new species characteristic of a salt marsh community colonized the area. The vegatation approached a stable state by the eighth year after the dyke removal (Dawe and McIntosh, 1993). During the study in 1979, semipermanent transects were established for long term studies and these transects were re-surveyed as part of the 1993 cooperative research project.

The importance of the estuary as a refuge for birds was also investigated by the Canadian Wildlife Service. Surveys of bird fauna were carried out in 1979-1980 and 1988-1989, documenting one hundred and thirteen species of birds in the area (Dawe et al., 1994). These surveys were continued in the 1993 study.

Prentice and Boyd (1988) carried out an assessment of the historical changes in habitat types and land uses in the estuaries on the east coast of Vancouver Island, including the Englishman River estuary. Using air photos, they calculated the area of each habitat type in the estuary between 1949 and 1984. They noted that the main use of the estuary around 1949 was as a storage area for logs, especially in the tidal channels. Their data show that during this period there was a net loss of both marsh (-7 ha) and meadow (-26 ha) habitat. This was due largely to the construction of the dyke on the western side of the estuary, effectively isolating the intertidal slough from further innundation, and the addition of structures such as canals and campsites. They noted that the building of the first residential and commercial subdivisions close to the estuary began in 1957.

Several consultants' reports, the most recent in 1990, have been commissioned on the social and environmental effects of proposed development of the estuary and the lands directly adjoining the river (Blood, 1976; Le Baron, 1976; Tera Planning Ltd., 1990). All of these reports emphasized the value of the estuary as a wildlife and recreational area and expressed concern for the preservation of the area.

In 1995, a management plan for the Parksville-Qualicum Beach Wildlife Management Area was prepared for B. C. Environment on behalf of the Habitat Conservation Fund, Ducks Unlimited Canada, the Nature Trust of B. C., Wildlife Habitat Canada and the Canadian Wildlife Service (Clermont, 1995). This report described the rivers, estuaries and foreshore areas which make up the 873 hectare wildlife management area, the history of its' acquisition and plans for potential enhancement and expansion of various habitat types.

The results of the initial survey carried out in 1993 may be found in Annand et al. (1993) which includes data on the benthos, birds, small mammals and vegetation as well as preliminary information on the fish populations. This previous report and the more in depth results presented here are the first baseline inventories of the ecosystem of this estuary. The raw data from the 1993 study will be made available in a data record as part of the Fisheries and Aquatic Sciences publication series.

MATERIALS AND METHODS

Field Surveys

Assessment of the Englishman River estuary fish community began in May 1993 when beach seine samples were collected at five sites by staff from Fisheries and Oceans South Coast Division in Nanaimo. The data from these trips were added to that collected on four more trips made between early June and late July. Eleven sites within the estuary and two sites on the marine foreshore at the mouth of the river were added to the original five locations (Fig. 1). These stations were chosen to represent the various habitats available within the estuary and nearshore area. They differed in elevation, substrate type, and salinity and temperature regimes (Table 1).

Salinity, temperature and conductivity were recorded with a YSI Model 33 S.C.T. meter at all stations during each trip from June 8 to July 30. At the time of sampling, water depth at most sites was usually less than one metre except in the dogleg slough, where water depth varied up to 4.5 m. The height and stage of the tide above chart datum at the time of sampling was calculated using Tide and Currents software from Nautical Software, Beaverton, Oregon, USA.

Fish were collected using either a 15.24 m beach seine (1.2 cm stretched mesh) or a stick seine 9.14 metres long (stretched length from pole to pole) with 5 mm mesh in the bunt. Sampling was usually carried out at low tide. The beach seine was set using a 3.7 m row boat, a 5.5 m jet boat, or on foot depending on the depth of water at the time of sampling. The stick seine was always used in shallow water and was set on foot. Duplicate sets were made with both net types and the total catch recorded. Sixty-nine beach seines and thirty stick seines were done. Where possible, at each site, at least ten of each species of fish were preserved in 10% formaldehyde and returned to the laboratory at the Pacific Biological Station.

On two evenings in late July, at high tide, sampling was also carried out at one site on the west side and three sites on the east side of the estuary.

To assess the food organisms available to the fish, triplicate samples of the near bottom community were collected at six sites with a small epibenthic sled, first described by Sibert et al. (1977). This sled had a mouth opening 10 cm x 10 cm and was fitted with a 100 μ net. Each replicate sampled the 10 cm of the water column immediately above the bottom over a 5 m transect. The transects were usually located within two metres of the shore in water less than one metre deep. Between June 8 and July 30, 1993, sixty-nine epibenthic samples were taken with the sled and preserved in a solution of rose bengal and 10% formaldehyde.

Laboratory Analysis

In the lab, the preserved fish were identified to species as described in Hart (1973) and Scott and Crossman (1973). Samples of each species were then placed in a reference collection which is stored at the Pacific Biological Station in Nanaimo. Sixty-seven chinook and two chum juveniles were weighed and measured. Fork length in mm was recorded and the fish were damp weighed in water to the nearest 0.1 gm on a Mettler balance. Scale samples were collected as well and analyzed by the Ageing Laboratory at the Pacific Biological Station to confirm species and document growth rate. Sixty-two chinook from eight sites in the estuary and two sites on the marine foreshore were set aside for diet analysis.

The stomachs, from the oesophagus to the pyloric caecae, were removed from the juvenile chinook and damp weighed to the nearest hundredth of a gram using an Ohaus Model TP400D balance. A subjective estimate of the stomach fullness from 0 to 100% was made. The contents were then removed, the stomach wall re-weighed and the bolus weight in grams calculated. The degree of digestion of the contents from 0 to 100% digested was estimated subjectively. Using a dissecting microscope, all undigested prey organisms were identified to either general group (fish larva, insect), family or order. Where possible, prey length was measured and percent volume of each prey type was visually estimated. An estimate of percent volume was also made for the digested contents which could not be measured and the probable prey type (insect, crustacean) was noted.

Numerical percent and percent frequency of occurrence were calculated for all food organisms. The Index of Relative Importance (IRI) (Pinkas et al., 1971, modified by Levy and Ysaki, 1981) was calculated for selected sites using the formula:

$$IRI = \% \text{ occurrence} \times (\% \text{ volume} + \% \text{ frequency}).$$

The IRI for each prey type is an indication of its' overall importance in the diet of the fish. The higher the IRI, the more important the diet item. Using this value, prey type can be ranked as a portion of the diet, independent of size or number. For this analysis, only sites with a total of at least ten chinook for the complete sampling period were chosen. This included sites 1 and 3 combined, site 6 and site 12. The prey were combined into ten categories and the IRI was calculated for each prey category at these three sites and for the entire estuary as a whole. Forage ratios were also calculated for the juvenile chinook by dividing the weight of the stomach contents by the weight of the fish and multiplying by 100.

Sixty-six epibenthic sled samples were counted using a dissecting microscope fitted with a plankton turntable. Three samples were not analyzed due to storage problems. The formaldehyde was decanted off each sample through a 30 μ sieve and water was added to bring the volume up to 250 ml. Each sample was then scanned and any large organisms were counted and removed.

Many of the samples could be processed as a whole, but, where the numbers of organisms were high, as in the case of copepod nauplii and polychaetes, progressive aliquots were taken until one hundred of the dominant organisms had been counted. Some samples were split a maximum of four times with the Folsom splitter. The total numbers for each sample were then calculated by multiplying the counts obtained by the split factor.

RESULTS

1. Physical data

Throughout the estuary, salinity at the time of sampling ranged from 6.5 ‰ at site 9 to 21.5 ‰ at site 17, with the salinity at most sites being below 20 ‰. At sites 10 and 11 on the marine foreshore, salinities were between 16.5 ‰ and 22.0 ‰ (Table 2).

The largest permanent pond on the west side of the estuary is the dogleg slough. During flooding tides, the sea water enters a channel leading from the dyke to this slough and, when the tide recedes, some of the salt water remains behind. Data recorded in this slough with the YSI S. C. T. meter showed this area to be usually well mixed. Almost equal concentrations of salt water were recorded from surface to bottom, ranging between 12.5 ‰ and 19.0 ‰. No stratification of this slough was observed.

On several trips, a distinct fresh water layer, less than 0.5 metre thick, was detected at sites 6 and 9. These sites are located directly adjacent to the river channel at the mouth of the estuary.

Temperatures varied at the sites sampled from 14 °C in early June to 26.5 °C in mid July, both the maximum and minimum occurring at site 7 in the landward end of the salt slough on the east side of the estuary. At low tide at both sites in the salt slough dead flatfish and sculpins were found on several trips, possibly due to the high temperatures and suspected low levels of oxygen.

Tide heights at the time of sampling ranged from 1.00 to 4.77 metres above chart datum.

2. Fish surveys

Sixty-four samples of the fish community were taken on a rising tide, twenty-eight on a falling tide and seven on a slack tide (Table 2).

Fifteen species of fish were found throughout the study area (Table 3) and a total of 5270 fish were caught in the 99 sets completed. Small numbers of juvenile chinook, coho and chum were found to be rearing in the estuarine waters. The remainder of the community consisted of staghorn sculpins (Leptocottus armatus), prickly sculpins (Cottus asper), tidepool sculpins (Oligocottus maculosus), sharpnose sculpins (Clinocottus acuticeps), saddleback gunnels (Pholis ornata), arrow gobies (Clevelandia ios), shiner perch (Cymatogaster aggregata), high cockscomb pricklebacks (Anoplarchus purpurescens), threespine sticklebacks

(Gasterosteus aculeatus) tubesnouts (Aulorhynchus flavidus), bay pipefish (Syngnathus griseolineatus) and starry flounders (Platichthys stellatus).

The highest mean total catch by set and date was 528.5 at site 1 on July 12 (Table 4, Fig. 4b). A single set at this site on May 4 caught 298 fish (262 chum, 35 sculpins and one threespine stickleback)(Table 4, Fig. 4a). For all samples combined from each site for the whole season, the highest mean total catch was 171.67 ± 71.88 at site 1 (Fig. 5a). For all samples combined by site, the second highest mean total catch was also in the dogleg slough, 79.82 ± 29.32 at site 3 (Fig. 5a). Both these sites were dominated by threespine stickleback.

At 12 sites, 558 juvenile salmon were captured (150 chinook, 393 chum and 15 coho). Chum were caught in the highest numbers in early to mid May in the dogleg slough and were no longer present in the catches by the first week of June. Chinook were also found in this slough and this was the area where they were captured in the highest numbers. Low numbers of chinook were consistently caught at site 6 at the mouth of the estuary, seeming to indicate migration of these fish in and out with the tide. By the end of the study in the last week of July, most of the chinook seemed to have left the area (Fig. 6). Coho fry were caught in low numbers at sites 1, 4 and 18 only.

On July 13, a survey was done of five of the shallow ponds throughout the estuary. These were sites 12, 13, 14, 15 and 16 (Fig. 1). These pools varied in size and were less than one metre deep at the time of sampling. Juvenile chinook were only found in a shallow pool at site 12 on the west side of the estuary in front of the dyke, where they appeared to have been trapped as the tide receded. This was the only area in the estuary, other than the dogleg slough, where groups of juvenile salmon were found on a low tide.

Samples of the juvenile salmon captured were collected starting with the June 8 trip. Lengths and weights for sixty-nine juvenile salmon preserved and returned to the lab are given in Table 5. Two chum juveniles, captured at site 3 on June 8, were 55 and 56 mm in length and weighed 2.0 and 2.1 grams respectively. The sixty-seven chinook juveniles varied in length from 43.5 to 92.0 mm with a mean of 68.2 ± 8.8 mm. They weighed between 1.2 and 8.6 grams with a mean of 3.79 ± 1.46 grams.

Analysis of the scale samples collected from all the juvenile salmon showed three chinook juveniles with release checks similar to those formed when enhanced juveniles are released into the wild. These fish were captured on June 28 at site 1 in the dogleg slough (87 mm, 7.3 g), June 29 at site 8 in the salt slough (69.5 mm, 3.7 g) and July 12 at site 10 on the marine foreshore (79 mm, 4.4 g). Prominent checks were also noted on one fish captured at site 6 on July 12 (72.5 mm, 4.1 g), two fish from site 12 on July 13 (59.5 mm, 2.9 g; 73.5 mm, 4.7 g), one fish from site 18 on July 22 (85.5 mm, 7.3 g) and one fish from site 6 on July 30 (80 mm, 5.6 g).

Threespine stickleback were the most numerous of all the fish species, occurring in most areas of the estuary. A total of 2383 were caught at fifteen sites, the highest densities occurring in the dogleg slough, where the presence of numerous young was noted on several trips (Fig. 5a-5d).

The four species of sculpins captured during the study were dominant in many areas of the estuary throughout the study period. Overall, there were a total of 1501 sculpins caught from all the sites sampled except site 4. Identification of these fish was carried out beginning with the June 8 sampling period. Staghorn sculpins were found the most often, populating ten of the sites. Prickly sculpins were captured in small numbers at five sites where the salinities varied from 6.5 ‰ to 19‰. Tidepool sculpins were captured at sites 3, 6 and 10 and sharpnose sculpins occurred only once at site 9 (Fig. 5a-5d).

Shiner perch were found at fourteen sites in the estuary and at site 10 on the outer foreshore of the spit (Fig. 5a-5d). The largest catch of this species was on July 12 at station 1 when 120 fish were captured. Altogether, 660 perch were caught in all the sets combined.

3. Contents of chinook stomachs

a) Lengths and weights of juvenile chinook analyzed for diet

Mean lengths and weights by site and for all sites combined of the sixty-two juvenile chinook analyzed for stomach contents are listed in Table 6 and graphed in Figures 7a and 7b. The overall mean length was 68.2 ± 1.1 mm and the overall mean weight was 3.8 ± 0.2 g.

b) Forage ratios

Data was available to calculate forage ratios ((stomach content weight/fish weight)x 100) for all but one fish from site 17. This ratio varied from 0.17 at site 6 to 3.74 at site 1, both on the June 28 sampling trip (Table 5).

The mean forage ratios ± 1SE by site varied from 0.46 at site 8 (where only one fish was analyzed) to 1.91 ± 0.56 at site 1 and the overall mean forage ratio ± 1SE for all sixty-one fish at all nine sites combined was 1.39 ± 0.09 (Table 6, Fig. 7c). At stations 1 and 3 combined, the mean forage ratio of sixteen stomachs was 1.56 ± 0.20. At site 6, the mean for twenty-four stomachs was 1.29 ± 0.12 and at site 12, where the stomach contents of fifteen chinook were analyzed, the mean forage ratio was 1.24 ± 0.22.

c) Prey consumed - IRI values

Prey identified in the juvenile chinook stomachs were combined into ten categories and the Index of Relative Importance (IRI) was calculated for each prey category (Table 7). The analysis of the diets of the sixty-two juvenile chinook from ten sites combined showed that for the estuary as a whole, insects from all life stages were the main food source in most areas (Table 8). Adult diptera were the mainstay of the diet (IRI=4137.5) followed by amphipoda (IRI=1620.9). Other adult insects combined (including Hemiptera, Homoptera and Hymenoptera) came third in importance with an IRI of 1428.0 (Fig. 8a).

Site 6, where the diet of twenty-five juvenile chinook was analyzed, was the only area where the chinook fed primarily on amphipoda (IRI=4153.1), followed by adult diptera (IRI=2185.6) and other adult insects combined (IRI=1323.1). Adult diptera (IRI=7950.8) were the primary diet items for the fifteen chinook juveniles from site 12. This was the only site where fish larvae were also an important dietary component (IRI=2228.9). In the dogleg slough (sites 1 and 3 combined), fifteen fish fed on diptera adults which were the main food item (IRI=5000.7), followed by other adult insects (IRI=1455.5) (Table 9, Fig. 8b).

d) Prey consumed - Numeric values

For the estuary overall, combining the results of the diet analysis for all fish from all sites combined showed that diptera adults occurred in 59.7% of the fish analyzed and numerically made up 34.5% of the diet (Table 10, Fig. 9a). They comprised close to 35% of the total food volume. Other adult insects had a frequency of occurrence of 46.8% and comprised 16% of the total numbers of prey. Their total volume was 14.6% of the diet.

Tables 11 to 13 list the numeric values for each prey item for sites 1 and 3 combined, site 6 and site 12 (Fig. 9b-9d). The same pattern was evident at the two sites in the dogleg slough combined and site 12. Adult diptera dominated the diet, occurring in 62.5% of the fish at sites 1 and 3 combined and 80% of the fish at site 12. Other adult insects were next in importance and were found in 50% of the fish at sites 1 and 3 combined and 60% of the salmon captured at site 12. Diptera adults numerically comprised between 36.7% (sites 1 + 3) and 50% (site 12) of the food organisms found at these two sites and ranged in volume from 49.4% at site 12 to 43.3% at sites 1 and 3. At site 6 amphipods dominated the diet. They were found in 62.5% of the fish and made up 30.5% of the total food organisms consumed at this site. Their total volume was 35.9% of the diet.

4. **Invertebrate densities**

In the sixty-six epibenthic sled samples analyzed, thirty-seven different groups of organisms were found. The more dominant groups included harpacticoid, calanoid and cyclopoid copepods, barnacle nauplii, ostracods, polychaetes, nematodes and copepod nauplii (Table 14).

Table 15 lists the mean numbers m^{-2} ± 1SE of the dominant epibenthic organisms captured in the sled tows, by site and sampling trip (Fig. 10a-10f). The highest densities recorded were for polychaetes, 12305.2 ± 5298.9 m^{-2}, on June 28 and 8184.7 ± 2893.8 m^{-2} on July 12, both at site 9. Harpacticoid copepods occurred in the second highest densities, reaching 5359.0 m^{-2}, also at site 9, on June 11. Copepod nauplii ranked third in abundance with counts of 5315.3 ± 1360.0 m^{-2}, at site 9 on July 12. The total densities of all epibenthic organisms combined by site varied from 1258.0 ± 594.4 m^{-2} at site 8 on July 13 to 20652.7± 6782.5 m^{-2} at site 9 on June 28.

Analysis of the mean densities m^{-2} at each site for all trips combined showed that harpacticoid copepods were dominant in the epibenthic community of the salt slough, ranging in density from 1370.0 ± 424.9 m^{-2} at site 8 (61.8 % of the total count) to 1038.8 ± 202.5 m^{-2} (40.7 %) at site 7 (Table 16, Fig. 11a-11d). They were also dominant at site 6 with a density of 818.7 ± 204.4 m^{-2} which was 31.7% of the total count at this site. Copepod nauplii dominated the epibenthos at site 4 (1149.0 ± 693.7 m^{-2}, 28.9%) and at site 9 polychaetes were collected in the highest numbers of any site (6250.8 ± 2317.9 m^{-2}) and made up 49.2% of the total count. Calanoids, calanoid juveniles and cyclopoids combined were the dominant group at site 3 (760.5 ± 126.2 m^{-2}, 28.7% of the total count).

For the estuary overall, polychaetes occurred in the highest mean densities (1255.4 ± 431.4 m^{-2}, 29.0% of the total count) followed by harpacticoids (1004.5 ± 153.6 m^{-2}, 23.2% of the total count) and copepod nauplii (843.3 ± 186.9 m^{-2}, 19.5% of the total count) (Table 16, Fig. 11c). The highest mean densities of all organisms combined occurred at site 9 (12713.6 ± 3034.4 m^{-2}) (Fig. 11d) followed by site 4 (3981.0 ± 1478.2 m^{-2}) (Fig. 11a). The overall mean density for the epibenthic community in the estuary was 4328.5 ± 695.3 m^{-2} (Fig. 11c).

DISCUSSION

Previous research carried out on the Pacific coast has shown that estuaries serve as vital rearing areas for juvenile salmon, especially chum and chinook, during their seaward migration (Sibert, 1979; Macdonald et al., 1987). Studies on the Nanaimo River estuary by Healey (1979, 1980) were among the first to report the use of estuaries by juvenile chum and chinook salmon as important rearing areas. The shallow shoreline habitats appear to be the most important areas for these young fish during their stay in the estuarine environment (Levings, 1994). As sampling of the populations of juvenile salmonids on the Englishman River estuary in 1993 found mostly juvenile chum and chinook present in the area, we will focus on these two species in our comparisons with previous studies.

Research similar to that on the Englishman River estuary in 1993 has been reported from the Nanaimo River and Campbell River estuaries, both on the east coast of Vancouver Island. Although each of these river systems is unique in structure, size of watershed and the numbers of adult salmon returning each year, they share in common their importance as rearing areas for juvenile chum and chinook. Our understanding of the requirements of juvenile chum and chinook salmon for successful rearing and migration to sea should be improved by identifying the similarities in the patterns of use of these estuaries.

Comparisons of size and hydrology

The Englishman River estuary, area 60 hectares, is the smallest of the three estuaries, compared to 72 hectares for the Campbell River estuary and 900 hectares for the Nanaimo River estuary. The watershed area for the Campbell River is the largest, draining 1461 km^2 followed by the Nanaimo River watershed at 894 km^2. The Englishman River watershed is the smallest at only 324 km^2. The largest mean annual flow is 108 m^3s^{-1} in the Campbell River (Bell and Thompson, 1977), followed by 40 m^3s^{-1} in the Nanaimo River (Bell and Kallman, 1976) and 14 m^3s^{-1} in the Englishman River system (Boom and Bryden, 1994).

Comparisons of physical data

The large freshwater flow in the Campbell River often dominates much of the estuarine habitat, especially in the low tide refuges. As a result of these higher flows, the lowest salinity range of all three estuaries of 0 - 9.9‰ was recorded here in 1983 and 1984 during a study similar to that carried out on the Englishman River estuary in 1993 (Kask et al., 1988 a, b). Lower river discharges in the other two systems may have contributed to the higher salinities recorded ranging from 2.0 - 24.6‰ in the Nanaimo River estuary (Healey, 1980) and 6.5 to 22.0‰ occurring in the Englishman River estuary in 1993.

Of the three estuaries, the Campbell River estuary was the coolest, with a maximum temperature of 20.7° C during the 1983 and 1984 studies (Kask et al., 1988 a, b). This could partly be due to the higher freshwater flows in this system, as well as interannual weather variations. The maximum temperature recorded in the Nanaimo River estuary of 26.0° C by Healey (1980) was higher than that recorded in the Campbell River estuary but close to the maximum of 26.5° C recorded in the Englishman River estuary during the sampling in 1993.

Comparisons of escapements of chum and chinook

Since 1953 the highest annual escapements of chum salmon, from 3500 to 80,000, were recorded in the Nanaimo River system, followed by the Englishman River system with runs of 250 to 15,000 fish. The lowest returns have occurred in the Campbell River and Quinsam River system, from 600 to 10,200 adults. During the same time period, the largest runs of chinook, 1500 to 13,000 fish, have been recorded from the Campbell River system. Escapement varied between 300 and 7500 chinook in the Nanaimo River system, much higher than in the Englishman River, where the numbers returning ranged between 0 and 115 fish (Serbic, pers. comm.).

Comparisons of enhancement of juvenile salmon populations

The populations of salmon in many of the river systems on the east coast of Vancouver Island have been enhanced over recent years with transplants of juvenile fish by the federal government's Salmonid Enhancement Program (SEP), which is now part of the new Habitat Enhancement Branch. Under this program, juvenile pink, chum, coho and chinook salmon and cutthroat and steelhead trout have been released into various parts of the Englishman River system since the early 1980's. In 1993 460,000 eyed chum eggs from the Big Qualicum River stock were transplanted to this river (Cook, pers. comm.). If we assume an egg to fry survival of 9% (Lill and Tautz, 1983), these eggs could have produced 41,400 juveniles. In addition, 65,030 juvenile chinook, weighing an average of 2 grams each, were confined in a side channel on the river in early spring. They were fed until the average weight approached approximately 3.6 grams. Although some of the larger juveniles were allowed to migrate downstream at will, the majority were released into the river between June 10 and June 14, 1993 (Clough, pers comm.). Slightly over 5000 of these fish were tagged with coded wire tags and fin clipped by removing the adipose fin (Cook, pers. comm.). However, none of these marked fish were recovered during the sampling on the estuary in 1993.

Since 1978, enhancement activities on the Nanaimo River have included the release of juvenile pink, chum, coho, chinook, cuttroat trout and steelhead. There is presently a small community hatchery on this system and in 1993, 511,850 juvenile chinook weighing between 5.8 and 6.0 grams average were released into this watershed (Cook, pers. comm.).

The greatest number of enhanced juvenile salmon have been released into the Campbell River and surrounding area. A hatchery on the Quinsam River releases juvenile pink, chum, coho, chinook, cutthroat trout and steelhead into this river system and the surrounding marine areas. Between April 19 and May 19, 1993, approximately 3.9 million juvenile chinook, weighing between 3.7 and 7.8 grams were released into the Campbell River system and the surrounding marine area from the Quinsam River hatchery and seapens located in Discovery Passage (Cook, pers. comm.).

Estimates of juvenile chinook populations

Using the biostandards developed by SEP (Lill and Tautz, 1983) each female chinook is capable of producing approximately 1250 fry (5,000 eggs/female x 25% egg to fry survival). In 1992, the observed escapement to the Englishman River of 40 chinook was made up of 15 jacks, 15 males and ten females (Clough, pers. comm.). These ten females could have produced a maximum of 12,500 chinook fry in 1993. Added to the enhanced juveniles, the number of young chinook in the Englishman River system in 1993 would have most likely been a maximum of 77,500 fish. This is much lower than the number of juvenile chinook historically in either the Nanaimo or Campbell River systems.

Healey (1980) estimated total fry production for chinook in the Nanaimo River in 1975 and 1976 to be between 0.18 and 1.3 million. In 1992, the escapement of chinook to this river was 793 adults (Serbic, pers. comm.). Using the SEP biostandards, the total number of fry from this run in 1993 would have been approximately 496,000, fourteen times the number from the natural chinook run in the Englishman River system in 1993. With the enhanced chinook juveniles, the total population would have been over 1.0 million.

In the Campbell and Quinsam Rivers combined total escapement of chinook in 1992 was 4994 (Serbic, pers. comm.). The fry produced in 1993 from this run should have been about 3.1 million juveniles and together with the enhanced juvenile chinook in the sytem, the total could have reached 7.0 million fry. This is substantially higher than the number in either the Englishman or Nanaimo River systems in 1993.

Estimates of juvenile chum populations

In 1992, the estimated escapement of chum to the Englishman River was 3500 fish (Serbic, pers. comm.). If we assume 50% females and apply a fecundity of 2800 eggs/female and egg to fry survival of 9%, these fish could have produced 441,000 chum fry in early 1993. With the addition of the enhanced juveniles from the eyed egg transplant, the total number of chum in the Englishman River was approximately 482,000 fry. This is much lower than the number of young chum produced in either the Nanaimo River or Campbell River systems.

Healey (1979) estimated total chum fry populations in the Nanaimo River system at 52.4 million in 1975 and 29.6 million in 1976. Using the SEP biostandards, the escapement of 85,000 chum to this river in 1992 (Serbic, pers. comm.) could have produced 10.7 million juveniles in 1993. The addition of the fry from the hatchery would have increased the total production to approximately 11.7 million juveniles.

In the Campbell River system in 1992, the total escapement of chum to the Quinsam and Campbell Rivers combined was 10,200 (Cook, pers. comm.). The resulting fry from these fish should have been approximately 1.3 million.

Juvenile chinook and chum distribution within estuarine habitats

The distribution of juvenile chum and chinook salmon within the Englishman River estuary at low tide during 1993 was similar to that documented earlier by Tutty et al. (1983) and observed by other researchers in the Campbell River and Nanaimo River estuaries. In his studies Healey (1979, 1980) documented the movement of groups of juvenile chum and chinook from the landward edge of the Nanaimo River delta at high tide to several low tide refuges and from this he implied that the fish were actively seeking certain habitats. In the Campbell River estuary Macdonald et al. (1987) observed wild chinook in large numbers along the shallow margins of the river when the tide was low and in the mouth of a large slough at other times and tidal heights. Similarly, Levings et al. (1986) observed chinook and chum juveniles in the shallow island habitats of the Campbell River estuary.

During the 1993 study in the Englishman River estuary, juvenile chinook were found in most areas of the estuary in small numbers but 92 of the 150 juvenile chinook captured (61.3%) were found at the two seining sites in the "dogleg" slough and 369 of the total 393 juvenile chum (93.9%) were also captured at the two sites in this slough. As in the Nanaimo River estuary and Campbell River estuary studies, protected low tide refuges, when present, are used extensively by these juvenile fish. The occurrence of small groups of chinook at the two sites close to the mouth of the river may indicate migration of these fish on and off the estuary with the tidal flows. It may also indicate the immigration to this estuary of juveniles from other river systems along the coast.

Residence of juvenile chinook in the estuaries

Healey (1980) captured chinook juveniles, many of them fry, on the Nanaimo River estuary as early as March. He concluded that a high proportion of Nanaimo River chinook salmon left the river as newly emerged fry and that they spent 25 to 60 days on the estuary. Similarly, research carried out between 1982-1986 in the Campbell River estuary also found that the fry migrant type appeared to dominate this system and they remained within the estuary for 40 to 60 days (Levings et al., 1986).

Although in 1993 five sites in the Englishman River estuary were sampled beginning in early May, chinook juveniles weren't caught on the estuary until early June. During the first sampling trip from June 8-11 twenty-four chinook were kept for length and weight measurements. The majority of these appeared to be enhanced juveniles which had been released by fisheries staff from a side channel on the river. These young fish originated from the Big Qualicum River stock, where the juveniles have a history of remaining in fresh water for up to ninety days before migrating to sea (Clough, pers. comm.). Although very few of the 65,000 fish released into this river were captured on the estuary, the catch data seems to confirm their presence in low numbers in the estuary for up to six weeks after they were released. Based on the 1992 escapement of chinook, an estimated 12,500 wild juvenile chinook should have been present in this area, but sampling carried out during the 1993 study failed to find any chinook in the estuary prior to the release of the enhanced juveniles from the side channel.

Residence of juvenile chum in the estuaries

Juvenile chum were already present in the Englishman River estuary when sampling began in early March 1993 and were still in the estuary until the first week of June 1993, which could indicate the use of the estuary as a rearing area by various groups of these young fish over a period of 95 days. Tutty et al. (1983) suggested a possible rearing time for individual juvenile chum salmon on this estuary of between 20 and 40 days during their 1979 study. The pattern documented by Healey (1979) in his Nanaimo River study showed that individual chum remained within the estuary for a shorter time of between 1.8 and 18.5 days in 1975 and 0 to 9.3 days in 1976. As in the Englishman River estuary, chum fry were present in the Nanaimo River estuary from March to late June. Studies carried out in the Campbell River estuary in the 1980's found chum fry present at the estuarine sampling sites from May 5 - 15 for most years (Levings et al., 1991).

Comparison of size and growth rates of juvenile salmon

In his three year study on the Nanaimo River estuary from 1975-1977 Healey (1980) reported the presence of juvenile chinook ranging in length from approximately 44 mm and 0.94 g weight to 70 mm and 4.2 g weight . He concluded that 70 mm fork length is the size at which these fish are ready to migrate to sea. From data from fin clipped and recaptured fish, he calculated a growth rate of 1.32 mm/day and 5.8% of body weight/day. This is a much higher growth rate than reported by Levings et al. (1986) for the Campbell River estuary. They found that wild chinook first entering the estuary in 1982 were 39 - 41 mm in length and weighed 0.6 - 0.7 g. Their departure weight was 7.0 g and they grew at 2.1 - 2.7%/day.

Juvenile chinook captured in the Englishman River estuary in early June were 43.5 - 78.0 mm in length with a mean length ± 1SE of 65.2 ± 1.8 mm (N=24). Their weights ranged from 1.2 -5.8 g with a mean of 3.6 ± 0.3 g. Only one of these, captured at site 9, was fry sized (43.5 mm). The majority of the juvenile chinook caught at site 1 and 3 in the "dogleg slough" during this trip ranged in length from 68 to 78 mm. These fish at arrival on the estuary were much larger than the juvenile chinook found entering either the Nanaimo River or Campbell River estuaries to rear and were likely mostly enhanced juveniles released into the system in early June. Some of these larger fish were captured either at high tide or at sites close to the mouth of the estuary, indicating possible movement on and off the estuary with the tidal flow or immigration into the estuary from other areas. By the end of July, when sampling was terminated, these fish had reached lengths of 74.0 to 92.0 mm (mean ± 1SE of 81.6 ± 3.8 mm) and weighed between 4.5 and 8.6 g with a mean of 6.2 ± 0.9 g (N=4). This gives the lowest growth rate of all three estuaries of 0.5%/day in length and 1.48%/day in weight and this is also lower than the growth rate reported for chum by Tutty et al., 1983. In their 1979 study on the Englishman River estuary they found the mean size of juvenile chum entering the estuary was 0.35 g. They estimated a growth rate of 6% to 13% per day for these young fish while they remained within the estuary. In 1993 lengths and weights for only two chum were recorded, giving insufficient data to calculate their possible growth rates.

Chinook diets - comparison with other estuaries

In the Nanaimo River estuary in 1976-77 Healey (1980) described a diet for juvenile chinook salmon consisting of five taxonomic groups which changed in importance as the fish grew over the spring. They progressed from feeding on harpacticoid copepods in early spring to decapod larvae, amphipods, mysids and insect larvae in early summer. This would appear to represent a mix of organisms from freshwater, estuarine and marine sources, although no species identifications were given.

Analysis of the diet of juvenile chinook in the Englishman River estuary showed that insects, mainly diptera adults but also including other adult insects and larvae, made up most of the diet. The numerical percent, by site, of all insects combined in the stomachs of the young chinook ranged from 43.3% to 70.6%. For the estuary as a whole, the mean numerical percent of all insects was 51.4% of the organisms in the stomachs.

In the Campbell River estuary, from 1982 to 1984, insects were less important in the diet, values ranging from <1.0% to 47.8% of the diet for the wild chinook with an overall mean value of 15.3%. Freshwater cladocerans (34.1%) and copepods (27.2%) combined made up the most significant portion of their diet (Kask et al. 1986, 1988 a, b)(Table 17). Consumption of food from freshwater, estuarine and marine origin in this estuary was also documented by Macdonald et al. (1987).

Chinook diets - comparison with previous studies in the Englishman River estuary

The diet of the juvenile chinook captured in 1993 was much different than that described by Tutty et al. (1983) for nineteen chinook captured in the estuary in 1979. These stomachs were all grouped together for analysis and the results showed that the mysid, Neomysis mercedis, was the dominant item in the diet of these fish, followed by Diptera pupae and harpacticoid copepods. It was not specified whether these fish were captured inside or outside of the slough area, but presumably may have been collected in both regions of the estuary.

In 1993 only one mysid was found in a chinook from one site in the salt slough on the east side of the estuary. The diet of the juvenile chinook salmon in 1993 both inside and outside of the slough area appears to have been the reverse of the pattern observed by Tutty et al. (1983) for chum salmon in 1979. They found that the diet of chum juveniles from outside the slough was dominated by all life stages of insects, while those collected from inside the slough had consumed more harpacticoids and amphipods. In 1993, insects comprised the majority of the diet inside the slough, and amphipods were most important outside the slough. In 1979, harpacticoids were an important diet item in the young chum and chinook from sites both inside and outside the estuary. In 1993, only five harpacticoid copepods were found in all the fish analyzed.

Chinook diets - comparison of forage ratios with other estuaries

The mean forage ratio for all the juvenile chinook analyzed from the Englishman River estuary was 1.39 ± 0.09 (N=61)(Table 6, Fig. 7c). This is higher than the mean forage ratio of 1.32 ± 0.95 (N=67) for wild chinook from all habitats combined in the Campbell River estuary in 1994 (Bravender, unpub.).

Macdonald et al. (1988) reported forage ratios for newly released hatchery chinook of 0.5 - 1.0, increasing to 2.0 - 3.5 several months later. These ratios were for chinook juveniles captured outside the estuary as well as inside and this may partially explain the higher values.

Epibenthic invertebrates - comparison with other estuaries

The epibenthic community in the Englishman River estuary in 1993 was dominated by harpacticoid and calanoid copepods, organisms which are known to be important as a food source for young salmon in other estuaries e.g the Campbell River (Kask et al., 1986, 1988 a, b; Macdonald et al., 1987). Few adult or larval insects were found in these samples, although they dominated the diet of the juvenile chinook at many sites. Amphipods, also important in the diet of the chinook were found at all the sites where the epibenthic sled samples were collected.

In their 1979 study, Tutty et al. (1983) towed a 30 cm wide epibenthic sled fitted with a 500 μ net for 10 metres. The samples were put through a sieve with mesh size of 500 μ. Although they used a much coarser net, they found very high densities m^{-2} of many of the epibenthic invertebrates both inside and outside the slough area from late March to mid May. In particular, the densities of some groups important as fish food, including harpacticoids, amphipods and tanaidacea greatly exceeded those recorded in the estuary in 1993.

The epibenthos was sampled in the same way in the Campbell River estuary in 1982-1984 as in the present study, and comparisons of the total mean densities over all sites in the two estuaries showed that the total mean density in the Englishman River estuary of 2891.9 $\pm$ 452.9 m^{-2} was almost four times higher than the total mean density in the Campbell River estuary of 758.6 $\pm$ 126.4 m^{-2} when it was last sampled in 1984 (Table 18). This may partly be due to the large freshwater influence in the Campbell River estuary (Levings and Macdonald, 1991; Kask et al., 1988 a, b), the impact of the construction of four new islands in 1982 (Brownlee et al., 1984) and the extensive modification of the estuary banks (Levings et al., 1989; Levings and Macdonald, 1991).

Future possibilities

Results from research on the Campbell River estuary support the hypothesis that an extended period of rearing in an estuarine environment is advantageous to juvenile chinook salmon and that the fish seem to exhibit a strong binding to the estuarine habitat (Macdonald et al., 1988). Although the Englishman River, Campbell River and Nanaimo River estuaries differ in size, freshwater flow and populations of adult and juvenile salmon, evidence collected from them in various studies points to a common preference by the juvenile salmonids within them for shallow, nearshore environments including low tide refuges within the estuary to successfully prepare for their migration to sea. The period of residency for these young fish also appears to be similar for the three estuaries (Healey, 1979, 1980; Levings et al., 1986).

Compared to other systems such as the Campbell River, the Englishman River historically has not produced large numbers of salmonid juveniles in the past. The presence of falls or rapids within the system restricts access by spawning fish to the lower reaches of the river (Hamilton and Kosakoski, 1982). The sampling in

1993 also showed that there is much less suitable rearing habitat in the estuary at low tide when compared with the more extensive low tide habitats available in the Nanaimo River or Campbell River estuaries. However, it is probable that the recent breaching of the dyke in 1994 will have increased the size of the slough on the western side of the estuary and the rearing area available for the juvenile salmonids as occurred after the 1979 breaching (Tutty et al., 1983). In particular, this modification in the dyke, allowing tidal flow in to the area of marsh grasses, should increase the access of the young fish to the insects which form the main part of their diet in this estuary. The Englishman River estuary also compares favourably with the others in terms of the epibenthic food available to the rearing fish.

The importance of complex estuarine habitats offering a variety of microhabitats for rearing juvenile salmonids has been pointed out by Macdonald et al. (1987). Habitats which offer varying temperature regimes, currents and salinities, slough regions, back eddies and stream side cover supply the young fish with areas in which to feed, rest and adjust to increasing salinity during their seaward migration. Enhancement of the habitats available in the Englishman River estuary for the rearing fish by increasing the estuarine flow over the western marsh and adding channels in this area have been suggested in the Management Plan recently adopted by B. C. Environment (Clermont, 1995). Given the small size of the estuary relative to the river's salmonid production and the apparent lack of sufficient low tide refuges, increasing the availability of habitat to the juvenile salmonids in the system would appear to have merit.

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REFERENCES

Annand, C., A. Hillaby and J. Naylor. 1993. Englishman River Estuary. (unpublished report prepared for Fisheries and Oceans, South Coast Division, Nanaimo, B. C.). 195 p.

Bell, L. M. and R. J. Kallman. 1976. The Nanaimo River estuary: Status of enviromental knowledge to 1976. Department of Environment, Special Estuary Series 5, Fisheries and Marine Service, West Vancouver Laboratory, West Vancouver, British Columbia. 298 p.

Bell, L. M. and J. M. Thompson. 1977. The Campbell River estuary: Status of environmental knowledge to 1977. Fisheries and Environment Canada, Special Estuary Series 7, Fisheries and Marine Service, West Vancouver Laboratory, West Vancouver, British Columbia. 346 p.

Blood, D. 1976. Lower Englishman River environmental impact study. Prepared for Environmental Services Section, Land Management Branch, B. C. Dep. Environment. 75 p.

Boom, A. and G. Bryden. 1994. Englishman River water allocation plan. 1994. B. C. Ministry of Environment, Lands and Parks, Vancouver Island Region. 27 p.

Brownlee, M. J., E. R. Mattice and C. D. Levings (compilers). 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 rehabilitation. Can. Manuscr. Rep. Fish. Aquat. Sci. 1789: 54 p.

Clermont, T. J. 1995. Parksville-Qualicum Beach wildlife management area management plan. Prepared for B. C. Environment on behalf of The Habitat Conservation Fund, Ducks Unlimited Canada, The Nature Trust of B. C., Wildlife Habitat Canada and the Canadian Wildlife Service. 61 p.

Clough, D. Pers. comm. 1996. D. Clough Consultants, Lantzville, B. C.

Cook, R. Pers. comm. 1996. Information Management Systems. Fisheries and Oceans, Habitat Enhancement Branch, Vancouver, B. C.

Dawe, N. K. and J. D. McIntosh. 1993. Vegetation change following dyke breaching on the Englishman River estuary, Vancouver Island, British Columbia. A multivariate analysis. Tech. Rep. Series 175, Can. Wild. Serv., Pacific and Yukon Region, British Columbia. 37 p.

Dawe, N. K., T. Martin and D. E. C. Trethewey. 1994. Bird use of the Englishman River estuary, Vancouver Island, British Columbia 1979-1980 and 1988-1989. Tech. Rep. Series 208, Can. Wild. Serv., Pacific and Yukon Region, British Columbia. 143 p.

Hamilton, R. E. and G. T. Kosakoski. 1982. Water requirement for the fisheries resource of the Englishman River, Vancouver Island, B. C. Can. Manuscr. Rep. Fish. Aquat. Sci: 1676. 42 p.

Hart, J. L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. 180:740 p.

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

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, Oncorhynchus tshawytscha. Fish. Bull. 77: 653-668.

Hutchinson, I. 1988. The biogeography of the coastal wetlands of the Puget Trough: deltaic form, environment, and marsh community structure. J. Biogeog. 15: 729-745.

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.

Kask, B. A., T. J. Brown and C. D. McAllister. 1988a. Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1983, in relation to juvenile chinook diets. Can. Tech. Rep. Fish. Aquat. Sci. 1616: 71 p.

Kask, B. A., T. J. Brown and C. D. McAllister. 1988b. Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1984, in relation to juvenile chinook diets. Can. Tech. Rep. Fish. Aquat. Sci. 1637: 73 p.

Kennedy, K. A. 1982. Plant communities and their standing crops on estuaries of the east coast of Vancouver Island. M. Sc. thesis, University of British Columbia. 412 p.

Le Baron, Bentley. 1976. Lower Englishman River environmental-social assessment. Prepared for Environmental Services Section, Land Management Branch. B. C. Dep. Environment. 58 p.

Levings, C. D., C. D. McAllister and B. D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 43: 1386-1397.

Levings, C. D., C. D. McAllister, J. S. Macdonald, T. J. Brown, M. S. Kotyk and B. A. Kask. 1989. Chinook salmon (Oncorhynchus tshawytscha) and estuarine habitat: a transfer experiment can help evaluate estuary dependency. Can. Spec. Publ. Fish. Aquat. Sci. 105: 116-122.

Levings, C. D. and J. S. Macdonald. 1991. Rehabilitation of estuarine fish habitat at Campbell River, British Columbia. Amer. Fish. Soc. Symp. 10: 176-190.

Levings, C. D. 1994. Feeding behaviour of juvenile salmon and significance of habitat during estuary and early sea phase. Nordic J. Freshw. Res. 69: 7-16.

Levy, D. A. and I. Yesaki. 1981. Graphical methods for fish stomach analysis. Fish Food Habits Studies. Proceedings of the third Pacific workshop. Gutshop '81. Washington Sea Grant Pub. 82-2: 16-23.

Lill, A. F. and A. Tautz. 1983. Opportunities for Salmonid Enhancement projects in British Columbia and the Yukon: a preliminary report by the Enhancement Phase II Planning Committee. Salmonid Enhancement Program. 49 p.

Macdonald, J. S., I. K. Birtwell and G. M. Kruzynski. 1987. Food and habitat utilization by juvenile salmonids in the Campbell River estuary. Can. J. Fish. Aquat. Sci. 44: 1233-1246.

Macdonald, J. S., C. D. Levings, C. D. McAllister, U. H. M. Fagerlund and J. R. McBride. 1988. A field experiment to test the importance of estuaries for chinook salmon (Oncorhynchus tshawytscha) survival: short term results. Can. J. Fish. Aquat. Sci. 45: 1366-1377.

Pinkas, L., M. S. Oliphant and I. L. K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Fish and Game Fish. Bull. 152: 105 p.

Prentice, A. C. and W. S. Boyd. 1988. Intertidal and adjacent upland habitat in estuaries located on the east coast of Vancouver Island - a pilot assessment of their historical changes. Tech. Rep. 38. Can. Wild. Serv., Pacific and Yukon Region, British Columbia. 75 p.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184: 966 p.

Serbic, G. Pers. comm. 1996. Salmon Escapement Data System. Fisheries and Oceans, Pacific Biological Station, Nanaimo, B. C.

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

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

Tera Planning Ltd. 1990. An environmental assessment of development implications at Parksville flats, B. C. Prepared for the City of Parksville. 95 p.

Tutty, B. D., B. A. Raymond and K. Conlin. 1983. Estuarine restoration and salmonid utilization of a previously dyked slough in the Englishman River estuary, Vancouver Island, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 1689: 51 p.

Table 1. Location of sites sampled for physical characteristics, fish and epibenthos.

Site No.	Description
1.	Situated at the south end of the man-made dogleg slough on the eastern shore.
2.	At the mid-point of the man-made dogleg slough on the western shore.
3.	Located at the north end of the man-made dogleg slough on the western shore.
4.	A site in a small pool west of the breach in the dyke.
5.	Northeast of the breach in the dyke.
6.	Located on the end of the spit on the west side of the estuary.
7.	In the upper reaches of the salt slough on the east side of the estuary.
8.	At the lower end of the salt slough on the east side of the estuary.
9.	Located on the east side of the estuary inside the point.
10.	Situated on the marine foreshore of the spit at the mouth of the estuary.
11.	On a sandbar at the mouth of the river.
12.	A site beside a large stump in a shallow slough east of the dyke.
13.	Located southeast of site 12 in the same shallow slough east of the dyke.
14.	Southeast of site 13 in the same shallow slough east of the dyke.
15.	Situated at the east end of a small slough branching from the nothern end of the dogleg slough.
16.	Located on the northern bank of a pool connected to the dogleg slough by a small channel.
17.	A site at the midpoint of the channel connecting the estuary and the dogleg slough.
18.	In the upper most reaches of the salt slough on the east side of the estuary.

Table 2. Summary of fish samples and physical data collected at each site. BS = beach seine, SS = stick seine, E = ebb, F = flood, SL = slack.

			Tide		Surface	
Dates	Site No.	No. Samp.	Type (E,F,SL)	Ht. (m)	Sal. (‰)	Temp. (°C)
May 4-Jul 29	1	BS-12	4E, 8F	1.00-3.67	12.5-19.0	18.0-21.0
Jun 8-Jul 29	2	-	1E, 3F	2.65-3.43	15.0-18.5	17.5-21.0
May 4-Jul 29	3	BS-11	3E, 8F	1.19-3.53	15.0-18.0	18.0-21.0
May 3-Jul 29	4	BS-6	3E, 9F	1.05-4.12	15.5-19.5	18.0-20.0
		SS-6				
May 3-May 26	5	BS-3	1E, 2F	1.46-3.59	-	-
May 3-Jul 30	6	BS-10	6E, 4F	2.57-3.56	7.5-20.0	18.0-20.0
Jun 11-Jul 30	7	BS-2	10F	3.10-4.60	7.5-19.0	14.0-26.5
		SS-8				
Jun 11-Jul 22	8	BS-1	5F, 2SL	3.19-4.66	8.0-20.5	14.5-24.5
		SS-6				
Jun 11-Jul 30	9	BS-8	6E, 2F	3.03-3.83	6.5-21.0	14.5-22.0
Jun 28-Jul 12	10	BS-4	2F, 2E	3.38-3.60	16.5-22.0	17.5-19.5
Jun 28-Jul 12	11	BS-4	2E, 2SL	3.37-3.61	16.5-20.5	20.0
Jun 29-Jul 30	12	SS-8	8F	2.12-4.22	14.5-18.5	18.5-19.5
Jul 13	13	SS-1	1F	2.62	15.0	22.0
Jul 13	14	SS-1	1F	2.72	19.0	22.0
Jul 13	15	SS-1	1F	2.89	19.0	23.0
Jul 13	16	SS-1	1F	3.33	17.0	25.0
Jul 21-Jul 29	17	BS-4	2F, 2SL	4.15-4.28	19.5-21.5	14.5-18.0
Jul 22	18	BS-2	1E, 1SL	4.76-4.77	19.5	16.0

Table 3. Species of fish captured and abbreviations used in figures 5a-d.

Abbrev.	Fish species	Common name
CHIN	Oncorhynchus tshawytscha	Juvenile chinook salmon
CHUM	Oncorhynchus keta	Juvenile chum salmon
COHO	Onchorhynchus kisutch	Juvenile coho salmon
UNSC	--	Unidentified sculpin
STSC	Leptocottus armatus	Staghorn sculpin
TISC	Oligocottus maculosus	Tidepool sculpin
SNSC	Clinocottus acuticeps	Sharpnose sculpin
PRSC	Cottus asper	Prickly sculpin
THST	Gasterosteus aculeatus	Threespine stickleback
SHPE	Cymatogaster aggregata	Shiner perch
STFL	Platichthys stellatus	Starry flounder
HCPR	Anoplarchus purpurescens	High cockscomb prickleback
SBGU	Pholis ornata	Saddleback gunnel
ARGO	Clevelandia ios	Arrow goby
TUSN	Aulorhynchus flavidus	Tubesnout
BAPI	Syngnathus griseolineatus	Bay pipefish
UNKN	--	Unidentified juvenile fish
TOTL	--	Total fish in set

Table 5. Length, weight and forage ratios of juvenile salmon.

Date	Site No.	Set No.	Time (PST)	Fish No.	Species	Fork Len. (mm)	Wgt. Fish (g)	Stom. Cont. (g)	Forage Ratio
June 8	3	BS1	1040	1	Chinook	73.5	4.8	0.061	1.27
"	"	"	"	2	Chinook	70.5	4.3	0.096	2.23
"	"	"	"	3	Chinook	69.5	4.4	0.068	1.55
"	"	"	"	4	Chinook	68.5	4.0	0.064	1.60
"	"	"	"	5	Chinook	72.5	4.8	0.077	1.60
"	"	"	"	6	Chinook	78.0	5.8	0.059	1.02
"	"	"	"	7	Chinook	74.0	5.1	0.075	1.47
"	"	"	"	8	Chinook	73.5	6.1	0.038	0.62
"	"	"	"	9	Chinook	74.0	5.2	0.090	1.73
"	"	"	"	10	Chinook	72.5	4.6	0.032	0.70
"	"	"	"	14	Chum	55.0	2.0	-	-
"	"	"	"	15	Chum	56.0	2.1	-	-
June 8	1	BS2	1150	16	Chinook	56.5	1.8	0.019	1.06
June 11	9	BS2	1145	36	Chinook	43.5	1.2	0.009	0.75
June 11	6	BS1	1315	11	Chinook	75.0	5.1	0.042	0.82
"	"	"	"	12	Chinook	57.5	2.4	-	-
"	"	BS2	1336	50	Chinook	62.0	2.9	0.023	0.79
"	"	"	"	51	Chinook	62.0	2.8	0.042	1.50
"	"	"	"	52	Chinook	58.0	2.4	0.050	2.08
"	"	"	"	53	Chinook	55.0	2.0	0.017	0.85
"	"	"	"	54	Chinook	63.0	3.3	0.036	1.09
"	"	"	"	55	Chinook	69.5	4.1	0.032	0.78
"	"	"	"	56	Chinook	52.5	1.6	0.029	1.81
"	"	"	"	57	Chinook	56.5	2.2	0.043	1.95
"	"	"	"	58	Chinook	67.5	2.8	0.039	1.39
"	"	"	"	59	Chinook	59.5	2.5	0.053	2.12
June 28	3	BS2	1126	62	Chinook	62.5	2.8	0.046	1.64
June 28	1	BS1	1245	64	Chinook	63.0	2.5	0.019	0.76
"	"	"	"	65	Chinook	70.5	3.9	0.052	1.33
"	"	BS2	1253	24	Chinook	87.0	7.3	0.273	3.74
June 28	10	BS1	1315	13	Chinook	58.0	2.3	-	-
June 28	11	BS1	1338	22	Chinook	73.5	4.2	0.088	2.10
June 28	6	BS1	1445	17	Chinook	73.5	4.5	0.028	0.62
"	"	"	"	18	Chinook	75.5	5.1	0.140	2.75
"	"	"	"	19	Chinook	60.0	2.2	0.028	1.27
"	"	"	"	20	Chinook	65.5	2.9	0.005	0.17
"	"	"	"	21	Chinook	57.5	2.2	0.029	1.32

Table 5 (cont'd). Length, weight and forage ratios of juvenile salmon.

Date	Site No.	Set No.	Time (PST)	Fish No.	Species	Fork Len. (mm)	Wgt. Fish (g)	Stom. Cont. (g)	Forage Ratio
June 29	12	SS2	1108	40	Chinook	63.0	2.9	0.046	1.59
"	"	"	"	41	Chinook	66.0	3.2	-	-
"	"	"	"	42	Chinook	63.5	2.7	-	-
"	"	"	"	43	Chinook	64.0	2.7	0.067	2.48
"	"	"	"	44	Chinook	57.0	2.1	0.009	0.43
"	"	"	"	45	Chinook	57.5	1.9	0.014	0.74
"	"	"	"	46	Chinook	68.5	3.5	0.042	1.20
"	"	"	"	47	Chinook	59.5	2.4	0.022	0.92
"	"	"	"	48	Chinook	64.5	2.8	0.022	0.79
"	"	"	"	49	Chinook	65.5	3.0	0.046	1.53
June 29	8	SS1	1232	23	Chinook	69.5	3.7	0.017	0.46
July 12	1	BS1	1146	60	Chinook	74.0	4.1	0.110	2.68
July 12	10	BS1	1303	32	Chinook	79.0	4.4	0.095	2.16
July 12	6	BS1	1430	66	Chinook	74.0	3.7	0.040	1.08
"	"	"	"	67	Chinook	73.0	3.9	0.044	1.13
"	"	"	"	68	Chinook	74.0	4.2	0.042	1.00
"	"	"	"	69	Chinook	63.5	2.6	0.031	1.19
"	"	BS2	1436	63	Chinook	72.5	4.1	0.045	1.10
July 13	12	SS2	0953	25	Chinook	67.0	3.5	0.018	0.51
"	"	"	"	26	Chinook	68.5	4.4	0.041	0.93
"	"	"	"	27	Chinook	59.5	2.9	0.099	3.41
"	"	"	"	28	Chinook	65.0	3.5	0.040	1.14
"	"	"	"	29	Chinook	66.0	3.8	0.044	1.16
"	"	"	"	30	Chinook	73.5	4.7	0.087	1.85
"	"	"	"	31	Chinook	61.5	2.6	0	0
July 22	18	BS1	2005	37	Chinook	85.5	7.3	0.158	2.16
"	"	"	"	38	Chinook	78.5	4.1	0.101	2.46
"	"	"	"	39	Chinook	59.0	2.6	-	-
July 29	17	BS2	1616	61	Chinook	74.0	4.5	-	-
July 30	6	BS1	1327	33	Chinook	92.0	8.6	0.145	1.69
"	"	"	"	34	Chinook	80.5	5.9	0.035	0.59
"	"	"	"	35	Chinook	80.0	5.6	0.105	1.88

Table 6. Juvenile chinook salmon stomach analysis. Mean length, weight and forage ratios ± 1SE by site and for all sites combined.

Site No.	No. fish	Mean length (mm) ± 1SE	Mean weight (g) ± 1SE	Mean forage ratio ± 1SE
1	5	70.2 ± 5.2	3.9 ± 0.9	1.91 ± 0.56
3	11	71.7 ± 1.2	4.7 ± 0.3	1.40 ± 0.14
6	24	67.6 ± 2.0	3.6 ± 0.3	1.29 ± 0.12
8	1	69.5	3.7	0.46
9	1	43.5	1.2	0.75
10	1	79.0	4.4	2.16
11	1	73.5	4.2	2.10
12	15	64.0 ± 1.2	3.1 ± 0.2	1.24 ± 0.22
17	1	74.0	4.5	-
18	2	82.0	5.7	2.31
ALL	62	68.2 ± 1.1	3.8 ± 0.2	1.39 ± 0.09

Table 7. Categories of prey used in IRI analysis.

Category no.	Category name	Groups included
1.	Adult insect (Diptera)	Order Diptera
2.	Adult insect (Other)	Orders Hemiptera, Homoptera and Hymenoptera
3.	Insect larvae	
4.	Amphipoda	
5.	Decapod	
6.	Mysidacea	
7.	Copepoda	
8.	Fish larvae	
9.	Isopoda	
10.	Other	Araneida, Cirripedia, Acarina, Pycnogonida, vegetation.

Table 8. IRI diet analysis for juvenile chinook for all sites combined and abbreviations used in figures 8a,b and 9a-d.

Prey categories	**IRI Value**
Diptera adult (DA)	4137.5
Amphipoda (AM)	1620.9
Other adult insects (AI)	1428.0
Decapoda (DE)	150.6
Other (OT)	114.7
Fish larvae (FL)	73.3
Copepoda (CO)	46.8
Insect larvae (IL)	15.5
Mysidacea (MY)	2.8
Isopoda (IS)	0.3

Table 9. IRI diet analysis for juvenile chinook by site.

	Site		
Prey Categories	**1 + 3**	**6**	**12**
Diptera adult (DA)	5000.7	2185.6	7950.8
Other adult insects (AI)	1455.5	1323.1	2206.9
Insect larvae (IL)	0	66.3	10.0
Amphipoda (AM)	337.4	4153.1	1253.4
Decapoda (DE)	19.3	490.6	0
Copepoda (CO)	309.9	6.7	10.0
Fish larvae (FL)	0	0	2228.9
Isopoda (IS)	0	0	4.5
Other (OT)	283.8	83.7	3.9

Table 10. Numeric values for each prey item for all sites combined within the estuary.

Prey Categories	**Freq. Occur. (%)**	**Numerical Percent**	**% Volume**
Diptera adult (DA)	59.7	34.5	34.8
Other insect adult (AI)	46.8	16.0	14.6
Insect larvae (IL)	8.1	0.9	1.0
Amphipoda (AM)	43.6	17.5	19.7
Decapoda (DE)	12.9	6.2	5.4
Mysidacea (MY)	1.6	0.8	0.9
Copepoda (CO)	9.7	2.9	2.0
Fish lar. (FL)	8.1	3.8	5.3
Isopoda (IS)	1.6	0.1	<0.1
Other (OT)	19.4	4.2	1.7

Table 11. Numeric values for each prey item for sites 1 and 3 combined.

Prey Categories	Freq. Occur. (%)	Numerical Percent	% Volume
Diptera adult (DA)	62.5	36.7	43.3
Other insect adult (AI)	50.0	14.5	14.7
Insect larvae (IL)	0	0	0
Amphipoda (AM)	20.0	8.0	8.9
Decapoda (DE)	6.7	2.2	0.7
Mysidacea (MY)	0	0	0
Copepoda (CO)	20.0	8.4	7.1
Fish larvae (FL)	0	0	0
Isopoda (IS)	0	0	0
Other (OT)	33.3	6.5	2.1

Table 12. Numeric values for each prey item for site 6.

Prey Categories	Freq. Occur. (%)	Numerical Percent	% Volume
Diptera adult (DA)	45.8	24.9	22.8
Other insect adult (AI)	41.7	16.5	15.2
Insect larvae (IL)	16.7	1.9	2.1
Amphipoda (AM)	62.5	30.5	35.9
Decapoda (DE)	20.8	13.7	9.9
Mysidacea (MY)	0	0	0
Copepoda (CO)	4.2	1.4	0.2
Fish larvae (FL)	0	0	0
Isopoda (IS)	0	0	0
Other (OT)	12.5	4.9	1.8

Table 13. Numeric values for each prey item for site 12.

Prey Categories	Freq. Occur. (%)	Numerical Percent	% Volume
Diptera adult (DA)	80.0	50.0	49.4
Other insect adult (AI)	60.0	19.9	16.9
Insect larvae (IL)	6.7	0.7	0.8
Amphipoda (AM)	46.7	13.1	13.8
Decapoda (DE)	0	0	0
Mysidacea (MY)	0	0	0
Copepoda (CO)	6.7	0.8	0.7
Fish larvae (FL)	13.3	7.5	9.7
Isopoda (IS)	6.7	0.5	0.2
Other (OT)	6.7	0.3	0.3

Table 14. Epibenthic organisms captured and abbreviations used in figures 11a-d.

Abbrev.	Epibenthos
AMPH	Amphipods
BCYP	Barnacle cypris
BIVA	Bivalves
BNAU	Barnacle nauplii
CALA	Calanoid copepods
CHIL	Chironomid larvae
CAJU	Calanoid copepod juveniles (copepodites)
CLAD	Cladocerans
CNAU	Copepod nauplii (calanoid, cyclopoid, harpacticoid)
COTT	Cottid fish
CRME	Crab megalops
CUMA	Cumaceans
CYCL	Cyclopoid copepods
DECA	Decapods
ECTO	Ectoprocts
EGGS	Unidentified eggs
EGSA	Egg sac
FIEG	Fish eggs
FILA	Fish larvae
GAEG	Gastropod egg cases
GAST	Gastropods
HARP	Harpacticoid copepods
INSE	Insects
INSL	Insect larvae
ISOP	Isopods
LARV	Larvacea
MEDU	Medusae
MITE	Mites
MYSI	Mysids
NEMA	Nematodes
OSTR	Ostracods
POLY	Polychaetes
ROTI	Rotifers
TANA	Tanadaceans
TARD	Tardigrades
TUNI	Tunicates
WORM	Unidentified worms

Table 15. Mean densities m^{-2} ± 1SE of dominant and total epibenthic organisms by site and sampling trip.

Trip	Site No.	Harpacticoids	Calanoids	Copepod Nauplii
June 8-11	3	1675.3±1137.1	276.7± 170.4	121.3± 102.4
"	4	2901.3± 852.2	182.0± 60.2	488.0± 146.7
"	7	1740.7± 662.9	264.0± 73.8	705.3± 231.8
"	8	1939.3±1118.8	87.3± 35.8	280.0± 139.7
"	9	5359.0	71.0	876.0
"	6	1610.7± 256.4	2.7± 1.3	110.0± 45.6
June 28-29	3	312.7± 111.6	620.0± 179.0	414.7± 119.6
"	4	352.0± 182.6	619.3± 411.8	114.0± 31.7
"	7	841.3± 257.0	36.7± 4.4	158.7± 40.4
"	8	1474.0± 562.1	244.0± 64.2	570.0± 79.8
"	9	78.0± 11.0	1884.7± 312.3	1478.7± 198.9
"	6	82.0	378.0	207.0
July 12-13	3	222.7± 153.4	1104.0± 158.9	253.3± 14.7
"	4	311.3± 180.7	670.7± 276.3	489.3± 105.1
"	7	639.3± 131.7	71.3± 17.9	359.3± 186.5
"	8	696.7± 452.0	102.0± 67.1	292.0± 86.0
"	9	402.0± 146.5	708.0± 109.8	5315.3±1360.0
"	6	423.3± 118.5	476.0± 151.9	1204.7± 83.0
July 29-30	3	288.0± 136.1	1021.3± 180.3	663.3± 51.5
"	4	132.7± 39.7	1994.0±1391.0	3504.7±2608.8
"	7	934.0± 168.7	81.3± 21.5	455.3± 101.4
"	9	876.0	910.0	314.0
"	6	913.3± 330.3	257.3± 122.8	644.0± 51.0

Trip	Site No.	Nematodes	Polychaetes	Total
June 8-11	3	101.3± 73.9	134.0± 59.5	2595.3±1605.3
"	4	102.7± 49.8	306.7± 22.8	4111.3±1078.8
"	7	653.3± 517.3	562.0± 365.1	4541.3±1925.5
"	8	97.3± 62.7	373.3± 244.5	2979.3±1710.5
"	9	24.0	251.0	6790.0
"	6	596.0± 171.4	98.7± 19.9	2824.7± 451.7
June 28-29	3	64.7± 23.8	924.7± 457.8	2456.0± 790.4
"	4	8.7± 1.3	147.3± 22.7	1319.3± 661.3
"	7	81.3± 23.2	86.7± 31.5	1561.3± 366.1
"	8	25.3± 9.3	61.3± 20.2	2417.3± 603.5
"	9	39.3± 5.5	12305.2±5298.9	20652.7±6782.5
"	6	24.0	170.0	1482.0
July 12-13	3	388.0± 300.3	209.3± 99.3	2513.3± 868.7
"	4	26.7± 14.0	466.7± 163.3	2104.7± 549.9
"	7	22.7± 9.8	199.3± 105.5	1376.7± 398.5

Table 15 (cont'd). Mean densities m^{-2} ± 1SE of dominant and total epibenthic organisms by site and sampling trip.

Trip	Site No.	Nematodes	Polychaetes	Total
July 12-13	8	36.0± 6.9	78.0± 34.1	1258.0± 594.4
"	9	27.3± 13.9	8184.7±2893.8	14724.0±4450.6
"	6	70.7± 18.6	384.7± 327.2	2726.0± 359.2
July 29-30	3	633.3± 202.7	122.7± 38.7	3024.0± 592.5
"	4	324.0± 81.0	1574.0±1262.3	8388.7±5580.6
"	7	447.3± 186.3	652.0± 168.5	2734.0± 471.0
"	9	37.0	268.0	3713.0
"	6	430.0± 187.3	288.7± 90.3	2931.3± 813.4

Table 16. Mean densities m^{-2} ± 1SE and percent of total population of dominant epibenthos at six stations and all stations combined.

Site	**3**		**4**	
# samples	12		12	
	Mean ± 1SE	**%**	**Mean ± 1SE**	**%**
Taxa				
Harpact.	624.7 ± 307.9	23.6	924.3 ± 393.9	23.2
Cope. naup.	363.2 ± 70.5	13.7	1149.0 ± 693.7	28.9
Barn. naup.	8.5 ± 4.3	0.3	91.7 ± 33.2	2.3
Amphipods	31.7 ± 17.3	1.2	7.0 ± 3.8	0.2
Cal. + Cycl.	760.5 ± 126.2	28.7	866.5 ± 375.6	21.8
Nematodes	296.8 ± 105.3	11.2	115.5 ± 43.0	2.9
Polychaetes	347.7 ± 142.8	13.1	623.7 ± 319.7	15.7
Ostracods	139.2 ± 40.7	5.3	14.2 ± 6.3	0.4
Worms	47.2 ± 11.2	1.8	6.2 ± 3.3	0.2
Total	2646.7 ± 447.6		3981.0 ± 1478.2	

Site	**7**		**8**	
# samples	12		9	
	Mean ± 1SE	**%**	**Mean ± 1SE**	**%**
Taxa				
Harpact.	1038.8 ± 202.5	40.7	1370.0 ± 424.9	61.8
Cope. naup.	419.7 ± 89.9	16.4	380.7 ± 70.8	17.2
Barn. naup.	17.2 ± 6.0	0.7	6.9 ± 2.9	0.3
Amphipods	27.5 ± 6.3	1.1	15.8 ± 5.6	0.7
Cal. + Cycl	113.3 ± 31.6	4.4	155.6 ± 40.1	7.0
Nematodes	301.2 ± 141.2	11.8	52.9 ± 21.5	2.4
Polychaetes	375.0 ± 114.1	14.7	170.9 ± 87.6	7.7
Ostracods	208.8 ± 86.8	8.2	37.1 ± 20.7	1.7
Worms	18.2 ± 4.6	0.7	5.8 ± 2.1	0.3
Total	2553.3 ± 579.9		2218.2 ± 606.5	

Table 16 (cont'd). Mean densities m^{-2} ± 1SE and percent of total population of dominant epibenthos at six stations and all stations combined.

Site	**9**		**6**	
# samples	10		11	
	Mean ± 1SE	**%**	**Mean ± 1SE**	**%**
Taxa				
Harpact.	1391.0 ± 669.2	10.9	818.7 ± 204.4	31.7
Cope. naup.	2276.2 ± 765.3	17.9	571.8 ± 142.5	22.1
Barn. naup.	1419.8 ± 793.7	11.2	114.9 ± 62.1	4.4
Amphipods	35.2 ± 29.8	0.3	2.5 ± 0.9	<0.1
Cal. + Cycl.	974.0 ± 235.8	7.7	269.5 ± 85.0	10.4
Nematodes	32.2 ± 4.4	0.3	303.5 ± 96.0	11.7
Polychaetes	6250.8 ± 2317.9	49.2	241.5 ± 87.5	9.3
Ostracods	23.2 ± 7.2	0.2	141.5 ± 74.2	5.5
Worms	2.0 ± 0.9	<0.1	4.9 ± 2.8	0.2
Total	12713.6 ± 3034.4		2582.7 ± 293.6	

Site	**TOTAL**	
# samples	66	
	Mean ± 1SE	**%**
Taxa		
Harpact.	1004.5 ± 153.6	23.2
Cope. naup.	843.3 ± 186.9	19.5
Barn. naup.	256.5 ± 130.8	5.9
Amphipods	19.9 ± 5.7	0.5
Cal. + Cycl.	530.9 ± 90.2	12.3
Nematodes	192.4 ± 38.3	4.4
Polychaetes	1255.4 ± 431.4	29.0
Ostracods	98.0 ± 22.8	2.3
Worms	14.9 ± 3.0	0.3
Total	4328.5 ± 695.3	

Table 17. Comparison of diet of juvenile wild chinook for the Englishman River and Campbell River estuaries - mean numerical percent of dominant food organisms.

Year	1982-1984	1993
Estuary	Campbell R.	Englishman R.
No. of fish	282	62
Range in length (mm)	33 - 185	55 - 92
Range in weight (g)	0.3 - 90.7	1.2 - 8.6
Insects - all stages	15.3	51.4
Freshwater cladocera	34.1	0
Copepoda (Cal. + harp.)	27.2	2.9
Amphipods	13.4	17.5
Decapods	0.9	6.2
Fish larvae	<0.1	3.8
Isopods	1.5	0.1
Other	0.9	4.2

Table 18. Comparison of mean density m^{-2} ± 1SE and percent of total populations of epibenthic organisms captured in sled tows at Campbell River and Englishman River estuaries.

Estuary	Campbell River		Englishman River	
Year	1984		1993	
Dates	Mar. 20 - Sept. 25		June 8 - July 30	
No. samples	112		45	
Taxa	**Mean m^{-2} ± 1SE**	**%**	**Mean m^{-2} ± 1SE**	**%**
Harpact.	87.8 ± 14.4	11.6	964.1±165.7	33.3
Cope.naup.	124.3± 18.6	16.4	591.3±189.0	20.5
Barn. naup.	-	-	32.7± 10.3	1.1
Amphipods	13.1± 4.3	1.7	20.8± 5.2	0.7
Calanoids	16.7± 3.2	2.2	480.0±113.6	16.6
Nematodes	252.9± 56.9	33.3	200.8± 49.7	6.9
Polychaetes	-	-	393.2± 99.4	13.6
Ostracods	161.4± 39.6	21.3	104.0± 27.8	3.6
Worms	38.1± 15.4	5.0	20.2± 4.2	0.7
Cladocerans	17.0± 4.9	2.2	6.7± 4.7	0.2
Mysids	18.7± 5.7	2.5	0.4± 0.2	<0.1
Acarinans	11.9± 1.7	1.6	-	
Eggs	7.7± 1.2	1.0	2.5± 0.7	<0.1
Total	758.6±126.4		2891.9±452.9	

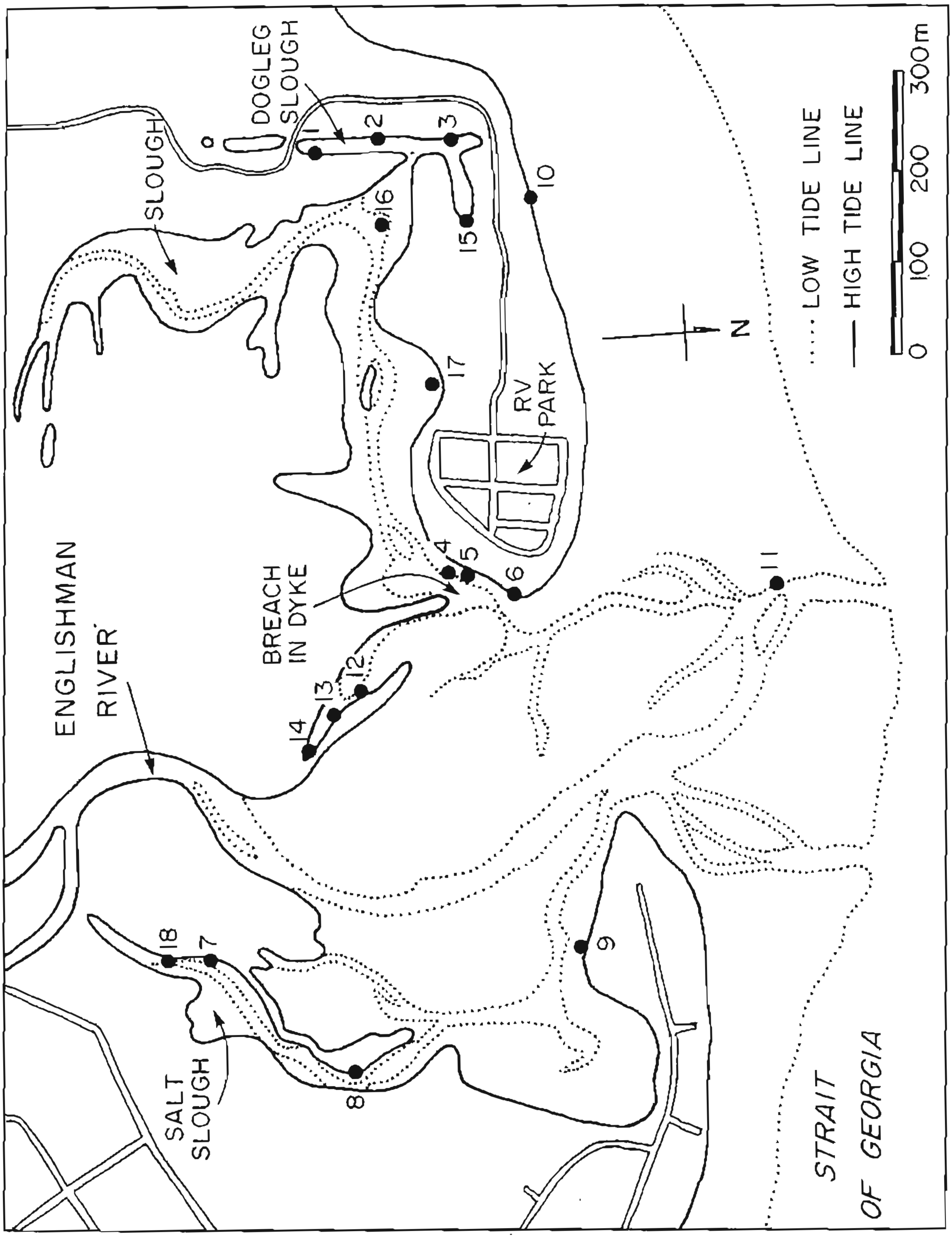
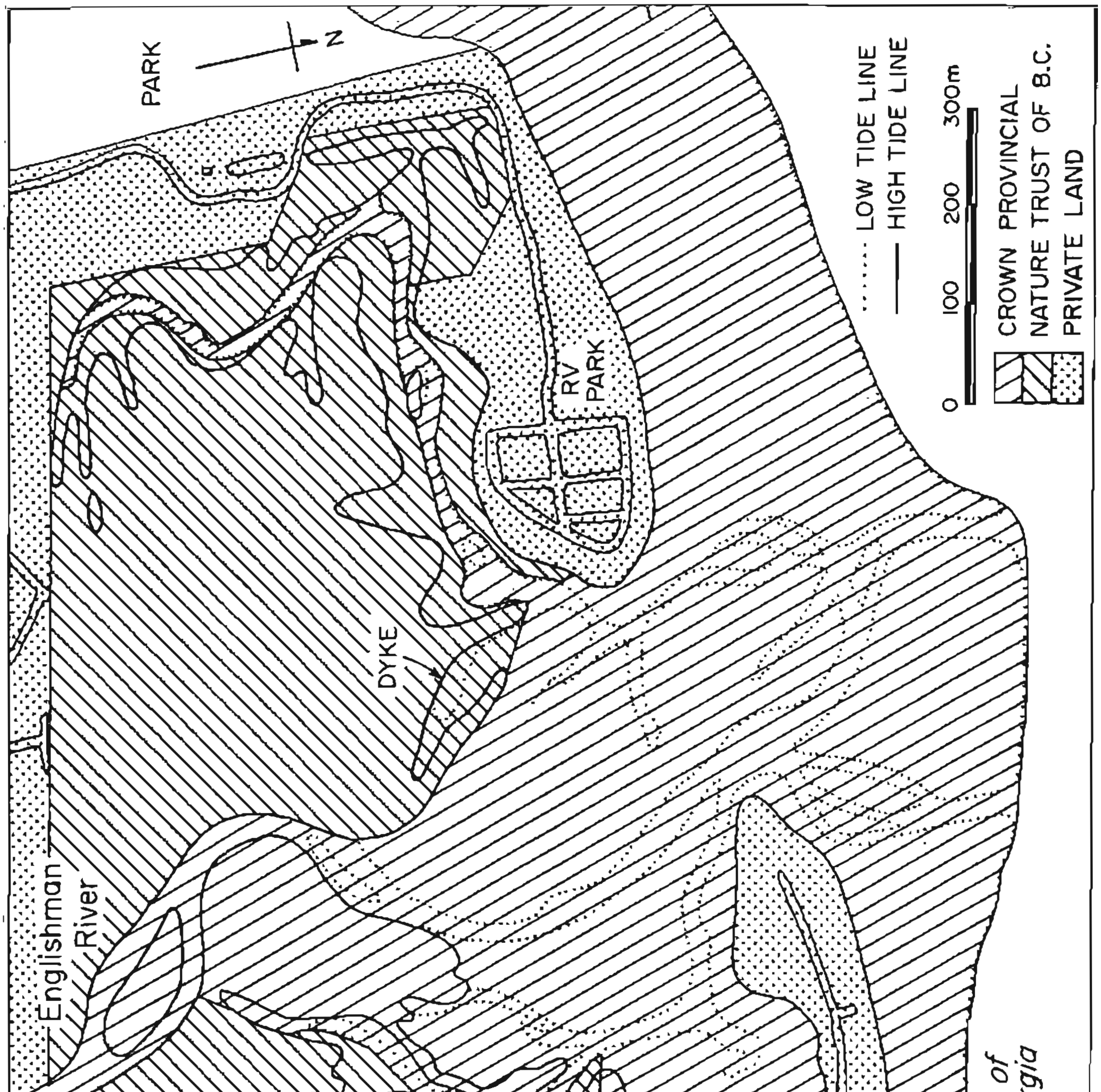


Figure 1. Map of the Englishman River estuary showing the location of the 18 sites sampled in the 1993 survey.

Figure 2. Map showing the location of the provincial and Nature Trust wildlife management areas.


PARK
N
LOW TIDE LINE
HIGH TIDE LINE
0 100 200 300m
CROWN PROVINCIAL
NATURE TRUST OF B.C.
PRIVATE LAND
RV PARK
DYKE
Englishman River
Strait of Georgia
124°17'
49°20'

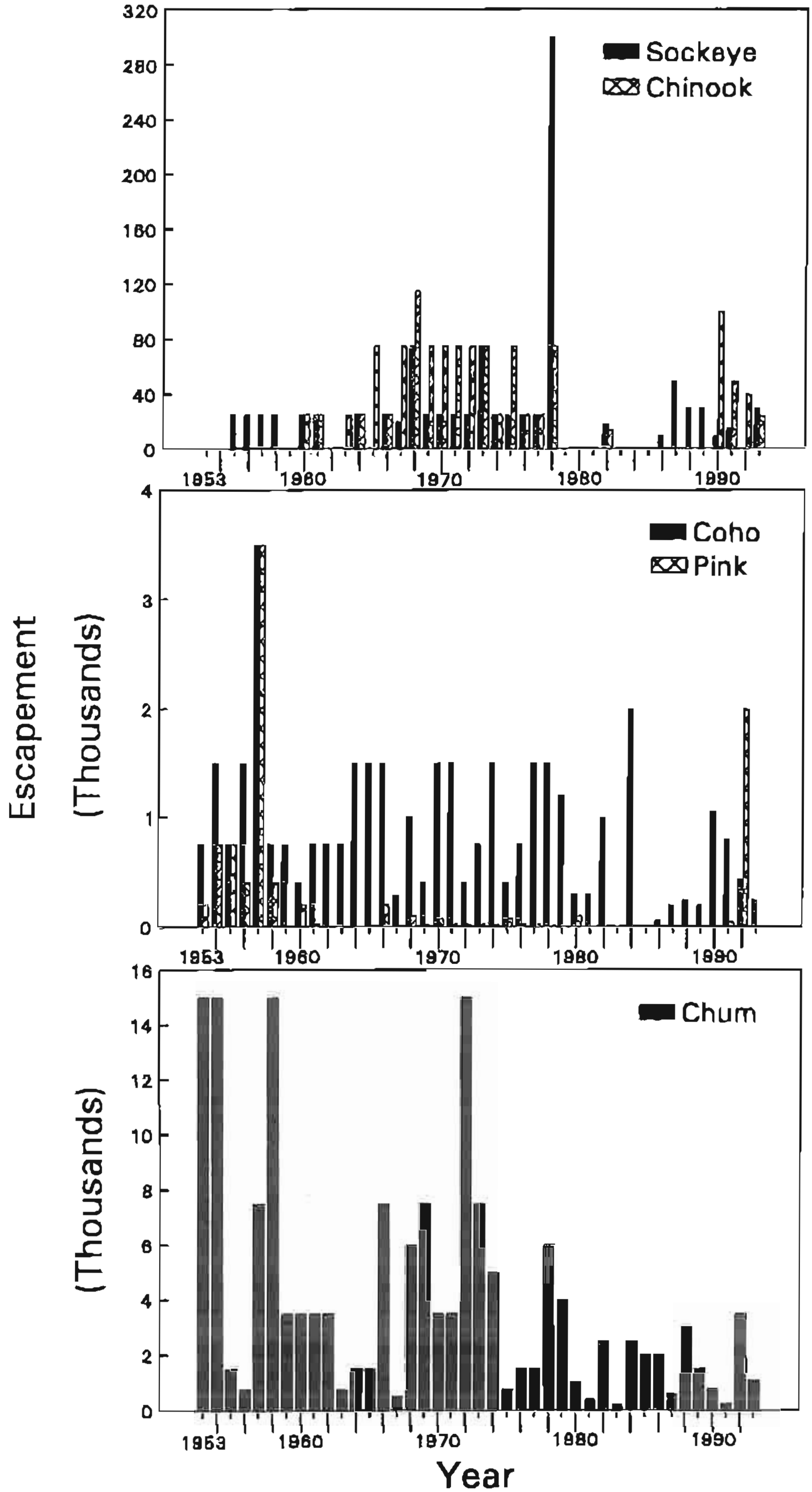


Figure 3. Escapement of five species of salmon in the Englishman River system 1953-1993.

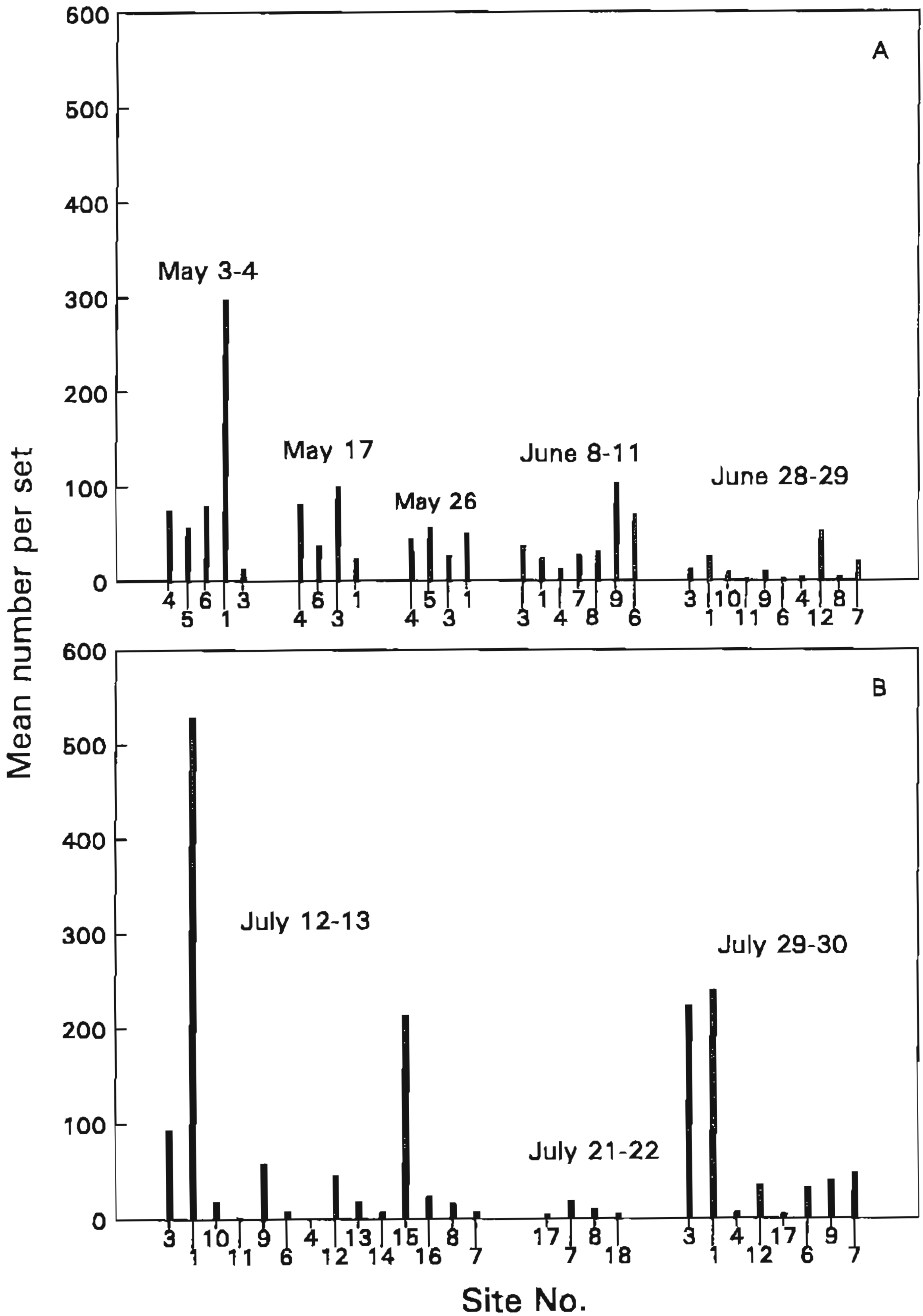


Figure 4. a) Mean total fish catch per set by site for May to June sampling trips.
b) Mean total fish catch per set by site for July sampling trips.

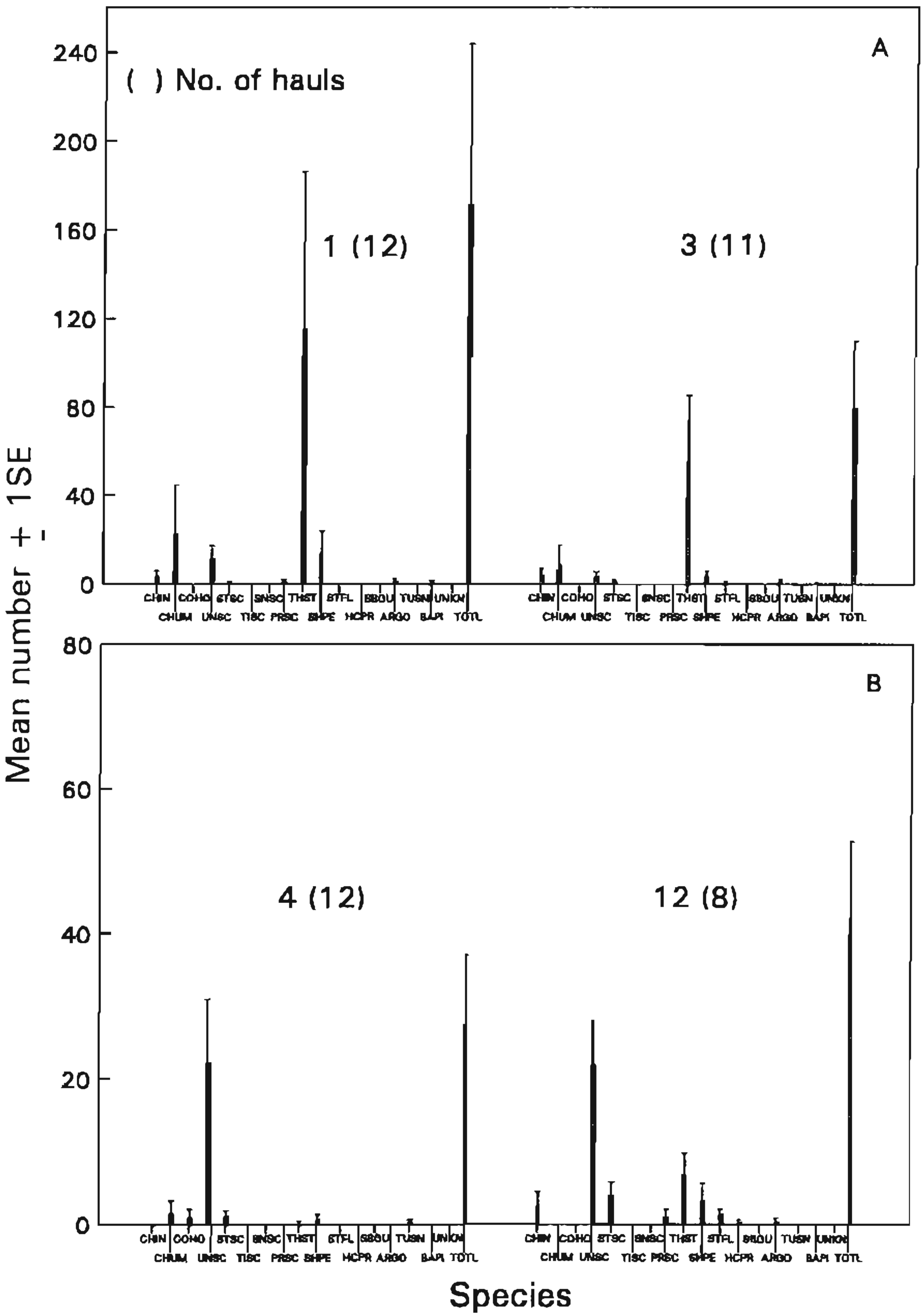


Figure 5. a) Mean catch ± 1SE of each fish species for sites 1 and 3 for all sampling trips combined. (See table 3 for definitions of species abbreviations.)

b) Mean catch ± 1SE of each fish species for sites 4 and 12 for all sampling trips combined.

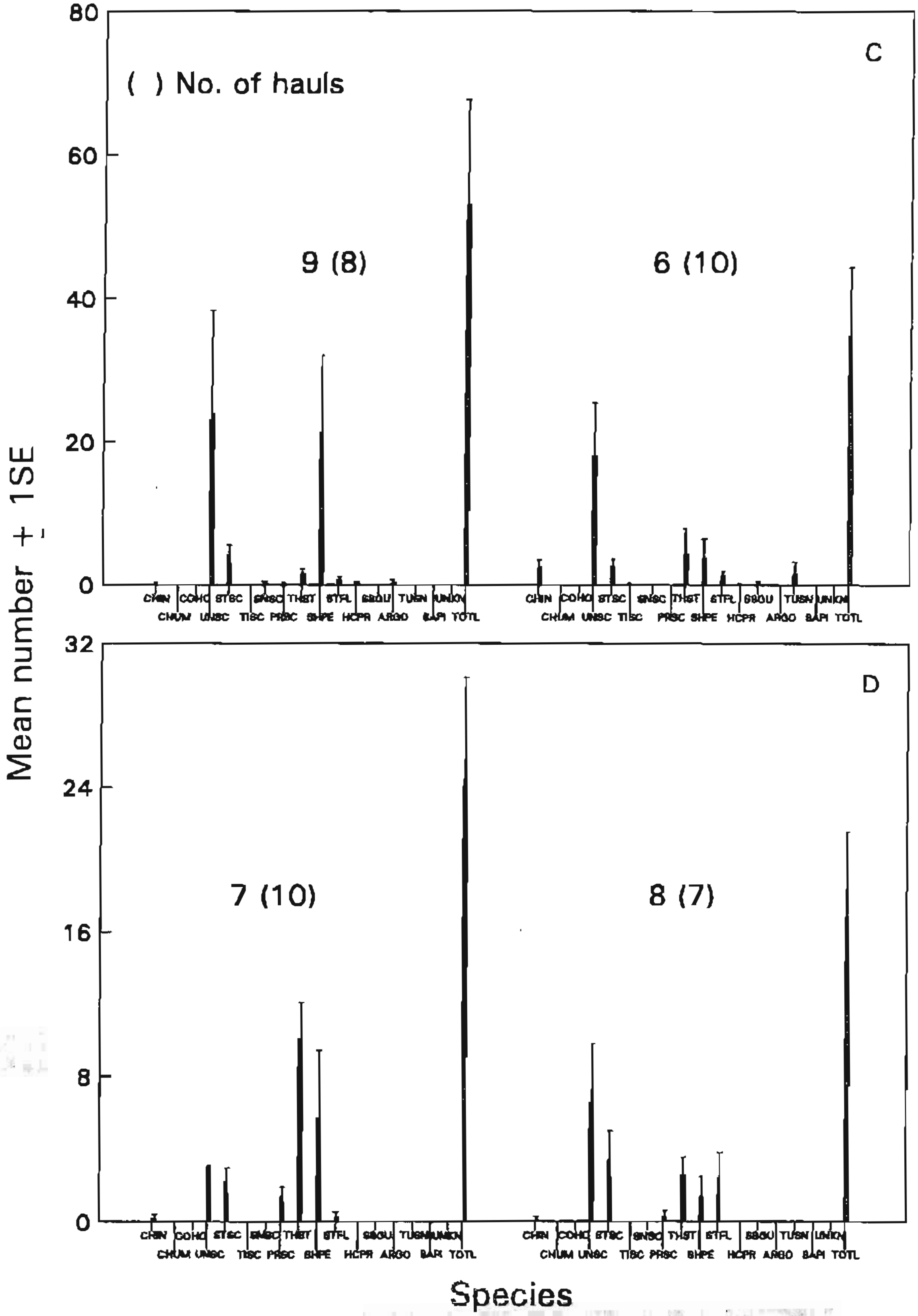


Figure 5. c) Mean catch ± 1SE of each fish species for sites 9 and 6 for all sampling trips combined. (See table 3 for definitions of species abbreviations.)

d) Mean catch ± 1SE of each fish species for sites 7 and 8 for all sampling trips combined.

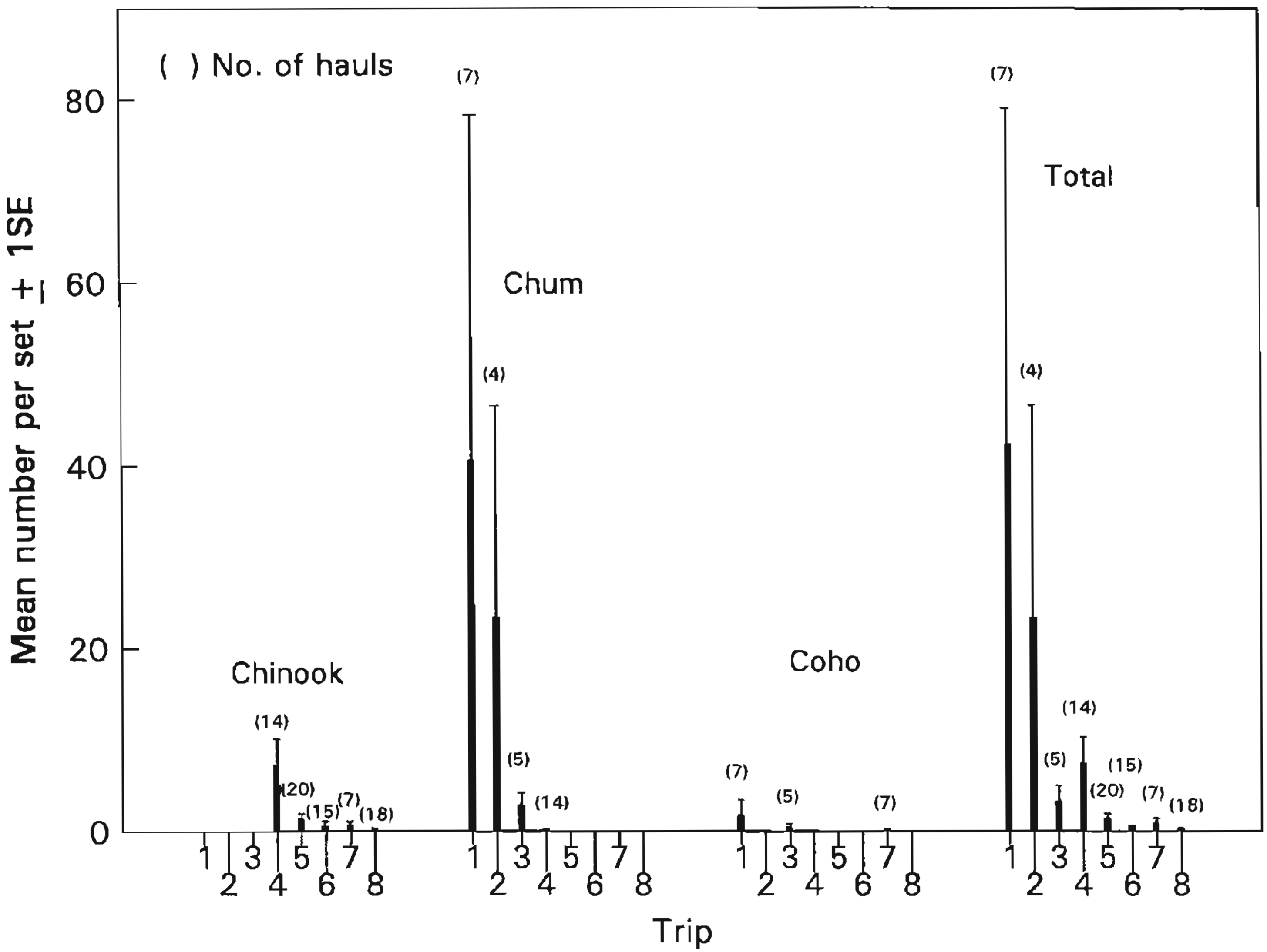


Figure 6. Mean catch ± 1SE of chinook, chum, coho and total salmon by trip for all sites combined. (See table 4 for trip dates.)

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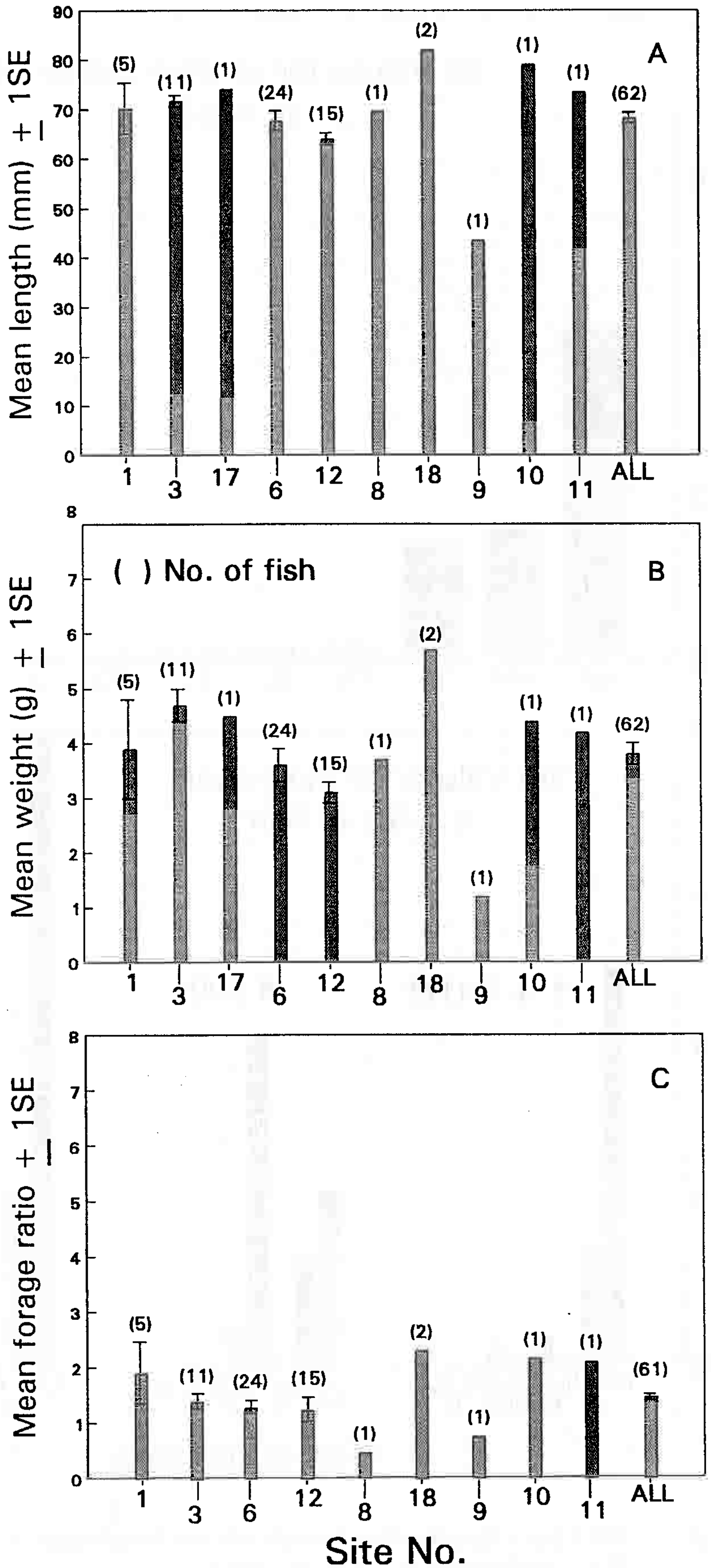
Figure 7. a) Mean length (mm) ± 1SE of juvenile chinook salmon analyzed for stomach contents for 10 sites and all sites combined.

b) Mean weight (g) ± 1SE of juvenile chinook salmon analyzed for stomach contents for 10 sites and all sites combined.

c) Mean forage ratio ± 1SE of juvenile chinook salmon analyzed for stomach contents for 9 sites and all sites combined.


A
Mean length (mm) ± 1SE
0
10
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30
40
50
60
70
80
90
(5)
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(1)
(24)
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(1)
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(1)
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(62)
1
3
17
6
12
8
18
9
10
11
ALL
B
( ) No. of fish
Mean weight (g) ± 1SE
0
1
2
3
4
5
6
7
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(5)
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(1)
(24)
(15)
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(62)
1
3
17
6
12
8
18
9
10
11
ALL
C
Mean forage ratio ± 1SE
0
1
2
3
4
5
6
7
8
(5)
(11)
(24)
(15)
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1
3
6
12
8
18
9
10
11
ALL
Site No.

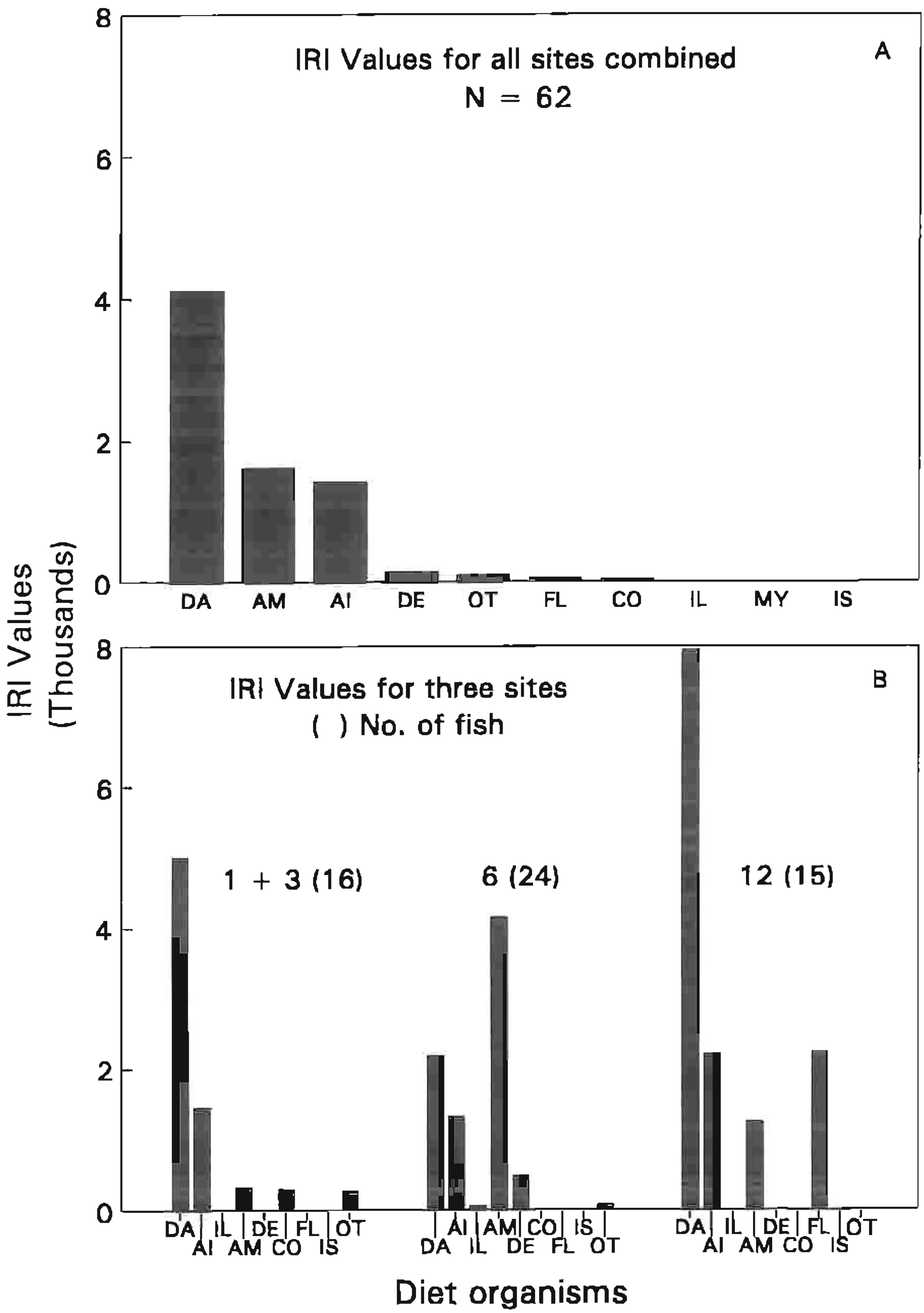

Figure 8. a) IRI values for juvenile chinook salmon for all sites combined. (See table 8 for definitions of abbreviations.)

b) IRI values for juvenile chinook salmon from three sites.

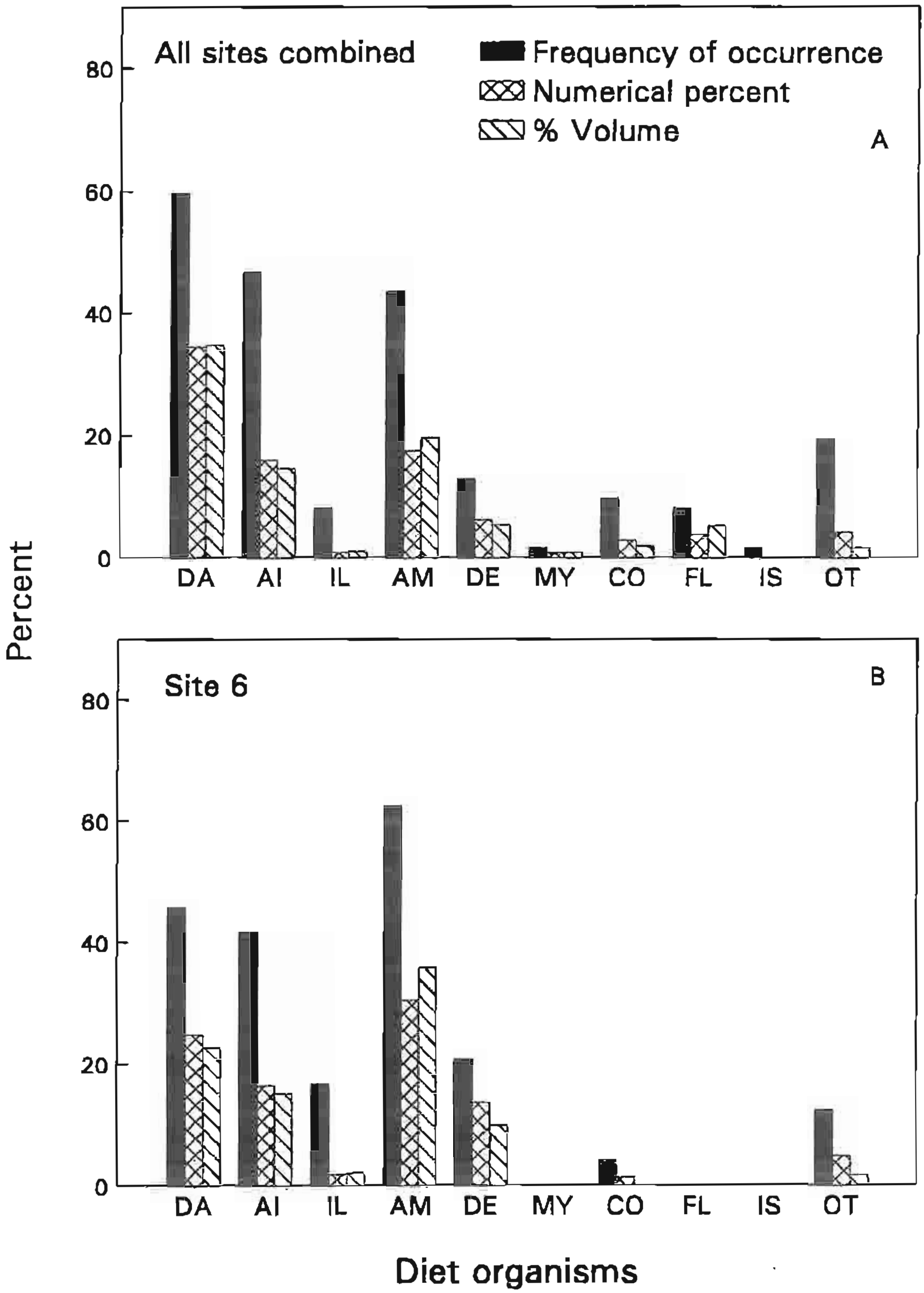

Figure 9. a) Numeric values for prey items in all juvenile chinook stomachs from all sites combined. (See table 8 for definitions of abbreviations.)
b) Numeric values for prey items in twenty-four juvenile chinook stomachs from site 6.

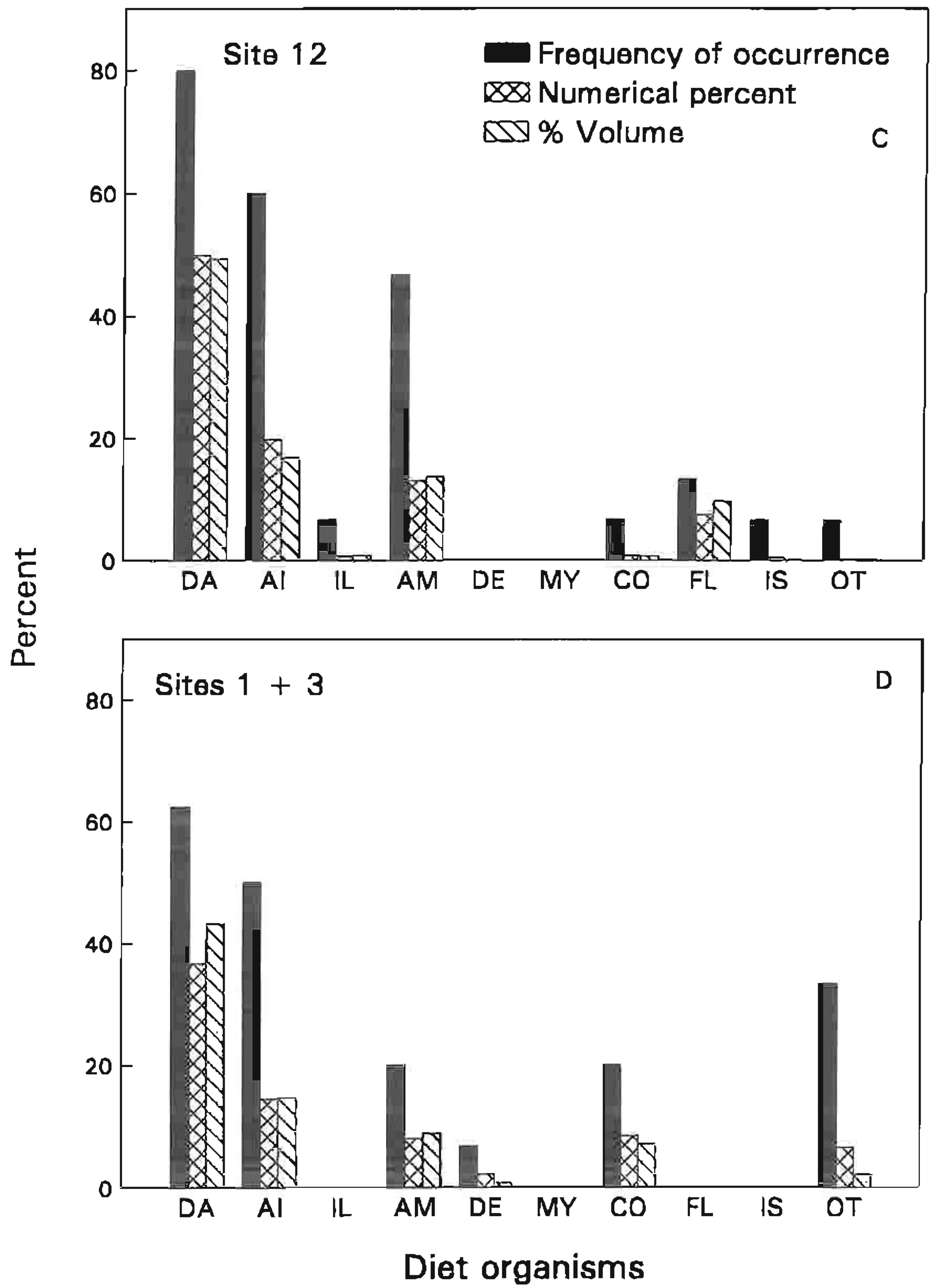

Figure 9. c) Numeric values for prey items in fifteen juvenile chinook stomachs from site 12. (See table 8 for definitions of abbreviations.)

d) Numeric values for prey items in sixteen juvenile chinook stomachs from sites 1 and 3.

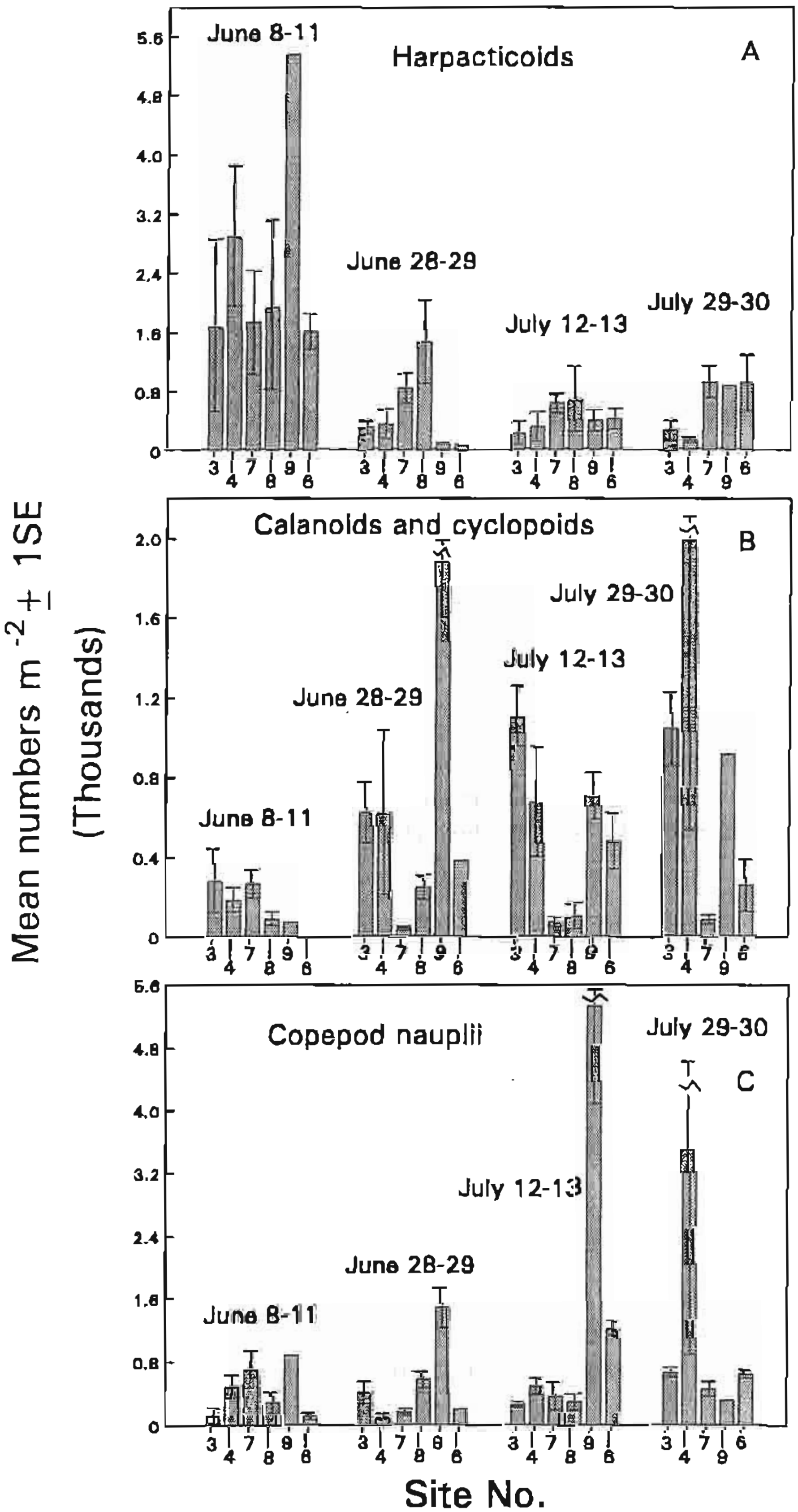

Figure 10. a) Mean numbers of harpacticoids $m^{-2} \pm 1SE$ in epibenthic sled samples by trip and site.
b) Mean numbers of calanoids and cyclopoids $m^{-2} \pm 1SE$ in epibenthic sled samples by trip and site.
c) Mean numbers of copepod nauplii $m^{-2} \pm 1SE$ in epibenthic sled samples by trip and site.

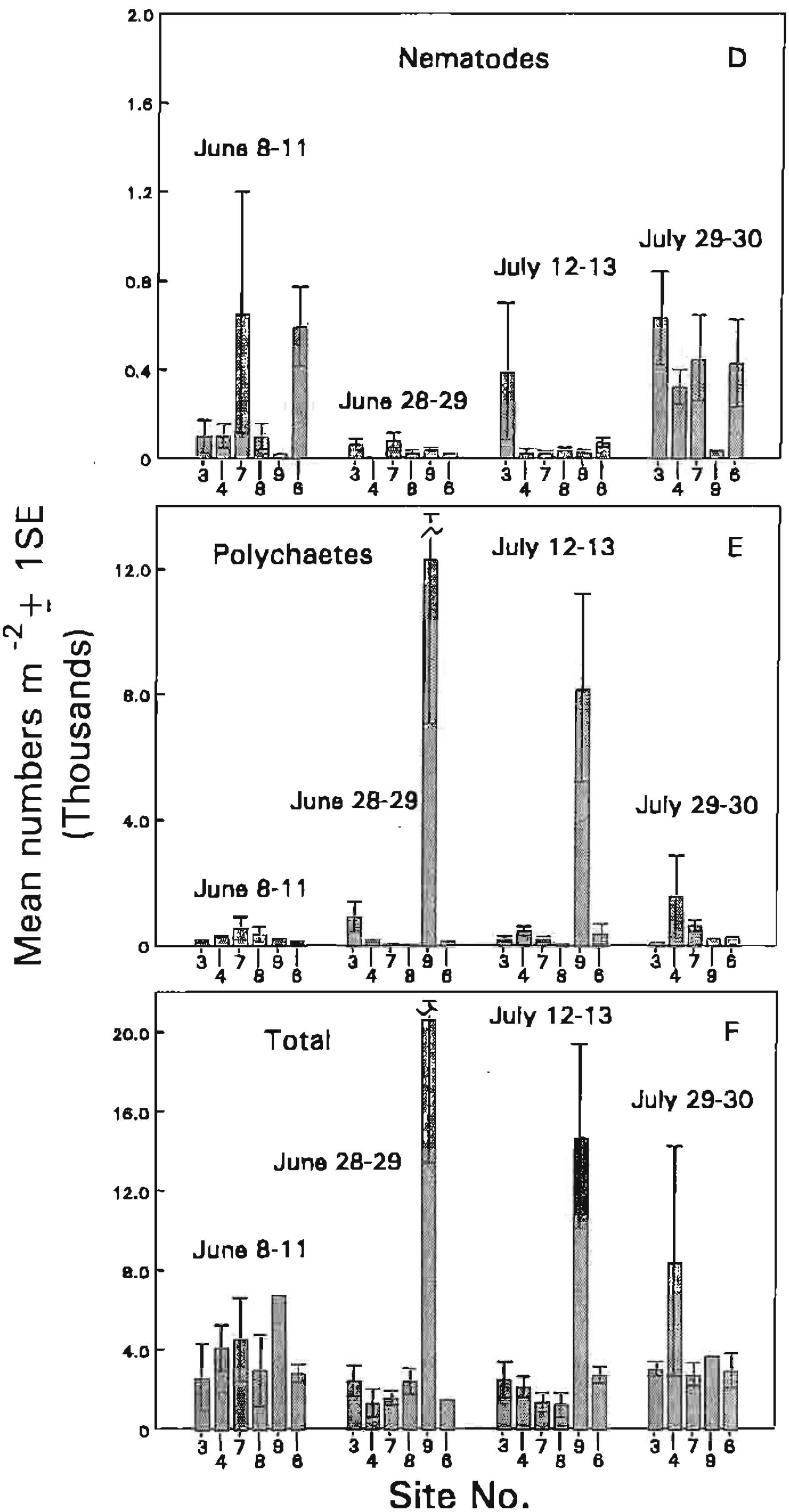

Figure 10.

d) Mean numbers of nematodes m^{-2} ± 1SE in epibenthic sled samples by trip and site.
e) Mean numbers of polychaetes m^{-2} ± 1SE in epibenthic sled samples by trip and site.
f) Mean numbers of total epibenthos m^{-2} ± 1SE in epibenthic sled samples by trip and site.

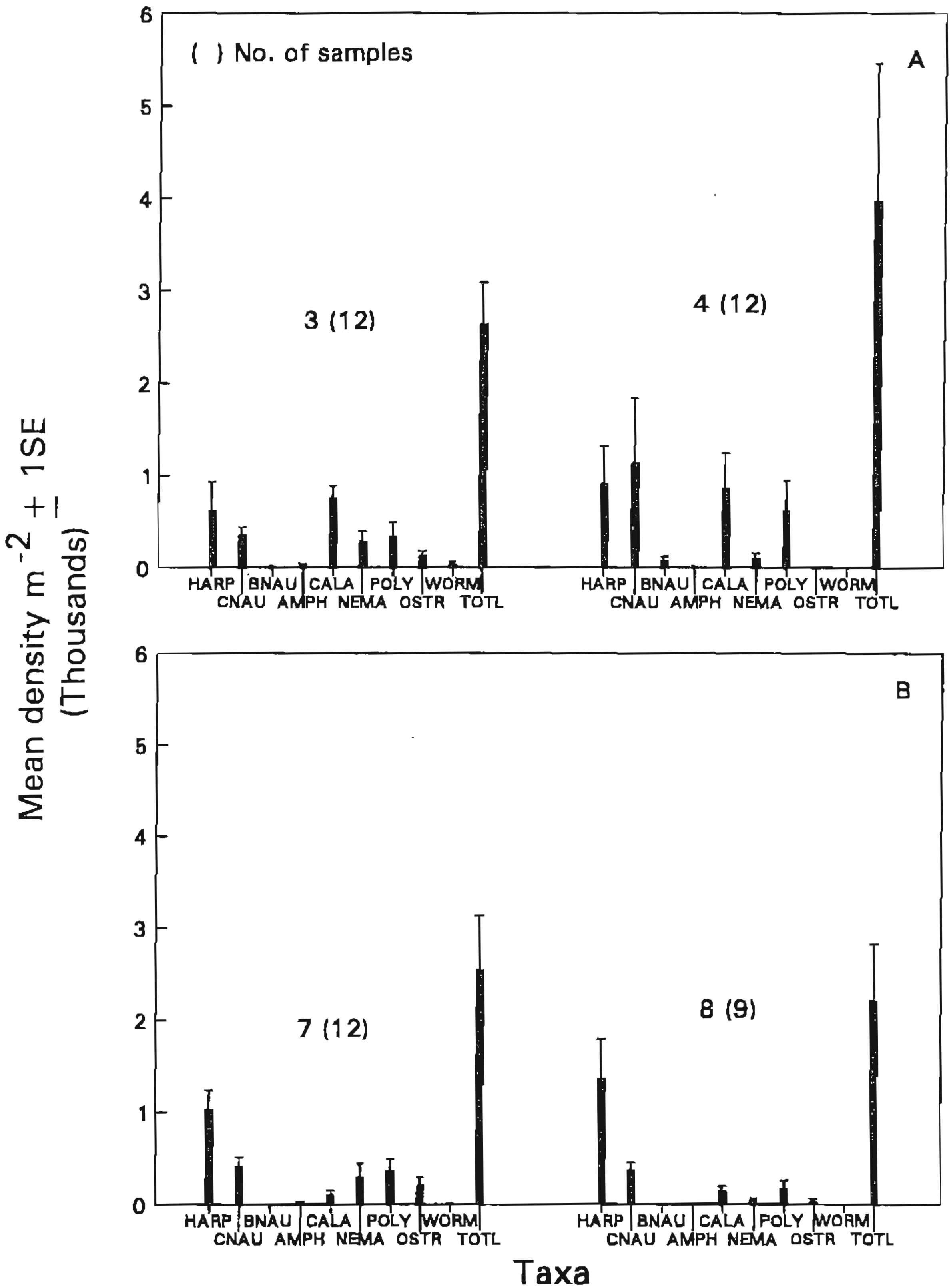

Figure 11. a) Mean density m^{-2} ± 1SE of dominant organisms for all epibenthic sled samples collected at sites 3 and 4. (See table 14 for definitions of abbreviations.)

b) Mean density m^{-2} ± 1SE of dominant organisms for all epibenthic sled samples collected at sites 7 and 8.

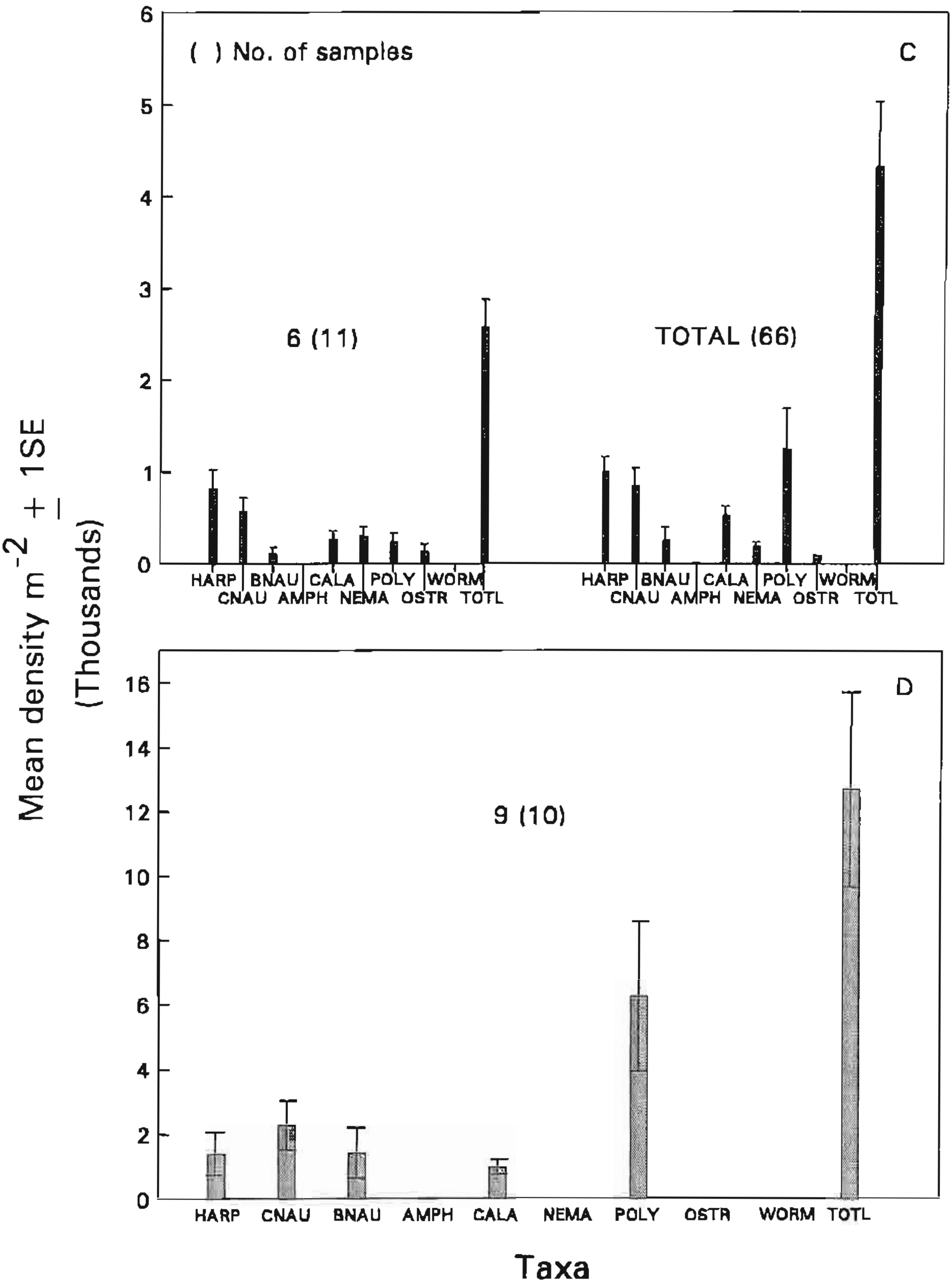

Figure 11. c) Mean density m^{-2} ± 1SE of dominant organisms for all epibenthic sled samples collected at site 6 and all sites combined. (See table 14 for definitions of abbreviations.)

d) Mean density m^{-2} ± 1SE of dominant organisms for all epibenthic sled samples collected at site 9.