OCEANOGRAPHY AND MID-SUMMER DISTRIBUTION AND ABUNDANCE OF PLANKTON AND FISH IN THE NELSON RIVER ESTUARY, HUDSON BAY

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A Report Prepared
for
Manitoba Hydro

by

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ABSTRACT

Estuaries are important areas because the mixing of fresh and marine waters enhances nutrient availability, which increases phytoplankton, invertebrate, fish and marine mammal production. The Nelson River estuary is the major estuary in western Hudson Bay but had received almost no study until an interdisciplinary survey in 1988 (Baker 1989). The use of rivers to generate electricity has raised concerns about the effect of changes in the pattern of freshwater discharge have on the aquatic biota in the river estuaries. To verify patterns observed in 1988 and to obtain quantitative or comparative qualitative estimates of biomass and distribution of aquatic biota, the survey of the Nelson River estuary was repeated in 1992 using a greater variety of sampling techniques.

As in 1988, the 1992 survey identified four physical zones in the estuary: 1) a freshwater or "riverine zone" of entirely of fresh water, extending from Gillam Island downstream to Port Nelson; 2) a "nearshore estuarine zone" with water of low salinity (1-8 ppt) that is completely vertically mixed; 3) a narrow, deep, "stratified zone" between the nearshore and offshore zones that contains water of moderate salinities (8 to 20 ppt) and is vertically stratified; and 4) a large "offshore estuarine zone" that is vertically mixed with cool waters of high salinity (>20 ppt), extending to the marine waters of Hudson Bay. Geographical limits of these zones are strongly influenced by tides, becoming compressed during high tide, and protracted during low tide.

Concentrations of most dissolved nutrients increased from the riverine to the furthest offshore estuarine areas. Nutrient concentrations in the offshore estuarine zone were substantially higher than those reported for the nutrient poor waters of marine Hudson Bay. The source of these nutrients was probably regeneration from bottom sediments and release from deeper waters during vigourous mixing in the nearshore estuarine zone.

The majority of phytoplankton species were freshwater in origin. Highest biomass and diversity was observed in the nearshore estuarine zone due to extremely large numbers of diatoms, which declined offshore. The reason for the offshore decline is unclear but may be related to reduced silica concentrations, a nutrient essential for diatom growth. Abundance (# cells/l) and biomass (mg/m^3) of phytoplankton in the Nelson River estuary was considerably higher than has been reported in surveys of marine waters of Hudson Bay.

The abundance and diversity of zooplankton species in the Nelson River estuary was opposite that of phytoplankton, with density and diversity increasing from on- to offshore. Combined with the 1988 survey, 77 species have been identified in zooplankton samples from the Nelson River estuary, although some groups such as insect larvae (chironomids), Hydrozoa, and polychaetes are primarily benthic. Strictly planktonic zooplankton species, were Copepoda (17), Cladocera (3), Amphipoda (8 species), *Mysis litoralis*, *Sagitta elegans*, and Larvacea (2 species). Virtually all zooplankters were marine or estuarine species, with only a few freshwater species present in the nearshore estuarine zone.

In the present survey, copepod abundance was similar in the nearshore estuarine zone ($383/m^3$), but considerably higher in the stratified and offshore estuarine zones ($>5,000/m^3$) than in the marine waters of Hudson Bay. The vast majority of this was due to large numbers of *Acartia clausi*. Among the invertebrates besides copepods, only *Mysis litoralis* occurred in large numbers at a few sites.

Few marine fish species have been recorded from the Nelson River estuary because of the relatively large volume of fresh to marine water along the coast. Marine species were limited to the nearshore, stratified and offshore estuarine zones, where large numbers of sand lance (*Ammodytes americanus*), and a few larval capelin (*Mallotus villosus*) and a single slender eelblenny (*Lumpenus fabricii*) were captured. The riverine and stratified zones harboured fresh or brackish water species such as fourhorn sculpin (*Myoxocephalus quadricornis*), juvenile lake cisco (*Coregonus artedii*), and nine-spine stickleback (*Pugnitius pungitius*).

In conclusion, the Nelson River estuary appears to be more productive than the marine waters of Hudson Bay and other estuaries in the eastern Hudson/St. James Bay region. The mid-summer distribution and abundance of organisms within the estuary is closely linked to the physical/chemical zonations as described.

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1.0 INTRODUCTION

The Nelson River drains approximately 1.1 million km^2 of central Canada and north-central United States and, together with water diverted from the Churchill River, contributes an annual average of more than 3,200 m^3/sec of water to Hudson Bay. The Nelson River is the largest river of the western Hudson Bay region with a discharge volume similar to that of the La Grande River Complex (i.e. Caniapiscau, Eastmain and La Grande rivers) in eastern Hudson/James Bay (Prinsenberg 1980, Roy 1989). Discharge of the Nelson River has been seasonally regulated for the generation of electricity since 1977 when Jenpeg was constructed at the outlet of Lake Winnipeg. Four large generating stations, Kelsey (1960), Kettle (1974), Long Spruce (1979) and Limestone (1992), currently are in operation downstream of Jenpeg. Although Kelsey and Kettle generating stations pre-dated Jenpeg, they did not discernibly affect the seasonal flow regime of the Nelson River.

Interdisciplinary biological studies of the Nelson River estuary were initiated in 1988 to describe the hydrodynamics, water chemistry, zooplankton, zoobenthos, fish, and marine mammals of the estuary as background to the environmental impact assessment of the proposed Conawapa G.S. (Baker 1989, 1990). With the exception of brief fisheries surveys conducted in 1914 (Comeau 1915) and by the Manitoba Fisheries Branch in 1979 (Gaboury 1980), no prior biological studies of the Nelson River estuary had been conducted.

Hudson Bay is one of the largest inland seas in the world (Martini 1986, Stewart et al. 1991). However, because Hudson Bay is remote, sparsely populated, and supports only a few small-scale, localized domestic and commercial fisheries, little is known about the oceanography and biology of Hudson Bay. The few surveys of the Hudson/James Bay region have revealed a remarkably diverse assemblage of aquatic biota. Phytoplankton and zooplankton are comprised of a mixture of arctic, boreal, and temperate forms of freshwater, estuarine, and marine species. These species occur due to the mixing of water from the North Atlantic and Arctic oceans, and freshwater rivers. Hudson Bay annually receives 0.5% of its total volume from rivers (Prinsenberg 1980), which is a greater proportion than any other large, inland sea.

Recently, the use of rivers entering the Hudson/James Bay region to generate electricity has raised concerns about the effect of changes in the pattern of freshwater discharge on the aquatic biota and hydrodynamics of Hudson Bay (e.g. Grainger and McSween 1976, Prinsenberg 1980, Messier 1985, Martini 1986, Rosenberg et al. 1987, Bunch and Reeves 1992, Lawrence et al. 1992). Investigations of flow changes in tributaries on the east side of Hudson Bay have included the Eastmain (Grenon 1982, Ingram et al. 1985), La Grande (Dadswell 1974, Hunter et al. 1976, Morin et al. 1981, 1982, Messier 1985, Messier et al. 1986), and Great Whale (Legendre et al. 1981, Poulin et al. 1983, Hsiao et al. 1984, Rochet and Grainger 1988) rivers. Studies conducted in western Hudson Bay have been restricted to an examination of the oceanography (Brooks 1979) and plankton ecology of Chesterfield Inlet (Roff et al. 1980, Rogers 1981). A recent survey of the Nelson River estuary (Baker 1989) was the first interdisciplinary study of a western Hudson Bay estuary. Results indicated that distinct zones exist in the Nelson River estuary, and that these zones affect zooplankton and phytoplankton distribution. During the 1992 survey, many of the 1988 techniques were repeated, but the sampling was limited to a single time and intensified to provide a more detailed description of zonation of biota in the estuary. Sampling was also altered to provide more quantitative estimates, including measurements of phytoplankton and a modified Isaacs-Kidd midwater trawl to sample small pelagic fish and large invertebrate zooplankton.

Following were objectives of the current study:

- describe water chemistry of the estuary, particularly with respect to zonation, and verify results observed in 1988;

- describe as quantitatively as possible, the summer distribution and abundance of phytoplankton, zooplankton, and fish in the Nelson River estuary, and compare with results from 1988 studies; and

- compare biological characteristics of the Nelson River estuary with eastern Hudson/James Bay estuaries.

2.0 SITE DESCRIPTION

The Nelson River estuary at Hudson Bay is broad and flat, with very little bottom relief. The river widens before entering Hudson Bay, giving the estuary a fluted shape (Fig. 1). The estuary is shallow, seldom exceeding five meters in depth, with the exception of a narrow, deep (8-30 m), central channel, that extends from just upstream of Port Nelson through the outer estuary and into Hudson Bay. Depths 30 km from Port Nelson, which was the limit of sampling in this study, ranged from 1-10 m. Because of the fluted shape of the river mouth and large tides, the marine limit of the estuary is difficult to define.

Extensive mudflats dominate the nearshore area of the estuary up to 10 km offshore. Much of the mudflat region is alternately exposed and flooded during the tidal cycle because of the large tidal range (up to 4.8 m). The bottom of the estuary is generally hard and subject to scouring action of tide-generated currents. The bottom is composed primarily of compacted fine silts and clays, with numerous boulders and gravel shoals. The physical and hydrodynamic characteristics of the Nelson River estuary are described in greater detail in Baker (1989).

Water movements in the Nelson River estuary are complex and extremely variable, and are affected by three main forces: 1) tides; 2) the Coriolis Force; and 3) weather-related effects (wind, air pressure). Discharge from the Nelson River has a negligible effect on stage and water movements in the estuary because river discharge constitutes only a small portion (1-3%) of the water volume moving on- or offshore because of tides (Baker 1993, Shumilak 1993).

The tides at Port Nelson have a maximum amplitude of 4.8 m and are semi-diurnal, with two complete high and low tides approximately every 25 hours. Each month there are two different tide cycles: a small cycle and a large cycle. The amplitude in stage between neap and spring tides ranges from 2.2 m during a small tide cycle to 4.8 m during a large tide cycle. The shallow, fluted shape of the estuary and large tidal amplitude causes water velocities as high as 2.0 m/sec. The strong currents circulate and mix water in a vertical (top to bottom) and a lateral (onshore to offshore) direction.

The Coriolis Force generated by Earth's rotation causes water to circulate in a counter-clockwise direction around Hudson Bay. Water flowing out of the Nelson River (and Hayes River) is pulled in a southeasterly direction, causing a horizontal separation in flow. This results in fresh, riverine water being drawn along the south shore of the estuary and causes an intrusion of more saline, marine water along the north shore of the estuary.

Weather-related effects increase lateral and vertical circulation of water. Strong northeasterly winds can exacerbate the effects of tides by causing higher stages and increased mixing of fresh and saline water.

The Nelson River estuary is intermediate between a partially mixed and an homogeneous estuary (Baker 1989). Because most of the estuary is very shallow, strong onshore/offshore movements of water cause almost complete vertical mixing. This results in roughly uniform temperature and salinity profiles over much of the estuary. Water is particularly well-mixed in the shallow, mudflat region of the estuary. A vertically stratified region exists in the deeper, central channel. The magnitude of vertical stratification is positively correlated with the height of the incoming tide. During summer, the difference in salinity and temperature between surface and bottom water usually ranges between 5 to 15 ppt and 6° to 7°C, respectively, during an incoming tide. This stratified zone is ephemeral, however, and breaks down during the ebb tide as water is pulled offshore.

Baker (1989) described four physical zones in the estuary: 1) a freshwater or "riverine zone" composed entirely of fresh water, extending between Gillam Island and Port Nelson; 2) a "nearshore estuarine zone" with water of low salinity (1-8 ppt) that is completely vertically mixed; 3) a narrow, "stratified zone" between the nearshore and offshore zones that contains water of moderate salinities (8 to 20 ppt) and is vertically weakly stratified; and 4) a large "offshore estuarine zone" that is vertically mixed with cool waters of high salinity (>20 ppt), extending to the marine waters of Hudson Bay. Geographical limits of these zones are strongly influenced by tides, becoming compressed during high tide, and protracted during low tide.

3.0 MATERIALS AND METHODS

An interdisciplinary biological survey of the Nelson River estuary was conducted between August 19 and 25, 1993. The survey consisted of coincident collections of water chemistry samples, phytoplankton, zooplankton, and pelagic fish and invertebrates at seventeen discrete sites between Gillam Island and 33 km offshore of Port Nelson into Hudson Bay (Fig. 2). Sites were positioned to represent each of the four estuarine zones. Table 1 documents depth, salinity, temperature, and specific data collected at each site.

During the study, tides ranged between a minimum of 0.1 m and a maximum of 3.8 m at Port Nelson. The midday high tide advanced by approximately 50 minutes daily from 3.8 m at 1430 h on August 19 to 3.4 m at 2035 h on August 25 (Fig. 3).

To obtain a longitudinal profile of the estuary at a single time, a separate transect to collect only surface water samples and vertical CTD profiles was conducted on August 25, 1993, between Gillam Island (Site TR1) and 33 km offshore of Port Nelson (TR8) (Fig. 4) from 1000h to 1200h, just following high tide. Sites were located approximately 5 km apart in a NNE direction from Port Nelson.

All sites were visited using a 6 m aluminum boat with a 115 HP jet-drive outboard motor. The location of all sites was fixed using a global positioning (GPS) hand-held satellite navigation system, with a nominal accuracy of 50-100 m.

3.1 WATER CHEMISTRY

Surface water samples were collected in 1 litre Nalgene containers from survey sites 6 to 18, and transect sites TR1 to TR8. Where significant vertical stratification existed (survey sites 6, 8, 12, and 16), one litre water samples also were collected from within 1 m of the bottom with a Van Dorn sampler. Containers were stored on ice in the dark for 1 to 4 days before being transported to Winnipeg for analysis by the Department of Fisheries and Oceans, Freshwater Institute, Analytical Services Section. All water samples were analyzed for the following parameters: nitrate (NO_3), nitrite (NO_2), ammonia (NH_4), suspended nitrogen (Sus N), carbon (Sus C), and phosphorus (Sus P), total dissolved nitrogen (TDN) and phosphorus (TDP), dissolved inorganic (DIC) and organic carbon (DOC), chlorophyll *a* (Chl a), suspended reactive silica (SRSI), chloride (Cl), sulphate (SO_4), sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), total suspended solids (TSS), pH, and alkalinity (Alk).

Vertical temperature (°C) conductivity (μS), and depth (m) profiles were taken using an Applied Microsystems Ltd. CTD-12 interfaced with a Model 100 TRS 80 computer that ran the real-time CTD processing program "RCTD" using the Practical Salinity Scale (1978) and the International Equation of State of seawater (1980). The meter was used at survey sites 5, 6, 7, 8, 10, 11, 12, and 13 and transect sites TR1 to TR8 before the meter ceased to operate. At all other sites, vertical temperature, salinity, and conductivity profiles were taken with a YSI-33 salinity-conductivity-temperature meter.

3.2 PHYTOPLANKTON

To determine phytoplankton composition and abundance, 10 ml aliquots of water were withdrawn from each of the surface and bottom water samples from survey sites 6 to 18, and transect sites TR1 to TR8. Samples were preserved in Lugol's solution and gravity settled for 24h. Phytoplankton were enumerated using an inverted microscope at magnifications of 125X, 400X and 1000X (oil immersion) with phase contrast illumination. Counts were performed according to the Utermohl technique as modified by Nauwerck (1963).

Density of cells of each species was converted to wet weight biomass (mg/m^3) by measuring individual cells of each species and applying the geometric formula best fitted to the cell shape as described by Vollenweider (1968). Volumes of colonial species were estimated based on the average cell size from at least 50 individuals per species per sample, and multiplied by the estimated number of cells in each colony.

3.3 ZOOPLANKTON

Sites 4 to 18 were sampled for zooplankton using a 2 m long, 243 μm Wisconsin zooplankton net with a 50 cm mouth diameter. A General Oceanics digital flow meter was suspended inside the mouth to record the amount of water that passed through the net. The net was towed behind the boat for 12 minutes, one to two meters below the water surface at an approximate speed of 1.0-1.25 m/sec. Details concerning time, location, salinity, and water depth of zooplankton tows are summarized in Appendix 1.

Contents of the net were washed into jars and fixed in formalin. Samples were later washed and transferred to 70% alcohol before shipping to Applied Technical Services, Saanichton, B.C., for identification and enumeration. Samples were rinsed using a 65 μm Nitex sieve with tap water to wash off the preservative, and the volume determined (to the nearest ml) by water displacement. Each sample (except 16) was then made up to either 100 or 200 ml in a beaker and subsamples taken with a Hensen-Stempel pipette. Further subsamples were taken by the same method (usually making up a subsample to 100 ml and removing 1 or 10 ml). Thus subsamples of 20, 200, 2000, or 10, 100, 1000 (and in one case 10,000) were obtained. The level of subsampling was determined by the number of organisms in the sample; a total of at least 200 organisms per subsample was optimally counted.

The sample from site 16 was sampled with a Folsom splitter because unlike other samples, the catch was composed mostly of mysids. After removal of the mysids, the sample was subsampled with the Hensen-Stempel pipette (to 1/320) to enumerate the copepods.

All zooplankters were identified to species where possible, and in the case of copepods, also classified according to life history stage (copepodite I to V, or adult, and sex). Organisms that were considered to be primarily benthic in origin (insect larvae, hydrozoans, oligochaetes, podocopid ostracods, etc.) were identified to family or class. Larval fish were also enumerated and identified to species.

The density (#/m^3) of organisms captured at each site was estimated by calculating the volume of water sampled during each tow, and assuming 100% filtering efficiency of the zooplankton net. The volume of water sampled was estimated using the distance (m) recorded by the flow meter and multiplying by the mouth area of the net. Although the time that each net was towed was the same, the actual volume of water filtered varied according to river and tidal flows and the direction of the plankton tow relative to the current.

3.4 ISAACS-KIDD TRAWL

An Isaacs-Kidd midwater trawl with a tapering range of mesh sizes was used to sample pelagic fish and large invertebrates. The net was 1.52 m x 1.52 m square, and 8 m in length, consisting of two sections of 76 and 13 mm mesh (approximately equal length), and a cod end of 3 mm mesh. Thus, the trawl did not collect all organisms of a particular size, but collected a subsample of a diversity of organisms of various sizes.

The trawl was towed 40 m behind the boat at a variable depth according to the amount of weight (5 or 10 kg) attached to the foot of the net frame, and boat speed, which ranged between 1.5 and 2.0 m/sec. Using simple trigonometry, and a cable inclinometer, the top of the net was calculated to be between 1.2 m and 5.3 m below the water surface. Tows were conducted for 20 minutes, generally in an onshore or offshore direction parallel with tidal flow. The location of the beginning of each trawl was fixed with the GPS. The end point was estimated from boat speed, time, and compass direction of the tow, or fixed using GPS. Details concerning the time, location, depth of tow, salinity, and water depth are presented in Appendix 2.

The distance and depth the net was towed through the water was affected by tidal currents, and no direct measurement of the amount of water filtered was possible. However, tows were always of the same duration and the boat was operated at constant power, approximately standardizing the amount of water filtered by the net. Therefore, although catches cannot be presented in a quantitative manner, effort between tows was roughly comparable.

The entire catch from most tows was fixed in formalin, transferred to alcohol, and transported to Winnipeg for identification and quantification. When large numbers of fish or mysids were captured, only a subsample was retained, with the remainder identified, counted, and released. The total estimated number of mysids was extrapolated from a number/weight relationship derived from the weight of five subsamples of 100 mysids each, weighed to within 1/1000 g.

Bottom and depth profiles for each tow were recorded with a Lowrance Model X-16 depth sounder.

4.0 RESULTS

4.1 WATER CHEMISTRY

4.1.1 Temperature and Salinity

In the 1988 study, the Nelson River estuary was primarily homogeneous, with temporary stratification occurring offshore in a narrow zone on incoming tides (Baker 1989). Based on the horizontal and vertical distribution of temperature and salinity, the estuary was divided into four zones, the riverine, nearshore estuarine, stratified, and offshore estuarine zones (Fig. 5). The current study confirms results of the 1988 survey and a study conducted by Manitoba Hydro describing surface temperature and salinity profiles (Manitoba Hydro, unpublished data).

Data from the vertical temperature and salinity profiles are presented in Appendix 3. In the riverine zone (sites 5, 17 and 18), water temperature was 14.5° to 16°C with 0 ppt salinity. In the nearshore estuarine zone (sites 6, 7, and 12), water temperature ranged from 12° to 14°C and salinity from 0.5 to 8 ppt, depending on the tide. All nearshore estuarine sites were weakly stratified because they were sampled on or just prior to a high tide.

Vertical water chemistry profiles in the ephemeral, stratified zone (sites 4, 8, 15, and 16) were stratified. Site 16, located in the deepest part of the central channel of the estuary, was strongly stratified, with surface salinity (0 ppt) and temperature (15°C) differing considerably from bottom salinity (15 ppt) and temperature (9°C).

In the offshore estuarine zone (sites 10, 11, 13, and 14), the water column was vertically completely mixed. Lower water temperatures (6° to 10°C) and higher salinity (13 to 27 ppt) were observed in this zone.

The separate transect (TR1 to TR8) conducted on an advancing tide between Gillam Island, Port Nelson, and offshore showed that, in the surface water, salinity gradually increased and temperature decreased with distance offshore (Fig. 6). Vertical salinity profiles indicated that all sites were completely mixed vertically (Fig. 7). This occurred because the transect was conducted in relatively shallow water, just north of the deeper, central channel, which is stratified.

4.1.2 Water Chemistry Analysis

Results of water chemistry analyses for all surface and bottom water samples collected from the estuary are presented in Appendix 4. Comparison of average concentrations among the four estuarine zones revealed marked differences in concentrations of most parameters (Table 2). Generally, most dissolved major nutrients (nitrate, ammonia, total dissolved nitrogen, total dissolved phosphorus, and inorganic carbon) increased from the riverine to offshore estuarine zones. Stratification in the nearshore and stratified zones was readily apparent: concentrations of these chemicals were lower in surface waters, originating from the riverine zone, and higher in bottom waters, originating from the offshore zone. Soluble reactive silica, decreased from the riverine to the estuarine zones and concentrations did not differ between surface and bottom waters. Dissolved organic carbon likewise decreased from riverine to offshore estuarine zones. Concentrations of nitrite were too low to permit comparison.

Concentrations of all other major ions (Cl, SO4, Na, K, Mg, Ca) increased from riverine to offshore zones as water became more saline.

Suspended materials include all substances retained on a 1 μm filter and are a mixture of living and dead organic particles and inorganic particles. Concentrations of suspended carbon, nitrogen, and phosphorus were lowest in the offshore estuarine zone and highest in the nearshore and stratified zones, with concentrations in the riverine zone being intermediate. Extremely large quantities of suspended materials occurred in bottom waters of the nearshore and estuarine zones, indicating intensive mixing and resuspension of bottom sediments in these areas. Concentrations of total suspended material increased from the riverine to the offshore estuarine zones. Larger concentrations were found in bottom waters of the nearshore and stratified zones as was the case for suspended carbon, nitrogen, and phosphorus. The large quantities of total suspended material found in the offshore estuarine zone, in conjunction with relatively small amounts of suspended carbon, nitrogen, and phosphorus, indicate a greater proportion of inorganic materials in this area.

The longitudinal transect confirmed many of the patterns observed by comparison among discrete zones. The transect was conducted on an incoming tide away from the deep central channel, so no stratified areas were included. Samples up to Port Nelson are in the river, samples from Port Nelson up to 25 km offshore correspond to the nearshore estuary, and samples collected 25 km or more offshore correspond to the offshore estuarine zone.

Concentrations of dissolved nitrogen decreased from the river to reach lowest levels 8 km off of Port Nelson and then increased to peak levels in the offshore region (Fig. 8). Dissolved phosphorus and ammonia followed a similar pattern, but concentrations in the river were low (Figures 9 and 10 respectively). Nitrate concentrations measured during the transect were different from those measured in the discrete zones, in terms of both absolute and relative amounts. Nitrate concentrations along the transect were highest in the river and decreased offshore (Fig. 11). These measurements may be anomalous because concentrations in the river were twice those observed 40 km upstream at the same time (North/South Consultants, unpublished data), and previous studies in the Nelson River have found that temporal variations in nitrate concentrations are very large (Schneider and Baker 1993). Soluble reactive silica declined from the river to 25 km offshore, where only small amounts were present (Fig. 12). Dissolved organic carbon was present in high concentrations in the river, but declined precipitously offshore (Fig. 13).

Concentrations of suspended carbon, phosphorus, and nitrogen along the transect were lowest in the river and offshore, but were 3-4 times higher in the nearshore estuarine zone, from 8-20 km offshore (Figures 14-16 respectively). This result matches patterns observed in 1988, lending further support to the hypothesis that intense vertical mixing maintains particles in suspension in this zone. As noted for between zone comparisons, total suspended solids did not decline after 25 km offshore (Fig. 17), suggesting an increase in the proportion of inorganic particulates.

4.2 PHYTOPLANKTON

Forty-eight species representing six classes of phytoplankton were recorded from the Nelson River and estuary (Table 3). The majority of these were freshwater species, dominated by diatoms, chrysophytes, and chlorophytes (green algae). The number and density of phytoplankters was relatively high throughout the estuary. The most numerous phytoplankters were chlorophytes and small chrysophytes, numbering as high as 539,000 cells/litre (Table 4). Due to their small size, biomass of chrysophytes was low, averaging 10 mg/m^3. The mean biomass of chlorophytes was 53 mg/m^3. Diatoms are relatively large phytoplankters and although they were less numerous (3,000-178,000 cells/l), they comprised the majority of the biomass with an average of 214 mg/m^3 (Table 4).

Phytoplankton abundance along the transect from Gillam Island (TR1) to the offshore estuarine zone (TR8) is illustrated in Figure 18a. Density was lowest in the river (260,000 cells/l), peaked at site TR6 (520,000), and declined to 340,000 further offshore at site TR8. Chlorophytes and chrysophytes were the most numerous at all points along the transect. Abundance of diatoms was much lower in the outer estuary (TR6 to TR8) compared with inshore areas.

Changes in biomass along the transect did not parallel changes in abundance due to large size differences among the main phytoplankton groups (Fig. 18b). Biomass was high at sites TR1 and TR2, peaked at site TR3 (325 mg/m^3), and declined further offshore to a low at site TR8 (31 mg/m^3). Diatoms dominated biomass between sites TR1 and TR4, in the riverine and nearshore estuarine zones.

Patterns of phytoplankton abundance and biomass among samples collected during the survey of the four zones of the estuary were similar to those observed along the transect (Fig. 19). The most numerous groups in all zones were chlorophytes and chrysophytes (Fig. 19a). However, species composition within groups differed between zones. In the riverine and nearshore estuarine zones, the most abundant chlorophyte species were *Pediastrum duplex* and *Ocystis* sp., while in the stratified and offshore zones *Chlamydomonas* spp. was predominant. Diatoms were the next most abundant species. Diatom abundance was highest in the riverine and nearshore estuarine zones, and declined through the stratified and offshore estuarine zones. *Melosira italica* and *M. binderana* were the overwhelmingly dominant diatom species except in the offshore marine zone where some marine species (*Chaetoceros* sp., *Rhizosolenia* sp.) were most abundant.

The biomass of phytoplankton in all zones, especially the riverine, nearshore estuarine, and stratified zones, was overwhelmingly dominated by diatoms (Fig 19b). Diatom biomass was high in the riverine zone (300 mg/m^3), nearshore estuarine (325 mg/m^3), and stratified zone (260 mg/m^3), and lowest in the offshore estuarine zone (31 mg/m^3). Biomass of chlorophytes was the next highest in all zones, increasing from the riverine (35 mg/m^3) to stratified zones (100 mg/m^3), and declining in the offshore estuarine zone (20 mg/m^3). Euglenophytes, chrysophytes, and cryptophytes comprised a very small portion of total biomass.

4.3 ZOOPLANKTON

At least 37 species of zooplankton representing six phyla were identified in the present survey (Table 5). The phylum Arthropoda was the most numerous and diverse group, especially calanoid copepods which comprised over 97% of all individuals. The copepod *Acartia clausi* dominated the fauna, comprising 95% of the total catch in the nearshore, stratified, and offshore estuarine zones. Two other copepods, *Pseudocalanus minutus* and *Eurytemora* sp., were the next most abundant species, increasing from the nearshore estuarine to the offshore estuarine zones. The majority of copepods identified were adults or copepodite stage IV and V.

Numbers of non-copepod organisms were generally low and relatively less abundant than copepods in all areas except the riverine zone. The fauna in the riverine zone consisted primarily of benthic organisms, such as oligochaetes, hydrozoans, and insect larvae. Rivers typically contain little zooplankton (Hynes 1970), with benthic organisms commonly found in zooplankton samples because of drifting of benthic invertebrates and accidental inclusion due to sampling too close to the sediment. In the nearshore, stratified, and offshore estuarine zones, ostracods were intermittently found in large numbers and Cirripedia (barnacles) became quite abundant in the offshore estuarine zone. The mysid, *Mysis litoralis*, was collected at three sites, one of which in extremely large numbers. Relatively large numbers of larval sand lance (*Ammodytes americanus*, formerly *hexapterus*) were captured in zooplankton nets in the nearshore, stratified, and offshore estuarine zones.

Average densities of zooplankton ranged between 12 individuals/m^3 in the riverine zone to 6,020 individuals/m^3 in the offshore estuarine zone (Table 6). Figure 20 compares the abundance of the six major species or groups among estuarine zones. The copepod *Acartia clausi* was primarily responsible for the large increase in numbers from the riverine to offshore estuarine zones. Numbers of two other copepod species, *P. minutus* and *E. herdmani*, as well as Cirripedia also increased in the offshore estuarine zone. Numbers of Ostracoda and Insecta were greatest in the riverine zone.

Although there were distinct differences in catch between the different zones, there was also considerable variation between sites within zones, illustrating the patchiness of zooplankton in the estuary. For example, total zooplankton densities at site 11 over a mudflat in the offshore estuarine zone were fourteen times higher than at other sites in the same zone due to extremely large numbers of *A. clausi*. Exclusion of site 11 from the calculation of average density in the offshore estuarine zone reduced average density to 1,447 organisms/m^3, considerably less than in the stratified zone.

4.4 ISAACS-KIDD TRAWL

Fish and large invertebrates (mysids and amphipods) were collected using an Isaacs-Kidd midwater trawl (Table 7). Due to the design of the trawl, catch could not be expressed in terms of numbers of organisms/m^3, but between tow comparisons were possible because sampling effort was relatively constant between tows (Table 8).

Seven fish species were captured including two species, American sand lance (*Ammodytes americanus*, Scott and Scott 1988) and slender eelblenny (*Lumpenus fabricii*), that had not previously been captured from the Nelson estuary (Baker 1989, 1990) (Table 7). Abundance and diversity of species of pelagic fish was generally low in the estuary, especially the riverine zone. Figure 21 compares the numbers of the major fish species captured by the Isaacs-Kidd trawl among estuarine zones. Juvenile (0+ and 1+) lake cisco (*Coregonus artedii*) and fourhorn sculpin (*Myoxocephalus quadricornis*) (0+) were present in most trawls from the riverine and stratified zones. Ninespine stickleback (*Pungitius pungitius*) were present in all zones, usually in low numbers. American sand lance was the most abundant species and was found primarily in the stratified and offshore estuarine zones. A length-frequency distribution of a subsample of sand lance ranged in size from 25-138 mm, with a modal size of 75 mm (Fig. 22).

The only non-fish species captured in the trawls were the mysid, *Mysis litoralis* (2 sites), and three individuals of two species of amphipod (Table 7). Mysids were caught at only two sites in the nearshore estuarine zone, although they were extremely abundant, numbering 417,366 and 695,196 individuals.

5.0 DISCUSSION

Estuaries are unique and highly productive environments because the mixture of fresh and saline waters creates conditions suitable for freshwater and marine species, as well as intermediate conditions for a few specialized species. The meeting of fresh and marine waters causes density gradients (stratification) in the water column that can result in dense aggregations of organisms. Increased nutrient levels also may result from upwelling of water from deeper marine sources and regeneration from sediments disturbed by tidal currents. In addition, estuaries receive both inorganic nutrients and organic materials (detritus) in river inflow, runoff from terrestrial areas, and outputs from beds of rooted plants and benthic algae which often occur in shallow embayments (Welch et al. 1982). The resulting nutrient-rich environment can support a higher biomass than offshore marine areas. The distribution of estuarine organisms is closely linked to local salinity conditions, as organisms often move onshore and offshore with the water mass with which they are associated. Abundance of these organisms is linked to biomass of lower trophic levels and ultimately, nutrient availability.

5.1 WATER CHEMISTRY

The Nelson River estuary is hydrodynamically a very complex environment. The combination of high semi-diurnal tides, large freshwater input, and the shallow, fluted shape of the estuary creates strong water currents and vigourous mixing. Temperature and salinity profiles collected in a transect extending offshore from Port Nelson indicate that temperature decreases and salinity increases at a relatively uniform rate with distance offshore. Vertical stratification is limited to a narrow, ephemeral zone in the deep central channel. Therefore, it appears that the net offshore flux of a large volume of water from the Nelson River occurs at a rapid rate (with the twice daily ebb tide) in a more or less homogeneous mass that is completely mixed vertically.

In contrast, eastern Hudson/James Bay estuaries are much deeper and less well mixed due to their enclosed nature. In the coastal plumes of eastern Hudson Bay estuaries, significant stratification exists between surface water (0-10 m) and water below the pycnocline (> 10 m), several kilometres from shore. Therefore, vertical mixing is hindered and the potential for nutrient limitation in surface waters exists.

Circulation patterns and mixing within estuaries have a major effect on the distribution of organic and inorganic materials. In many homogenous or partially stratified estuaries (such as the Nelson estuary), concentrations of most substances are elevated in the middle region of the estuary (Officer 1983). The flow of fresh, riverine water in a seaward direction in the surface waters creates a bottom return flow of marine water. Material settling out of the surface river water is thus brought back into the estuary by the return flow. At some middle point in the estuary, the combination of these two processes, as well as mixing within the water column, creates a concentration peak. In addition, these estuarine circulation patterns create areas of longer water retention time; biomass peaks of plankton occur in or near such areas (Roff et al. 1980). Water circulation is probably partially responsible for elevated concentrations of particulates in the middle region of the Nelson River estuary, especially in bottom waters of the stratified zone. In addition, vigorous mixing contributes to elevated concentrations of particulates.

The major inorganic nutrients for phytoplankton are nitrogen (in the form of nitrate, nitrite, and ammonia) and phosphorus (as phosphate). In marine areas, nitrogen availability appears to be a principle determinant of phytoplankton production during the growing season (Boynton et al. 1982). Among the nitrogenous compounds, phytoplankton generally use either nitrate or ammonia. Although the situation is not clear, preferential use of these compounds appears to differ among areas: phytoplankton in temperate areas use ammonia before nitrate and arctic phytoplankton exhibit the opposite preference (Hood 1983, Smayder 1983). These compounds cycle very rapidly under conditions of high phytoplankton growth; therefore, concentrations in the water reflect input and uptake, and low concentrations do not necessarily indicate low input (Boynton et al. 1982). In the Nelson River estuary, concentrations of most dissolved nutrients (nitrogen, phosphorus, ammonia) increased from the riverine to the most marine areas (i.e. bottom waters in stratified samples).

Nitrate concentrations in both the Nelson River and its estuary were low, ranging from 1-10 mg/m^3 (i.e. $\mu g/l$), and were comparable to concentrations in upstream forebays (Schneider and Baker 1993). Nitrate can be extremely low or undetectable in surface waters during the growing season; for example, concentrations of 0.7 mg/m^3 and 0.8 mg/m^3 were recorded in Chesterfield Inlet (Roff et al. 1980) and La Grande estuary respectively (Grainger and McSween 1976). By comparison, surface waters of the Labrador Shelf can contain up to 84 mg/m^3 of nitrate (Sutcliffe et al. 1983). Few data exist concerning nutrient concentrations in marine waters of Hudson Bay, but nitrate is believed to be generally low (Roff and Legendre 1986).

During winter, when uptake of nitrate is reduced, values are considerably higher, ranging from 2.4 mg/m^3 in La Grande River estuary (Grainger and McSween 1976) to 31-82 mg/m^3 in Chesterfield inlet (Welch et al. 1991). Given the low nitrate concentrations in the Nelson River, and slightly higher concentrations in offshore estuarine water, upwelling from deep water is the most likely source of nitrate, as is believed to be the case for the La Grande River estuary (Grainger and McSween 1976).

Nitrate, nitrite, ammonia, and other nitrogen containing organic compounds, such as amino acids, constitute the major sources of nitrogen. Due to the labile nature of these compounds, conversions between one form and another can occur rapidly, and it may not always be appropriate to compare concentrations of one form (such as nitrate) from the Nelson River with another area, such as La Grande. Because most of the nitrogen in the Nelson River estuary occurs as ammonia (an excretory product of animals and is released during the decomposition of plant material) it may be more appropriate to compare ammonia and total dissolved nitrogen concentrations.

The northern portion of the Nelson River drainage basin and the land surrounding the estuary is predominantly bog. Dissolved organic compounds and decaying plant material released from these bogs and decay of organic material in the extensive mudflats of the estuary are likely sources of ammonia. Ammonia concentrations ranged from 30 mg/m^3 in the riverine zone to 268 mg/m^3 in the outer estuary. Concentrations of total dissolved nitrogen (Fig. 8) followed a similar pattern as ammonia. Although little ammonia is generally present in seawater (e.g. 0.1-2.0 mg/m^3 in the Bering Sea; Hood 1983), comparable data from Hudson Bay are not available. Elevated ammonia concentrations within the estuary are likely the result of release from bottom sediments, input from terrestrial sources, and concentration due to water circulation patterns. Lower levels in inshore regions are attributable to greater uptake by phytoplankton, since phytoplankton biomass and nutrient levels appear to be inversely related.

In addition to important inorganic nutrients, estuaries are often rich in detrital matter (i.e. organic carbon from dead plants and animals). Detrital matter that is colonized and broken down by microorganisms (bacteria) provide nourishment for zooplankton. Dissolved organic carbon that is released by senescent or dead organisms, and also can be taken up by microscopic forms, particularly bacteria. In the Nelson River, concentrations of dissolved organic carbon (DOC) declined from 6.9 g/m^3 in the riverine zone, to 1.1 g/m^3 in the offshore estuarine zone. These values encompass the range for estuaries reported by Mclusky (1981) who listed typical ranges of DOC (g/m^3) as follows: rivers (5-10), estuaries (0.5-5), coastal seas (0.1-1), and open seas (0.01-1), with values at depth 1/10 of those at the surface. Dissolved organic carbon concentrations in the Nelson appear to be comparatively high for northern waters (e.g. dissolved organic carbon on the productive Bering Sea shelf ranged from 1.0-1.85 g/m^3; Hood 1983). The decline in organic carbon from onshore to offshore zones in the Nelson River estuary is most likely related to reduced supply from the river, and possibly uptake by microorganisms.

The ratio of carbon to nitrogen is indicative of the nature of the material. Live organisms have a ratio in the vicinity of 9:1. After death, nitrogenous compounds are preferentially used by bacteria, and the carbon:nitrogen ratio frequently exceeds 15:1. In inner regions of the Nelson River estuary, the carbon:nitrogen ratio averaged 28, but declined to six in the offshore zone. The high ratio in the inshore areas is consistent with the presence of large amounts of humic materials released by decaying plants.

Suspended carbon and nitrogen include organic and inorganic particles from living and non-living sources. Average concentrations of suspended material ranged from 0.6-8 g/m^3 and 0.04-0.3 g/m^3 for carbon and nitrogen, respectively (Appendix 4). Values for suspended carbon were within the range reported by McLusky (1981) as typical of estuaries (1-10 g/m^3). Particulate concentrations in the Nelson estuary were considerably higher than those reported for coastal and marine waters of Hudson Bay (0.07 and 0.01 g/m^3 in inshore waters and 60-70% less in offshore waters for carbon and nitrogen, respectively; Anderson and Roff 1980a). The carbon:nitrogen ratio in the suspended material in the Nelson River estuary ranged from 15 to 20, indicating a high relative proportion of dead material.

5.2 PHYTOPLANKTON

The majority of the 45 phytoplankton species identified in the present survey were freshwater in origin. A few marine and salinity tolerant species such as (*Navicula* and *Rhizosolenia* sp.) appeared in the stratified and offshore estuarine zones, while freshwater species such as *Nitzschia filiformis* declined considerably offshore. Gerrath et al. (1980) identified 42 species of freshwater algae in Hudson Bay, distributed as far offshore as 400 km. The southwest coast of Hudson Bay, 100 km offshore of the mouth of the Nelson River, had the highest number of freshwater species (15; 13% of the total cell count), probably because of the large volume of freshwater runoff from the Nelson River.

Diatoms dominated phytoplankton biomass in the nearshore estuary and decreased offshore. The reason for their decline in the outer regions of the estuary is not clear but may be related to declining levels of silica, a nutrient essential for diatom growth. Other possible explanations for the general decline in phytoplankton abundance in the outer regions of the estuary are decreased growth due to declining water temperature and greater retention and concentration of cells in inshore areas due to water circulation patterns.

Biomass of phytoplankton in the Nelson River estuary ranged from a peak of 425 mg/m^3 in the nearshore estuarine zone to 75 mg/m^3 in the offshore estuarine zone. Biomass in the nearshore region was comparable to that observed in two small upstream reservoirs (Schneider and Baker 1993). Few direct measurements of phytoplankton biomass exist for Hudson Bay. Anderson et al. (1981) reported that mean abundance of diatoms and dinoflagellates in Hudson Bay ranged between 20,000-50,000 cells/l, and 10,000-30,000 cells/l respectively with peak values of 200,000 and 125,000 cells/l in certain inshore areas. Peak diatom abundance in the Nelson River estuary was similar to that observed by Anderson et al. (1981), but dinoflagellates were rare.

Concentration of the photosynthetic pigment chlorophyll *a* provides a rough estimate of phytoplankton biomass and is measured more frequently than phytoplankton biomass. In the Nelson River estuary, chlorophyll *a* in surface waters was highest in the riverine zone (4.9 mg/m^3) and lowest in the offshore estuarine zone (0.69 mg/m^3). Chlorophyll *a* concentrations in Chesterfield Inlet were lower (highest values of 1.9 mg/m^3) but the distribution was similar with a decline from riverine to outer estuarine areas (Roff et al. 1980). Likewise, chlorophyll *a* concentrations under normal flow conditions in the Eastmain estuary in James Bay ranged from 1.0-2.0 mg/m^3 (Ingram et al. 1985). In surface waters of marine Hudson Bay, chlorophyll *a* concentrations were 0.28 mg/m^3 in shallow coastal waters and 0.09 mg/m^3 in central areas (Anderson and Roff 1980b). However, a deep chlorophyll *a* maximum below the pycnocline ranged from 0.3-10.75 mg/m^3 (Anderson and Roff 1980b).

5.4 ZOOPLANKTON AND OTHER INVERTEBRATES

The abundance and diversity of zooplankton species in the Nelson River estuary was opposite that of phytoplankton, with density and diversity increasing from on- to offshore. Combined with the 1988 survey, 77 species have been identified in zooplankton samples from the Nelson River estuary, although some groups such as insect larvae (especially chironomids), Hydrozoa, and polychaetes are primarily benthic. Thirty-two strictly planktonic zooplankton species, primarily copepods (17) and Cladocera (3), have been identified from the Nelson River estuary. The remainder consist of amphipods (8 species), *Mysis litoralis*, *Sagitta elegans*, and Larvacea (2 species). Virtually all zooplankters were marine or estuarine species, with only a few freshwater species (i.e., *Tisbe furcata*, *Daphnia* sp., *Bosmina* sp.) present in the nearshore estuarine zone.

Most invertebrates found in Hudson Bay are considered "arctic marine" species. However, some species, including the most abundant species in the Nelson River estuary, *Acartia clausi* and *Eurytemora herdmani*, are characteristic of warm coastal waters of the North Atlantic, and are widespread in James Bay and Richmond Gulf (Grainger 1968). Few studies of pelagic zooplankton have been conducted in Hudson Bay or its estuaries. Grainger and McSween (1976) identified only 26 zooplankters from the La Grande River estuary, while Rochet and Grainger (1988) found 24 species in nearshore Hudson Bay near Richmond Gulf.

More is known about the ecology of copepods in Hudson Bay than other zooplankters because similar assemblages occur in Arctic and Atlantic waters. Inshore, neritic areas of Hudson Bay are dominated by *Acartia* spp., *Pseudocalanus* spp., and *Microcalanus pygmaeus*. These endemic species are also common in the northern and eastern Atlantic Ocean. In deep, offshore waters, arctic species such as *Calanus* spp., and *Pseudocalanus minutus* are most common (Roff and Legendre 1986).

Copepods dominated the zooplankton fauna of the Nelson River estuary, accounting for 98% of individuals. Grainger and McSween (1976) divided James Bay copepods into three groups based on association with salinity and temperature: freshwater; euryhaline and eurythermal; and arctic species. *Diaptomus* sp. and *Daphnia* sp. were the only strictly freshwater species found in the Nelson River estuary. *Acartia* sp., *Derjuginia tolli*, *Centropages abdominalis*, *Eurytemora* sp., and *Tortanus discaudatus* were considered estuarine. Each of these species except *Centropages abdominalis* and *Tortanus discaudatus* were the most common zooplankters in the Nelson River estuary (Table 5). Similar abundances were observed in the La Grande River estuary, as *Acartia clausi* was also the most common zooplankter nearshore, with *A. longiremis* and *Pseudocalanus minutus* dominating offshore.

Rochet and Grainger (1988) identified only 12 copepod species from eastern Hudson Bay, including many of the same species as the current study, though relative abundance differed considerably. The survey by Rochet and Grainger (1988) was largely conducted offshore, and therefore "arctic" species were relatively more abundant, notably *Microcalanus pygmaeus*, a typical arctic species, that was not observed in the present study. A few individual *M. pygmaeus* were observed from the furthest offshore station in the 1988 survey (Baker 1989). The nearshore, estuarine area sampled by Rochet and Grainger (1988) in the vicinity of the Great Whale River contained only seven species of copepod, dominated by *Pseudocalanus* sp., *Acartia longiremis*, *Centropages abdominalis*, and *Eurytemora herdmani*.

In the Nelson River estuary, copepod abundance in the nearshore estuarine zone was $383/m^3$), and considerably higher in the stratified and offshore estuarine zones ($>5,000/m^3$). These high abundances were due to large numbers of *Acartia clausi*. The diversity of zooplankton in surface waters of central Hudson Bay is considerably greater than in coastal waters, but abundance (50-100 individuals/m^3) is considerably less (Rochet and Grainger 1988).

The distribution of zooplankton in the Nelson River was very patchy, similar to results from 1988 (Baker 1989). The higher density of organisms in the offshore estuarine zone than other zones was primarily due to an exceptionally large abundance of *Acartia clausi*, numbering more than 2 million individuals at Site 11 near the mudflat area. Otherwise, density of *A. clausi* in the stratified zone was higher than in the offshore estuarine zone, although diversity of species was still significantly greater offshore.

When present, *Mysis litoralis*, a widespread benthic/epibenthic zooplankter, was next most abundant, although its distribution was extremely patchy, as was found in the 1988 survey (Baker 1989). *Mysis* was very abundant in the deep central channel (Site 16) and margins of the mudflats (sites 2 and 12)(Table 5). *M. litoralis* has not been reported as abundant in Hudson Bay except in the Nelson River estuary.

Two other mysids, *M. mixta*, and *M. oculata* have been reported from the Eastmain River estuary (Grenon 1982), and James Bay and Richardson Gulf (Grainger and McSween 1976, Roff and Legendre 1986) respectively. Cumaceans and Euphausidacea (marine krill) are also common benthic/epibenthic species in Hudson Bay (Roff and Legendre 1986) that are not presently known from the Nelson River estuary.

Several other groups such as barnacles (Cirripedia), Ostractoda (Podocopa) and chaetognaths (arrowworms) were relatively more abundant in the present survey than in 1988 (Baker 1989). A new class of zooplankter, Larvacea (within the Phylum Chordata) represented by *Oikopleura* sp. and *Fritillaria borealis* was found in the offshore estuarine zone in the present survey (Table 5). Both are common northern marine species and *Oikopleura* is previously known from Hudson Bay (Stewart et al. 1991).

Amphipods are important as food for seabirds and seals in Hudson Bay, but were present in low abundance in zooplankton nets and Isaacs-Kidd midwater trawls (Tables 5 and 7). Stewart et al. (1991) listed 40 species present in Hudson Bay, with many of these present in western Hudson Bay (Dunbar 1964). Eight species of amphipod including common estuarine (*Onisimus litoralis*) and arctic marine species (*Gammarus oceanicus*, *Monoculodes borealis*) have been identified from the Nelson River estuary. Amphipods were present in very low numbers in the zooplankton fauna and were much more abundant (10-20 times) in zoobenthos in 1988 (Baker 1989).

5.4 FISH

A total of 19 families and 55 species of marine fish have been recorded from James Bay, Hudson Bay and Hudson Strait (Morin and Dodson 1986). Some marine species, such as fourhorn sculpin, sand lance (*Ammodytes americanus*), capelin, and some stichaeids are commonly found in estuaries (Ochman and Dodson 1982). In addition, estuaries often harbour significant numbers of freshwater fish. Of the 42 species of freshwater fish known from coastal waters of James and Hudson Bay, at least 22 of these seasonally visit estuarine waters of salinity up to 15 ppt (Table 9). Some of these species, such as walleye and longnose sucker, are not known to frequent estuarine water throughout the rest of their range. Of the 42 species listed by Morin and Dodson (1986), 32 of these are present in the lower Nelson River, of which at least 20 have been found in brackish water along the coast of the estuary. Some of these species, such as emerald shiner, longnose and pearl dace, spottail shiner, and trout-perch have not been found in brackish water in eastern Hudson/James Bay estuaries, but are present in the Nelson River estuary.

The number of marine fish relative to freshwater fish in Hudson Bay varies according to the volume of fresh to marine water along the coast, and with latitude. The number of marine species increases northward from James Bay to Hudson Bay, and Hudson Strait. Few marine species have been recorded from the Nelson River estuary because of the relatively large volume of fresh to marine water along the coast. In 1988, only larval capelin, Arctic shanny (*Stichaeus punctatus*), and fourhorn sculpin were observed (Baker 1989). In the present survey, capelin, fourhorn sculpin, and two new species, a single slender eelblenny (*Lumpenus fabricii*), and large numbers of sand lance (*Ammodytes americanus*) were captured.

American sand lance were the most abundant fish species captured in Isaacs-Kidd trawls and zooplankton nets in the Nelson River estuary (Tables 5 and 7). Sand lance are a schooling, bottom dwelling or burrowing marine fish that are common in littoral and shoal waters of the world's oceans, including the Arctic. Abundance of sand lance in the estuary was patchy, however, they were consistently captured in shallow depth (3-6 m), and intermediate salinity (15-20 ppt), and were most common in the stratified and offshore estuarine zones (Table 7).

The majority of American sand lance captured were juveniles or adults (Fig. 22), with only a few larvae captured, some still with an egg sac. Normally, spawning occurs during winter (December to January), and eggs hatch in early spring. Larvae remain planktonic until about 30 mm long, at which time they become primarily benthic. The presence of small larvae (5-8 mm) in the Nelson estuary during August suggests that hatching of sand lance may occur later in Hudson Bay than in temperate oceans.

Capelin are a marine fish that inhabit cold, deep waters of offshore banks and in coastal areas of the Atlantic Ocean and Hudson Bay. Adult capelin are normally distributed offshore in deep, marine water, except during spawning season when they have been reported to spawn in the vicinity of the Nelson River estuary (Comeau 1915). Although a few larvae were captured, no juvenile or adult capelin were captured in this, or previous studies (Baker 1989, 1990). Large numbers of adult capelin move inshore during June and July to spawn over coarse sand or fine gravel beaches where eggs are buried by wave action and are presumably safe from being predated, or drawn offshore by tidal movement of water (Scott and Scott 1988).

Although Comeau (1915) reported that capelin were observed spawning on beaches in the vicinity of Port Nelson during June, it is likely that spawning by capelin may not occur within the estuary itself, because the strong currents would cause eggs to be washed offshore, or become exposed during a low tide. After hatching, dispersal of larvae is initially passive, but is later moderated by vertical movements, that may alter the dispersion pattern of larvae (Scott and Scott 1988). This may account for the few number of larval capelin captured during these surveys (Baker 1989, 1990).

The Nelson River estuary is also seasonally frequented by anadromous freshwater fish, primarily lake cisco. In eastern Hudson Bay, lake cisco, lake whitefish, and round whitefish are relatively abundant in coastal embayments and estuaries during summer (Greendale and Hunter 1978, Ochman and Dodson 1982, Morin et al. 1980, 1982, Morin and Dodson 1986, Kemp et al. 1989, Le Groupe Steica 1990). Brook trout was also one of the most abundant species in an extensive gillnetting survey of the Eastmain, La Grande, Great Whale, Innuksuac and Povungnituk rivers in eastern Hudson-James Bay, although they are scarce in the lower Nelson River and estuary.

The distribution of lake whitefish and lake cisco in river mouths, and estuaries of eastern Hudson/James Bay is not yet clear. Ochman and Dodson (1982) found that coregonid larvae in the Eastmain River were passively transported downstream from spawning grounds, shortly after spring break-up, into the river mouth, through the estuary and into Hudson Bay. They speculated that transport of coregonid larvae into Hudson Bay may be advantageous because of the greater availability of food in the bay than in the river during early spring. Once larvae became more mobile later in the summer, juvenile fish moved back into the river mouths to feed. However, the distribution and abundance of coregonids in the Eastmain River and estuary was patchy, as salinity, water temperature, tides, and wind events affected the distribution of fish. Abundance of coregonids in the river and nearshore area was generally low in this study of the Eastmain River, as in previous studies of the Nelson River estuary in seines, gillnets, and in an electrofishing survey (Baker 1989, 1990, North/South Consultants Inc., unpublished data).

Until recently, it was believed that a latitudinal cline in the relative abundance of lake cisco and lake whitefish existed, with lake whitefish being relatively more abundant further north (Morin et al. 1980, 1982). It was hypothesized that colder temperatures and a shorter growing season posed energetic constraints that limited the northward distribution of lake cisco. However, recent studies of major eastern Hudson/James Bay estuaries have revealed that considerable differences in abundance of lake cisco and lake whitefish existed between rivers, but that these differences were not attributable to a physiological inability to cope with a reduced growing season (Kemp et al. 1989).

Kemp et al. (1989) also found considerable variation in abundance (based on catch-per-unit-effort), and species composition of salmonids in different sampling areas (rapids, river, estuary, bay), in open water months (June-October). During summer, mature and immature lake cisco gather in the estuary to feed. During fall, non-reproductive adults remain in the estuary while sexually mature fish migrate upstream to spawning grounds. Juvenile lake cisco (2+ to 5+) were rare throughout the present study, as well as previous studies of the Nelson River mainstem (Swanson et al. 1988, Remnant and Baker 1993). Kemp et al. (1989) hypothesized that: 1) different rivers may be used by immature cisco for overwintering, or as nursery habitat than adults; or 2) cisco migrate very early into the bay during spring, thus explaining their absence in sampling gear during the open water season. They also caution that discrepancies between the results of different studies conducted at different times or locations may lead to considerable error in evaluating and understanding the community structure of anadromous coregonids.

In the current study, young (1+) cisco were widely dispersed in the estuary (Fig. 2), but appeared to be low in abundance. Adults cisco were not captured during the present survey, nor in an electrofishing survey of the lower Nelson River and nearshore estuarine zone during August (North/South Consultants Inc., unpublished data). Surveys of the Nelson River mainstem (Remnant and Baker 1993) have revealed that lake cisco are virtually absent from the river except during fall when mature adults return to the Limestone and Weir rivers to spawn (MacDonell 1993). The large freshwater plume of the Nelson and Hayes rivers that is drawn in a southerly direction by the Coreolis Force may provide a corridor within which fish may disperse a considerable distance from the Nelson River.

5.5 GENERAL DISCUSSION

The Nelson River appears to be among the more productive estuarine environments in Hudson Bay, and is especially high compared to the adjacent marine waters of Hudson Bay. The estuary is enriched by organic inputs from the river and surrounding terrestrial areas, which in turn increases the production of microorganisms, phytoplankton, and zooplankton. Elevated concentrations of most living and dead material in the middle regions of the estuary is attributable to accumulation and retention due to water circulation patterns, and higher growth rates of plankton. The emphasis on sampling during summer months would fail to reveal major nutrient and production peaks, which usually occur in early spring (Roff and Legendre 1983).

Freshwater inflow is the most important determinant of estuarine characteristics because of its effect on total salinity, ice formation, accretion of nutrients and humic substances, and circulation and residence time (Smayder 1983). However, the relationship between freshwater input, nutrient concentration, and phytoplankton growth is complex. Freshwater inflow can directly input nutrients to an estuary and increase upwelling and thus nutrient regeneration from deep waters.

Generally, hydroelectric development of several rivers entering Hudson Bay has reversed the seasonal pattern of freshwater input, such that highest flows occur in winter, and lowest flows occur in summer. Altered flows could affect inorganic and organic nutrient input and regeneration, and estuarine circulation, which could be reflected through the entire food web. In northern waters, a large proportion of growth occurs in early spring under the ice before breakup. Production of "ice algae" can contribute a significant portion of annual production (Roff and Legendre 1983, Hood 1983). There is some concern that expansion of the freshwater plume under the ice during winter may considerably reduce the production of ice algae, which may in turn affect zooplankton production and early feeding of larval fish (Drolet et al. 1991, Gilbert et al. 1992).

Increases in the surface freshwater layer can have other effects as well. In a study of the vertical distribution of phytoplankton, zooplankton, and fish in the Great Whale River estuary (currently unregulated), Ponton and Fortier (1992) and Gilbert et al. (1992) demonstrated that feeding efficiency of larval sand lance was considerably reduced in marine waters beneath the turbid freshwater layer because light penetration was reduced to the point where foraging was impaired. Gilbert et al. (1992) determined that extension of the Great Whale River plume during spring was responsible for a complete halt in the foraging activity of sand lance. Feeding resumed after ice break-up, once vertical mixing and deepening of the photic zone occurred.

This has considerable implications for northern rivers entering Hudson Bay whose discharge is regulated by hydroelectric generating stations, such as the Nelson River. Typically, hydroelectric development reduces spring and summer inputs, and augments winter inputs to Hudson Bay. Gilbert et al. (1992) stated that a reduction or elimination of the spring freshet may be beneficial to first feeding marine fish larvae. However, the impacts of a reduced plume during summer, or an expanded plume during winter on algal productivity has yet to be determined.

In the Nelson River estuary and peripheral offshore area, the seasonal manipulation of freshwater inputs has potential to also affect marine mammals directly through impacts on habitat, or indirectly through the food web. Marine fish, especially sand lance, capelin, and benthic invertebrates are important food items for marine mammals. Because the Nelson River estuary contains the largest concentration of beluga whales in the world, numbering as many as 19,500 individuals in June and July within 145 km of the estuary (Richard et al. 1990), a considerable food supply must exist in Hudson Bay in the vicinity of the estuary. However, it is not known whether, or the extent to which beluga feed in nearshore waters of the Nelson River estuary. They are thought to move offshore with the tides (Baker 1989) presumably, to feed (Lawrence et al. 1992). Comeau (1915) found capelin, as well as whitefish and suckers in the stomachs of beluga whales from the Nelson River estuary.

6.0 CONCLUSIONS

Studies to date have provided a description of the distribution and abundance of biota in relation to estuarine zones of the Nelson River estuary under open water conditions. These studies have shown that the Nelson River estuary is among the more productive estuaries in Hudson Bay, and supports a greater density of organisms than adjacent marine waters of Hudson Bay. This estuary is markedly different than estuaries in the eastern Hudson/James Bay region because it is largely unstratified, while the latter are strongly stratified.

Diversion of the Churchill River and regulation of the upper Nelson River basin have altered the seasonal timing of freshwater input, but presumably not the physical structure of the estuary. How the change in seasonal supply of inorganic and organic nutrients has affected production of higher and lower trophic levels through hetero- and autotrophic pathways may only be postulated at this time. To understand the effects of changes in freshwater inputs on the Nelson River estuarine ecosystem, additional information on the relationships between seasonal freshwater input and the relative importance of productive pathways and mechanisms are required.

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Table 1. Depth, salinity, temperature and summary of information collected at each site during the August 1992 survey of the Nelson River estuary.

Date	Site	Zone	Depth (m)	Temperature		Salinity		Temperature/ Salinity	Water Chemistry	Phytoplankton	Zooplankton	Isaacs-Kidd Trawl
				Surface	Bottom	Surface	Bottom					
Aug 19	1	S	8									X
Aug 19	2	S	5	15.1	15.1	1.8	1.8	X				X
Aug 19	3	OE	4	10.3	10.3	15.4	15.4	X				X
Aug 19	4	S	12	11.0	8.5	15.0	19.0	X			X	X
Aug 22	5	R	2.44	14.9	14.8	0	0	X			X	X
Aug 22	6	NE	8.51	13.0	11.6	3.7	8.2	X	X	X	X	X
Aug 22	7	NE	3.37	14.1	13.2	1.0	4.45	X	X	X	X	X
Aug 23	8	S	4.7	12.6	10.6	4.9	10.1	X	X	X	X	X
Aug 23	9	abandoned										
Aug 23	10	OE	6.9	6.0	5.67	26.0	26.2	X	X	X	X	X
Aug 23	11	OE	3.6	9.7	9.14	13.5	15.19	X	X	X	X	X
Aug 23	12	NE	2.86	13.4	12.85	0.59	3.96	X	X	X	X	X
Aug 25	13	OE	6.1	6.3	4.9	26.0	27.7	X	X	X	X	X
Aug 25	14	OE	6	8.5	6.5	20.2	23.7	X	X	X	X	X
Aug 25	15	S	9	13.8	7.8	5.0	18.5	X	X	X	X	X
Aug 25	16	S	24	14.9	9.5	0	15.5	X	X	X	X	X
Aug 25	17	R	6	14.5	14.5	0	0	X	X	X	X	X
Aug 25	18	R	5	16.0	16.0	0	0	X	X	X	X	X

Table 2. Average water chemistry parameters from the four estuarine zones, August 1992 for surface (SUR) and bottom (BOT) samples. Parameters are: nitrate (NO3), nitrite (NO2), ammonia (NH4), suspended nitrogen (Sus N), total dissolved nitrogen (TDN), suspended phosphorus (Sus P), total dissolved phosphorus (TDP), dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), suspended carbon (Sus C), chlorophyll a (Chl a), soluble reactive silica (SRSI), chlorine (Cl), sulphate (SO4), total suspended solids (TSS), conductivity (Cond), sodium (Na), phosphorus (K), magnesium (Mg), calcium (Ca), iron (Fe), pH, alkaline (Alk).

Station	Depth	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	SUS N (ug/l)	TDN (ug/l)	Sus P (ug/l)	TDP (ug/l)	DIC (um/l)	DOC (um/l)	Sus C (ug/l)	Chl a (ug/l)	SRSI (mg/l)	Cl (mg/l)	SO4 (mg/l)	TSS (mg/l)	Cond. (uS)	Na (mg/l)	K (mg/l)	Mg (mg/l)	Ca (mg/l)	Fe (mg/l)	pH	Alk (ueq/l)
Riverine	SUR	4	1	30	84	350	19	11	1745	575	1065	4.90	0.56	10	14	18	227	10	2	8	25	0.65	8.61	1710
Nearshore	SUR	2	0	33	91	263	22	12	1763	513	1177	4.10	0.46	687	110	22	2449	321	14	47	39	0.30	8.54	1752
	BOT	5	0	80	157	295	57	15	1825	545	4790	4.70	0.49	2930	405	94	9179	1115	49	145	70	0.35	8.44	1956
Stratified	SUR	4	0	67	74	253	17	12	1843	387	787	3.53	0.48	2001	305	20	6277	923	42	130	63	0.53	8.50	1798
	BOT	8	1	155	302	400	105	21	1960	120	8175	5.65	0.45	7900	1040	177	22095	3240	172	395	174	0.45	8.37	2093
Offshore	SUR	6	1	268	43	515	13	33	2040	88	558	0.69	0.21	11475	1508	45	30670	4728	226	560	223	0.58	8.31	2070

Table 3. Species list of phytoplankton collected in the Nelson River estuary, August 1992.

CLASS Species
DINOPHYCEAE (dinoflagellates)
Gymnodinium sp.
Peridinium inconspicum
CRYPTOPHYCEAE (cryptophytes)
Cryptomonas rostratiform
Katablepharis ovalis
Rhodomonas minuta
CHRYSOPHYCEAE (chrysophytes)
Chrysidiastrum catenatum
Ochromonas sp.
Ophiocytium cochleare
Stelexomonas dichotoms
Stichogloea spp.
BACILLARIOPHYCEAE (diatoms)
Amphora sp.
Asterionella formosa
Chaetoceros sp.
Cyclotella bodanica
Cyclotella stelligera
Eunotia sp.
Fragilaria construens
Gomphonema sp.
Melosira binderana
Melosira italica
Navicula sp.
Nitzschia fonticola
Nitzschia filiformis
Rhoicosphenia curvata
Stephanodiscus astreae
Surirella delicatissima
Surirella ovata
Synedra acus
Synedra ulna
Tabellaria flocculsa

Table 3. (cont'd)

CLASS Species
CHLOROPHYCEAE (green algae)
Ankistrodesmus braunii
Ankrya judai
Botryococcus braunii
Chlamydomonas spp.
Closterium kutzingii
Closterium sp.
Crucigeniella quadrata
Monoraphidium contortum
Monoraphidium setiforme
Monoraphidium sp.
Mougeotia sp.
Oocystis borgei
Pediastrum duplex
Tetraedron minimum
Scenedesmus denticulatus
Scenedesmus quadricauda
Staurastrum paradoxum
Staurastrum sp.

Table 4. Density (cells/1 x 1,000) and biomass (mg/m^3) of major phytoplankton groups from samples collected in the Nelson River estuary, August 1992. The four zones of the estuary were: riverine (R), nearshore estuarine (NE), stratified (S), and offshore estuarine (OE).

Site	Location	Zone	Cyanophyte		Chlorophyte		Euglenophyte		Chrysophyte		Diatom		Cryptophyte		Total		# of Species
			cells/l	mg/m^3	cells/l	mg/m^3	cells/l	mg/m^3	cells/l	mg/m^3	cells/l	mg/m^3	cells/l	mg/m^3	cells/l	mg/m^3	
6	surface	NE	35.9	1.7	255.8	70.7	0	0.0	423.9	27.9	141.4	89.4	0	0.0	857.0	189.6	27
6	bottom	NE	0	0.0	110.0	74.6	0	0.0	107.8	1.5	48.2	296.5	0	0.0	265.9	372.6	23
7	surface	NE	0	0.0	169.0	12.7	0	0.0	553.2	111.9	110.5	387.0	0	0.0	832.7	511.6	27
8	surface	S	230.3	3.9	539.2	132.0	0	0.0	14.4	0.2	51.0	108.2	0	0.0	834.8	244.3	25
8	bottom	S	0	0.0	119.3	24.8	0	0.0	57.5	0.8	34.0	511.8	0	0.0	210.8	537.4	16
10	surface	OE	0	0.0	14.4	1.2	0	0.0	172.4	6.4	22.4	53.0	71.8	18.4	281.4	84.4	19
11	surface	OE	0	0.0	136.7	28.4	0	0.0	237.1	4.0	37.5	58.4	86.2	9.5	497.5	100.3	21
12	surface	NE	0.2	0.8	234.9	35.0	7.2	10.3	215.5	29.7	178.7	354.7	0	0.0	636.5	430.3	30
12	bottom	NE	0	0.0	482.7	59.4	7.2	14.6	143.7	9.3	167.2	525.7	0	0.0	800.8	609.1	27
13	surface	OE	0	0.0	28.9	17.8	0	0.0	301.7	4.3	3.0	8.2	7.2	0.9	340.8	31.2	9
14	surface	OE	0	0.0	74.8	31.4	0	0.0	114.9	1.6	67.1	63.6	0	0.0	256.8	96.6	11
15	surface	S	0	0.0	390.9	174.3	7.2	3.9	122.1	2.7	27.2	98.3	28.7	4.3	576.2	283.4	20
16	surface	S	0.2	1.9	167.8	43.7	0	0.0	165.2	4.0	98.0	555.8	0	0.0	431.2	605.4	23
16	bottom	S	0	0.0	208.7	53.3	0	0.0	165.2	2.7	125.2	247.6	0	0.0	499.1	303.6	21
17	surface	R	0	0.0	105.4	73.9	7.2	2.5	316.1	11.7	118.9	438.7	43.7	7.2	591.2	534.0	29
18	surface	R	0	0.0	139.5	37.5	7.2	6.0	100.6	1.8	122.2	290.0	21.8	2.0	391.2	337.3	26
TR1	surface	R	0	0.0	130.5	16.6	0	0.0	43.1	2.5	77.7	220.1	0	0.0	251.3	239.3	21
TR2	surface	R	0	0.0	51.9	17.4	0	0.0	222.7	3.9	74.6	278.2	0	0.0	349.2	299.5	19
TR3	surface	NE	0	0.0	126.3	26.5	0	0.0	136.5	1.9	82.7	289.5	0	0.0	345.6	318.0	22
TR4	surface	NE	0	0.0	151.3	36.7	0	0.0	237.1	4.6	30.8	163.5	0.4	0.8	419.7	208.8	22
TR5	surface	NE	0	0.0	151.1	119.8	0	0.0	122.1	4.6	64.5	33.7	0	0.0	344.8	175.5	15
TR6	surface	NE	0	0.0	237.1	25.1	0	0.0	222.7	2.0	17.6	23.0	36.0	3.9	513.3	54.0	13
TR7	surface	OE	0	0.0	165.2	143.4	0	0.0	229.9	3.2	12.2	36.1	7.2	0.9	421.7	186.5	12
TR8	see 13																

Table 5. Numbers and taxon of organisms collected in zooplankton tows in the Nelson River estuary, August 1992.

	Riverine Zone			Nearshore Estuarine Zone			Stratified Zone				Offshore Estuarine Zone			
	5	17	18	6	7	12	4	8	15	16	10	11	13	14
Ph. ANNELIDA														
Cl. Oligochaeta	40	80	60											6
Cl. Polychaeta														
Autolytes alexandri											4		6	
Syllidae													30	
Ph. ARTHROPODA														
Cl. Arachnida														
O. Acarina														
Hydracarina					1	1								
Cl. Crustacea														
SCl. Branchiopoda														
O. Diplostraca														
Bosmina sp.					10	200				32				
Daphnia sp.					10									
SCl. Copepoda														
O. Calanoida							10000						10	
Acartia sp.													22000	
Acartia clausi		40		63400	8000	29700	700000	942000	91000	164512	121500	2070000	106000	115400
Acartia longiremis								200			100		1100	
Calanus glacialis						2	400	1			134	1	1	26
Derjuginia tolli											1		10	
Diaptomus sp.					30				10					
Ectinosomidae						1								1
Epischura lacustris				1	51	2							10	
Epischura nevadensis						2								
Eurytemora sp.									20				620	60
Eurytemora americana				40	10			2200			20	100	180	
Eurytemora herdmani						10	600				4420	200	10	10
Eurytemora raboti				660	155	587				544	10	20	20	
Pseudocalanus minutus						20	4000	600	30		11600	220	460	250
O. Harpacticoida														
Harpacticus uniremis														7
O. Cyclopoida														
Tisbe furcata		200	20	20	60	500				96	30		10	
SCl. Cirripedia							200		10		8610	100	2700	1501

Table 5. Continued.

	Riverine Zone			Nearshore Estuarine Zone			Stratified Zone				Offshore Estuarine Zone			
	5	17	18	6	7	12	4	8	15	16	10	11	13	14
O. Amphipoda														
Gammarus setosus							1				1			2
Pontoporiea affinis											1			
Oedicerotidae														1
O. Decapoda														
Sec. Anomura							1				1		1	7
O. Mysidacea														
Mysis litoralis		1		20						33664				
O. Cumacea														1
SCl. Ostracoda														
Podocopa		1020	620	140	50	3		400		192	30	300		
Cl. Insecta														
O. Diptera														
Orthocladinae	60	60	80	1	1									
Chironomidae		60												
O. Trichoptera														
Hydropsychidae	20		20			1								
Psychomyidae			20											
O. Ephemeroptera					3	1								
Ph. CHAETOGNATHA														
Sagitta elegans							1				5		4	1
Ph. CNIDARIA														
Cl. Hydrozoa														
Aglantha digitale							1							
Hydra sp.	20	460	780		10	10								
Sarsia princeps													3	5
Ph. MOLLUSCA														
Cl. Bivalvia													10	10
Cl. Gastropoda			40											
Ph. CHORDATA														
Cl. Larvacea														
Oikoplera sp.													1	
Fritillaria borealis													1	
Cl. Pices														
Ammodytes hexapterus				18+7		1	680	48	20	1	100	401	26	22
TOTAL	140	1921	1640	64307	8391	31041	715884	945449	91090	199041	146567	2071342	133233	117312

Table 6. Details of zooplankton tows conducted in the zones of the Nelson River estuary, August 1992.

Zone	Trawl #	Distance through water (m)	Volume (m^3)	# Zooplankters/m^3	Average/m^3/zone
Riverine	5	321	63	2	
	17	581	114	17	
	18	484	95	17	12
Nearshore Estuarine	6	542	106	607	
	7	459	90	93	
	12	351	69	450	383
Stratified	4	407	80	8,949	
	8	539	106	8,919	
	15	563	111	821	
	16	781	153	1,301	4,998
Offshore Estuarine	10	511	100	1,466	
	11	534	105	19,727	
	13	560	110	1,211	
	14	355	70	1,676	6,020

Table 7. Numbers of organisms by taxon and site collected in Isaacs-Kidd trawls from the Nelson River estuary, August 1992.

	Riverine Zone			Nearshore Estuarine Zone				Stratified Zone					Offshore Estuarine Zone			
Taxa	5	17	18	1	2	7	12	3	4	8	15	16	10	11	13	14
Ph. Arthropoda																
Cl. Crustacea																
O. Amphipoda																
Gammarus loricatus				1	1											
Onisimus glacialis															1	
O. Mysidacea																
Mysis litoralis					695196		417366									
Ph. Mollusca																
Cl. Bivalvia																
Sphaeriidae								2						5		
Ph. Chordata																
Cl. Pices																
Salmonidae																
Coregonus artedii	2		2	3	1		10					1				
Osmeridae																
Mallotus villosus														12		
Gasterosteidae																
Pungitius pungitius		1		1	2	1	3		2	46	1	9	1			
Gasterosteus aculeatus			1			1				2						
Cottidae																
Myoxocephalus quadricornis	1			7	24											
Stichaeidae																
Lumpenus fabricii								1								
Ammodytidae																
Ammodytes americanus							7	27	28	386		12		172		
TOTAL	3	1	3	12	695224	2	417386	30	30	434	1	22	1	189	1	0

Table 8. Details of Isaacs-Kidd mid-water trawls conducted in the riverine, nearshore estuarine, stratified and offshore estuarine zones of the Nelson River estuary, August 1992.

Zone	Trawl #	Tide	Direction[a] of tow	Distance through water (km)	Volume (m^3)	# Organisms/ 1000m^3
Riverine	5	flood	-	1.1[b]	2,607	1.2
	17	flood	+	2.9	6,873	0.2
	18	flood	+	2.6	6,162	0.5
Nearshore Estuarine	1	flood	+	2.2	5,214	2.3
	2	flood	+	2.2	5,214	133,400
	6	flood	-	1.1[b]	2,607	0.8
	7	slack	0	1.5[b]	3,555	0.5
	12	slack	0	1.4[b]	3,318	125,800
Stratified	3	flood	-	1.1	2,607	11.5
	4	slack	0	1.4	3,318	9.1
	8	flood	+	2.0[b]	4,740	91.7
	15	slack	0	1.3	3,081	0.4
	16	flood	+	1.9	4,503	4.9
Offshore Estuarine	10	flood	-	1.1[b]	2,607	0.4
	11	flood	+	2.4[b]	5,688	33.3
	13	ebb	+	1.5	3,555	0.3
	14	ebb	-	1.5	3,555	-

[a] + with tide; - against tide
[b] estimated

Table 9. Species and common name of known fresh and brackish water fish species from Hudson Bay, and their presence (X) in the Nelson River and Nelson River estuary.

Family Species	Common Name	Known Brackish Water Species	Known from Nelson River	Known from Nelson Estuary
Petromyzonidae				
Ichthyomyzon unicuspis	Silver lamprey		X	
Acipenseridae				
Acipenser fulvescens	Lake sturgeon	X	X	X
Hiodontidae				
Hiodon alosoides	Goldeye		X	
Hiodon tergisus	Mooneye		X	
Salmonidae				
Coregonus artedii	Lake cisco	X	X	X
Coregous clupeaformis	Lake whitefish	X	X	X
Coregonus cylindraceum	Round whitefish	X		
Salmo salar	Atlantic salmon	X		
Salvelinus alpinus	Arctic charr	X		
Salvelinus fontinalis	Brook trout	X	X	X
Salvelinus namaycush	Lake trout	X		
Thymallus arcticus	Arctic grayling			
Esocidae				
Esox lucius	Northern pike	X	X	X
Cyprinidae				
Cousesius plumbeus	Lake chub	X	X	
Notropis atherinoides	Emerald shiner		X	X
Notropis cornutus	Common shiner			
Notropis heterolepis	Blacknose shiner			
Notropis hudonius	Spottail shiner		X	X
Phoxinus eos	Northern redbelly dace	X	X	
Phoninus neogaeus	Finescale dace		X	X
Pimephales promelas	Fathead minnow		X	
Rhinythys cataractae	Longnose dace		X	X
Semotilus atromaculatus	Creek chub			
Semotilus corporalis	Fallfish			
Semotilus margarita	Pearl dace		X	X
Catostomidae				
Catostomus catostomus	Longnose sucker	X	X	X
Catostomus commersoni	White sucker	X	X	X
Moxostoma macrolepidotum	Shorthead redhorse	X	X	
Percopsidae				
Percopsis omiscomaycus	Trout-perch		X	X
Gadidae				
Lota lota	Burbot	X	X	X
Gasterosteidae				
Culea inconstans	Brook sticklback	X	X	X
Gasterosteus aculeatus	Threespine stickleback	X	X	X
Pungitius pungitius	Ninespine stickleback	X	X	X
Percidae				
Perca flavescens	Yellow perch		X	X
Stizostedion canadense	Sauger	X	X	
Stizostedion vitreum	Walleye	X	X	
Etheostoma exile	Iowa darter		X	
Etheostoma nigrum	Johnny darter		X	
Percina caprodes	Logperch		X	
Cottidae				
Cottus bairdi	Mottled sculpin			
Cottus cognatus	Slimy sculpin	X	X	X
Cottus ricei	Spoonhead sculpin	X	X	X

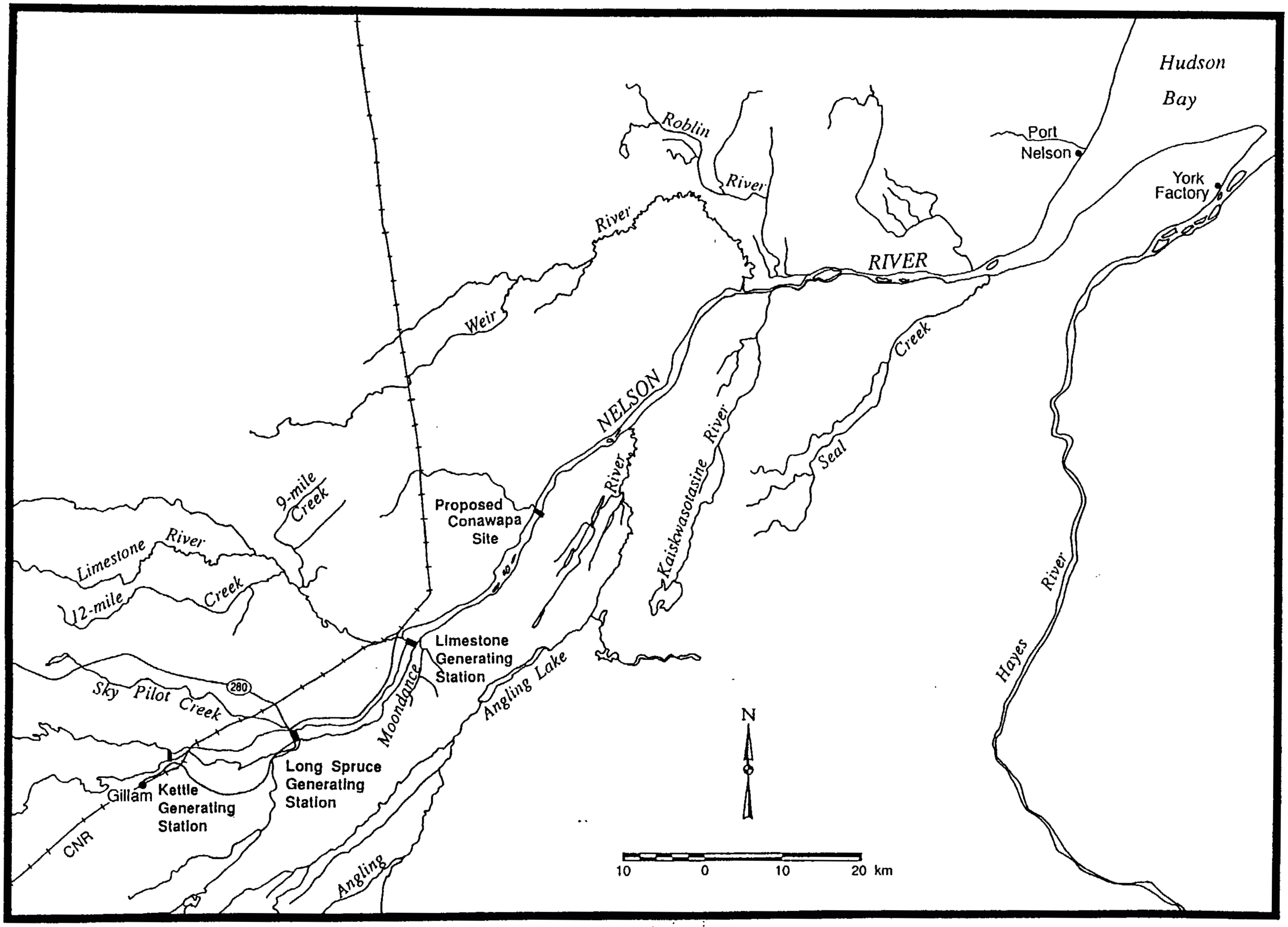


Figure 1. Location of the Nelson River estuary.

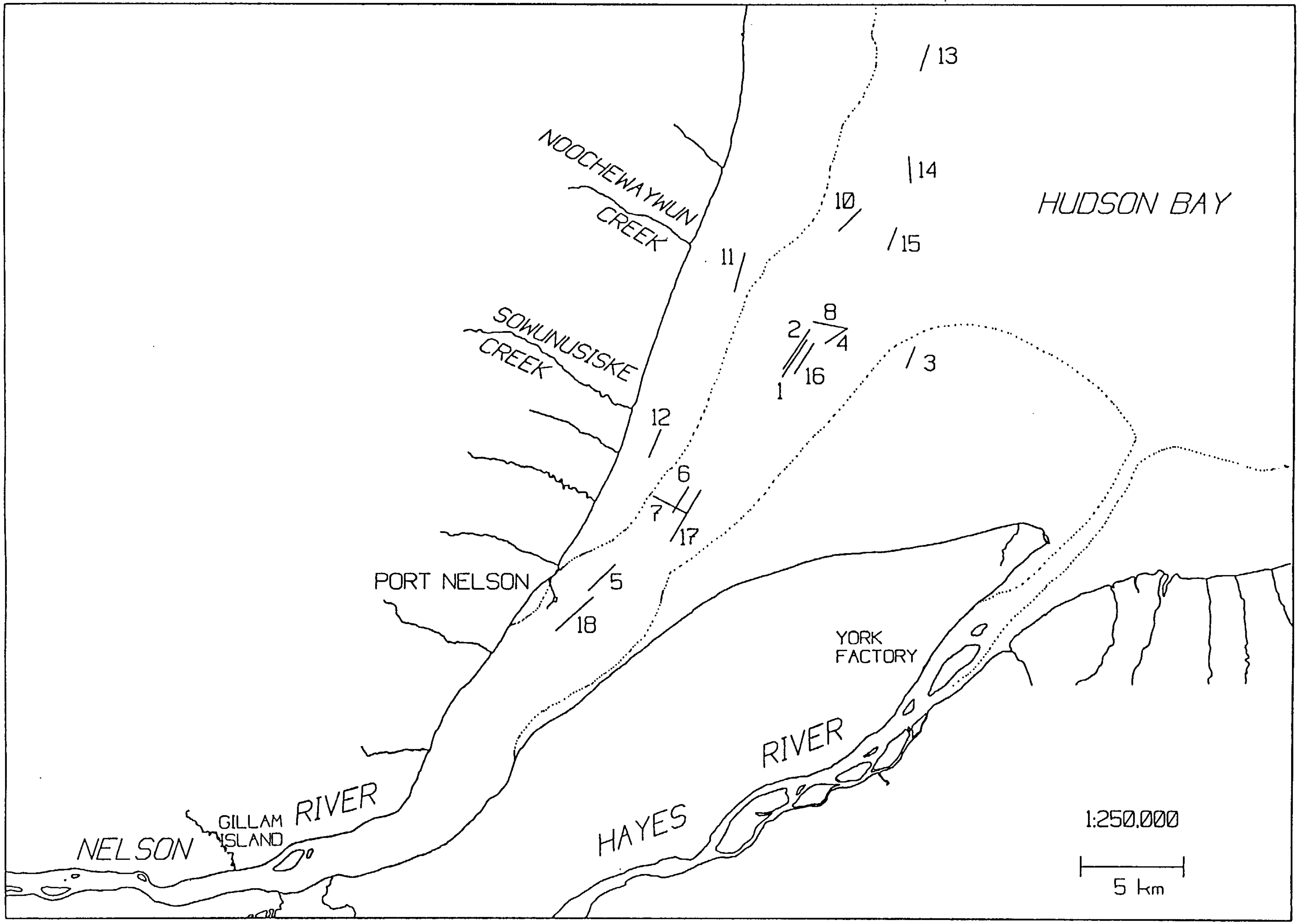


Figure 2. Sampling site locations for the August 1992 survey of the Nelson River estuary.

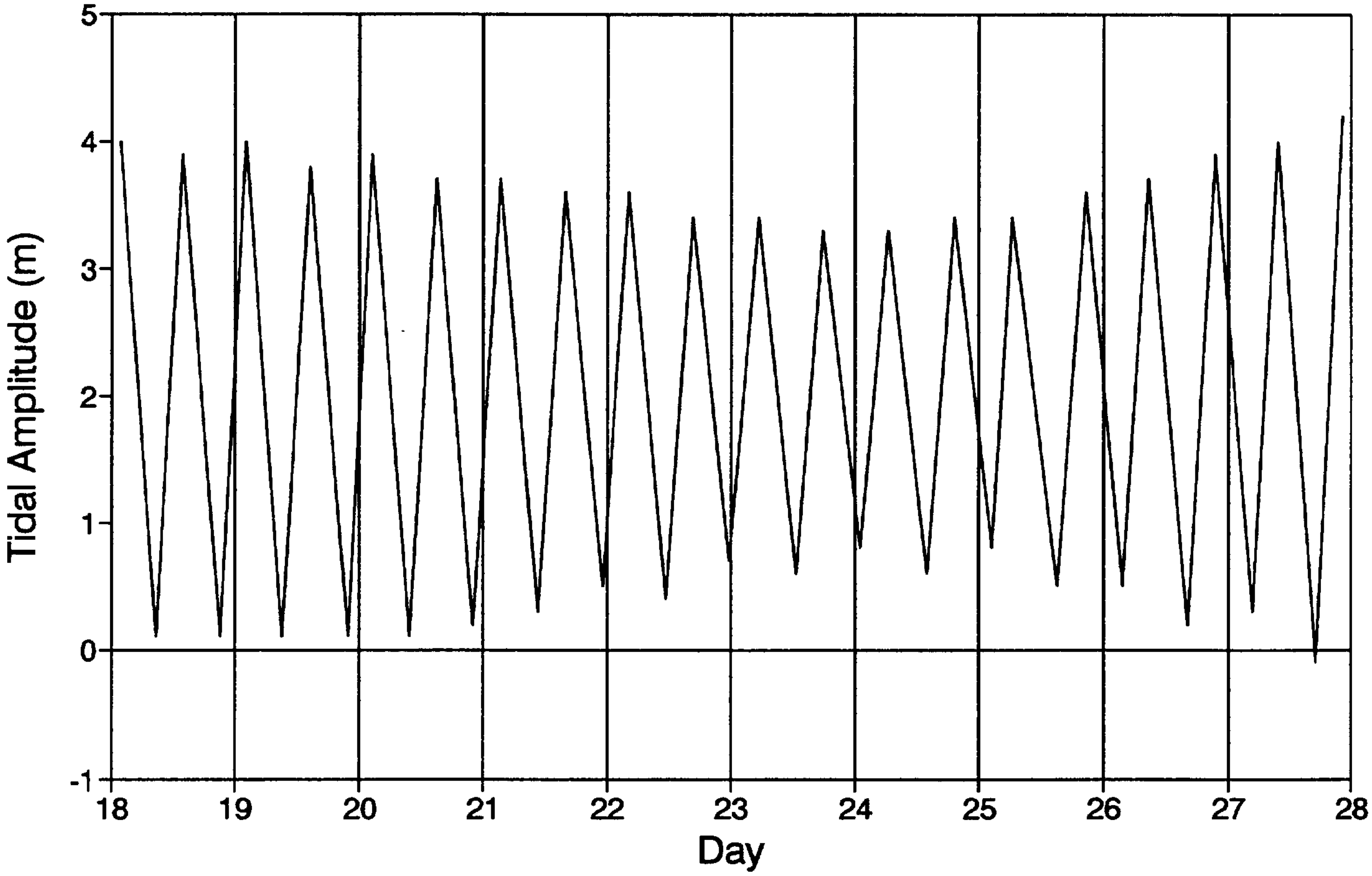


Figure 3. Estimated tidal amplitude (m) for Port Nelson between August 18 - 28, 1992.

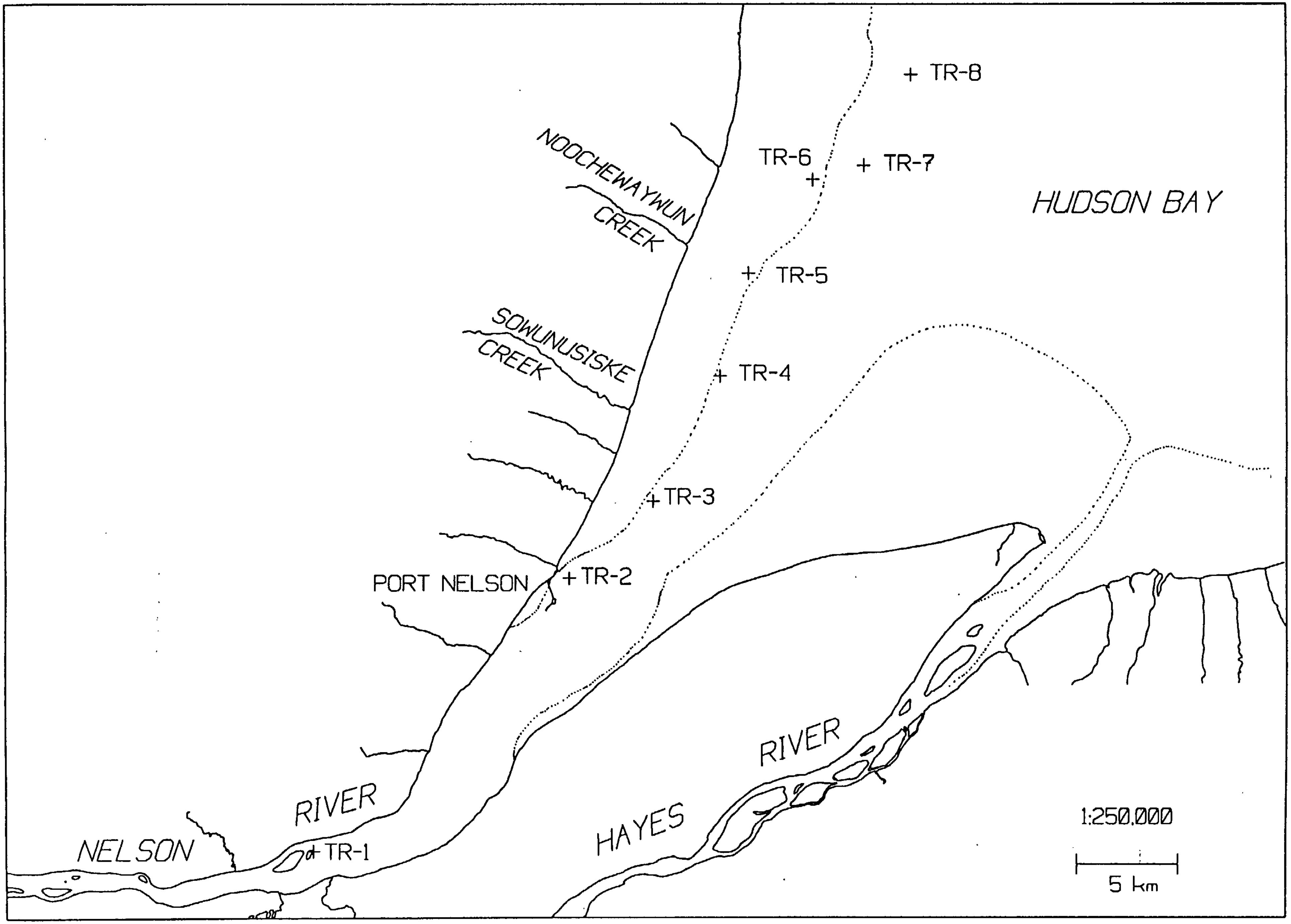


Figure 4. Transect site locations for the August 1992 survey of the Nelson River estuary.

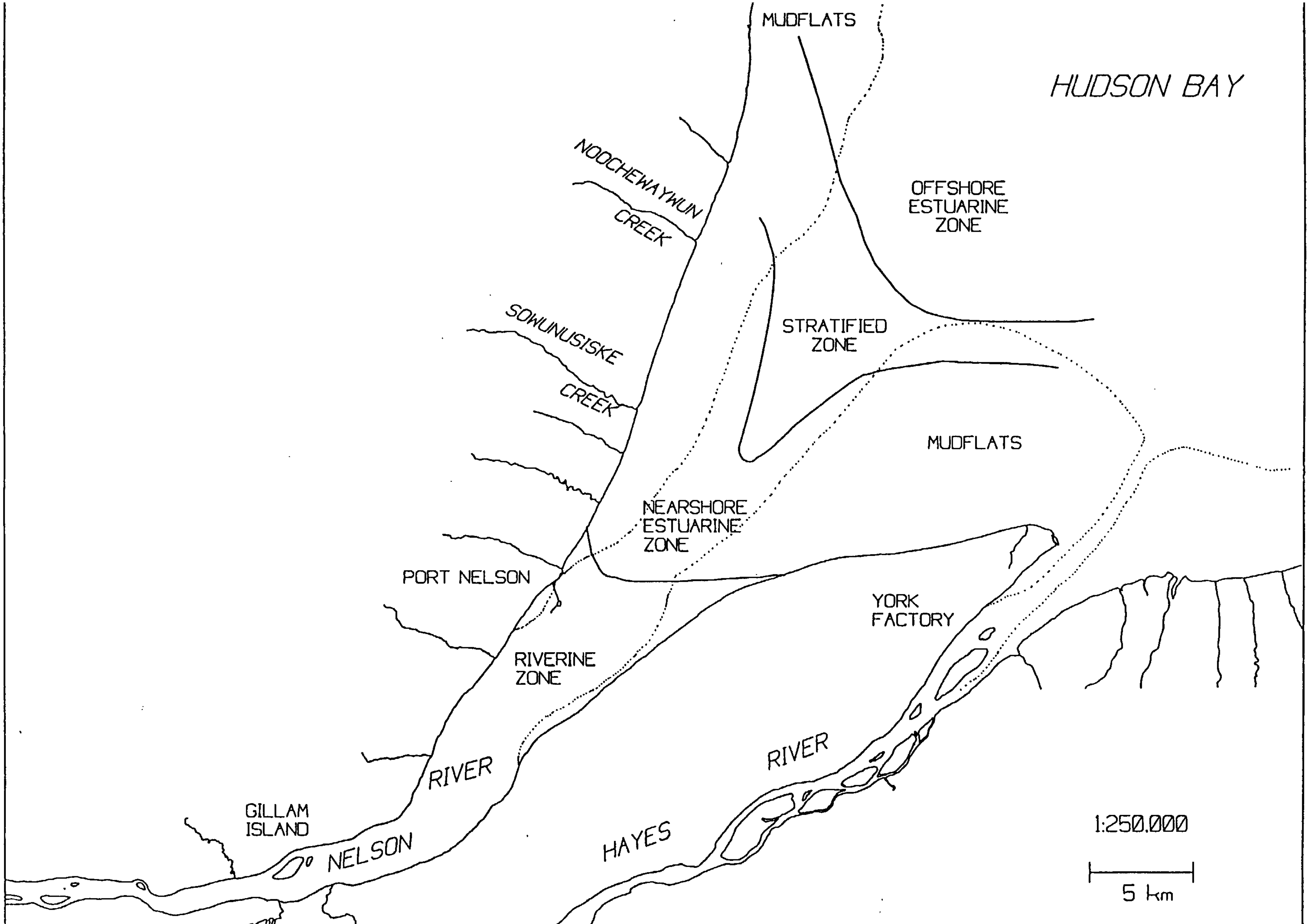


Figure 5. Riverine, nearshore, stratified and offshore estuarine zones described in 1988 survey of the Nelson River estuary (after Baker 1989).

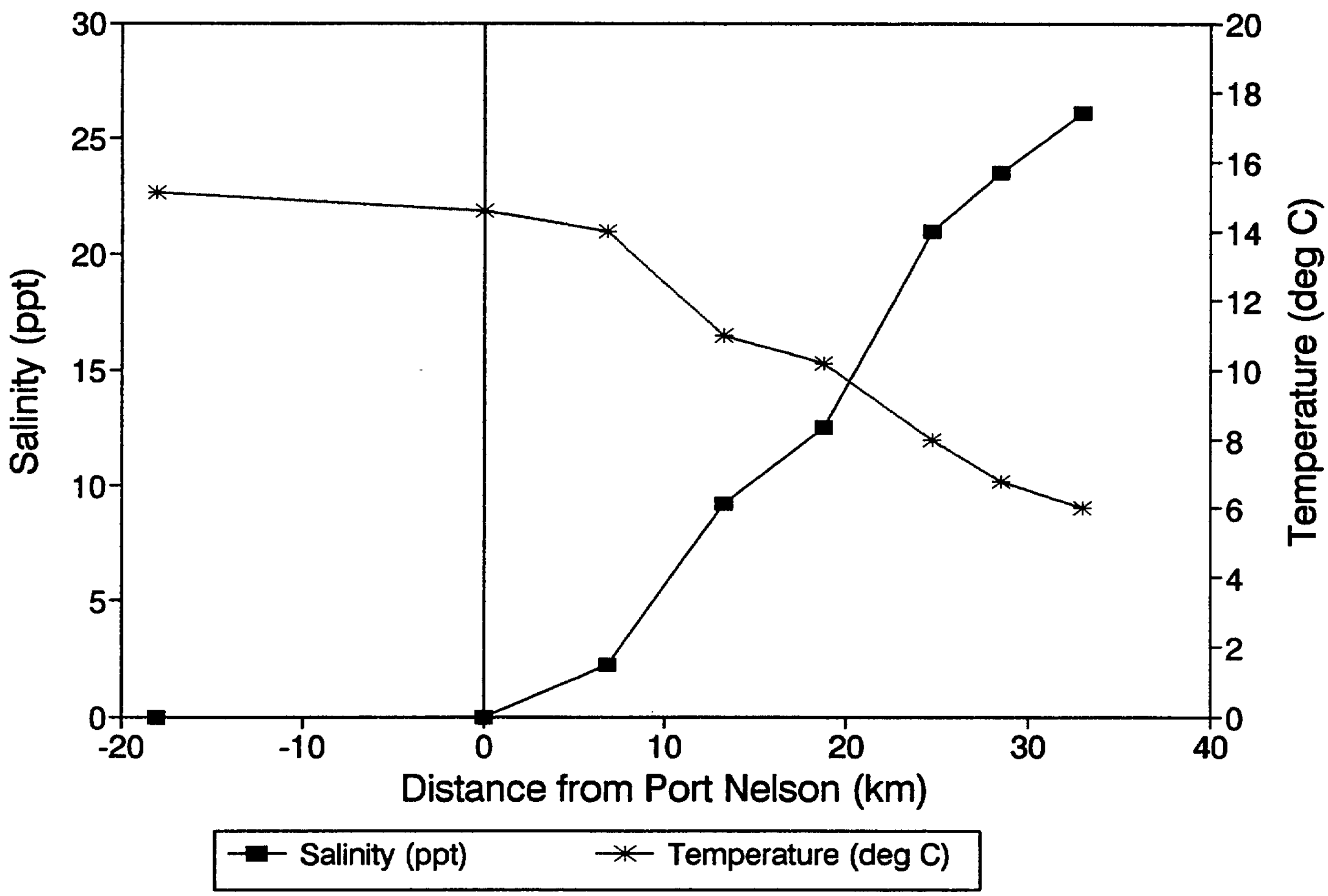


Figure 6. Salinity (ppt) and temperature (deg C) of surface waters for transect sites TR1 to TR8 from the Nelson River estuary, August, 1992.

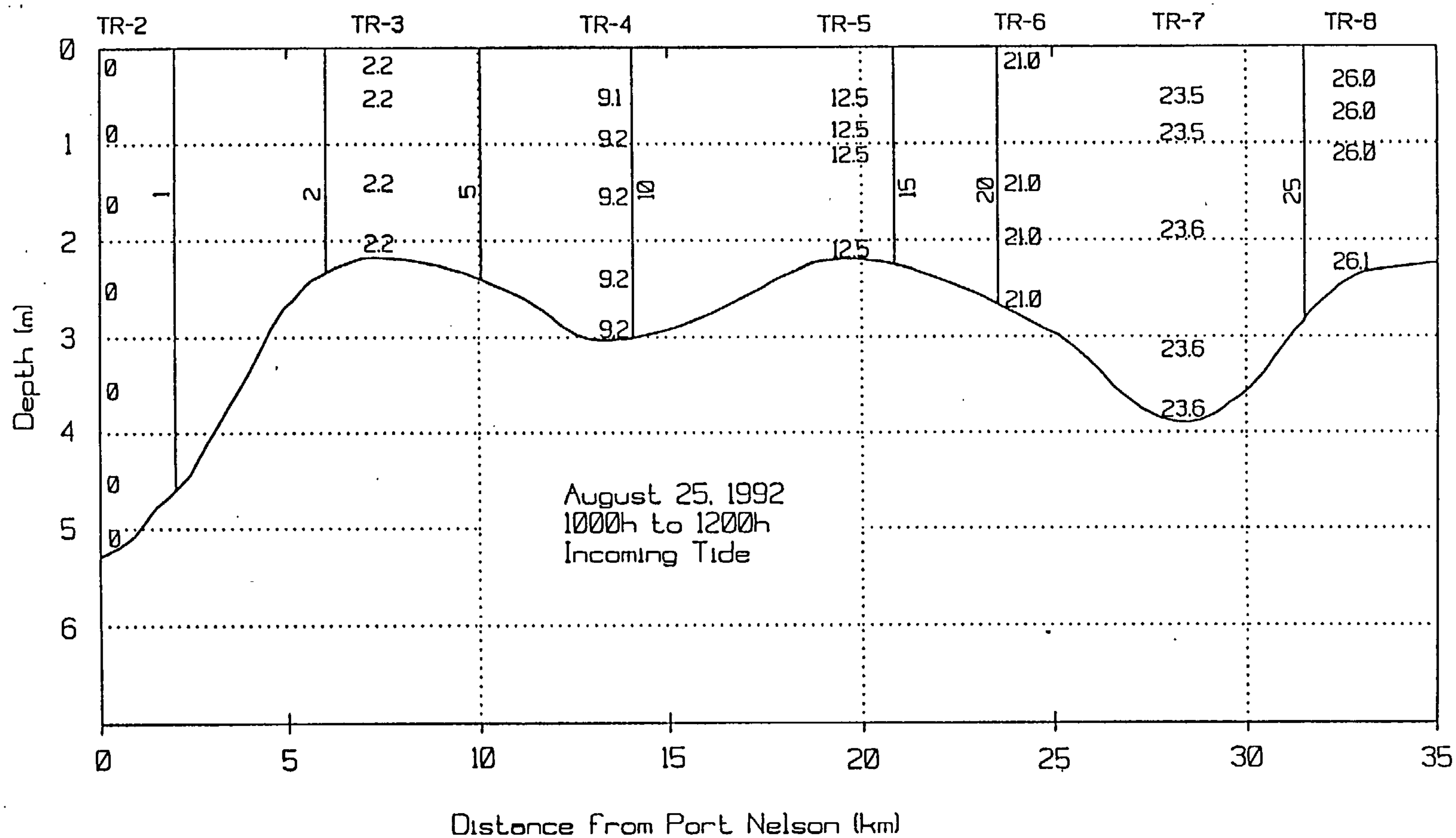


Figure 7. Vertical salinity (ppt) profile along transect sites TR2 to TR8, Nelson River estuary, August 1992.

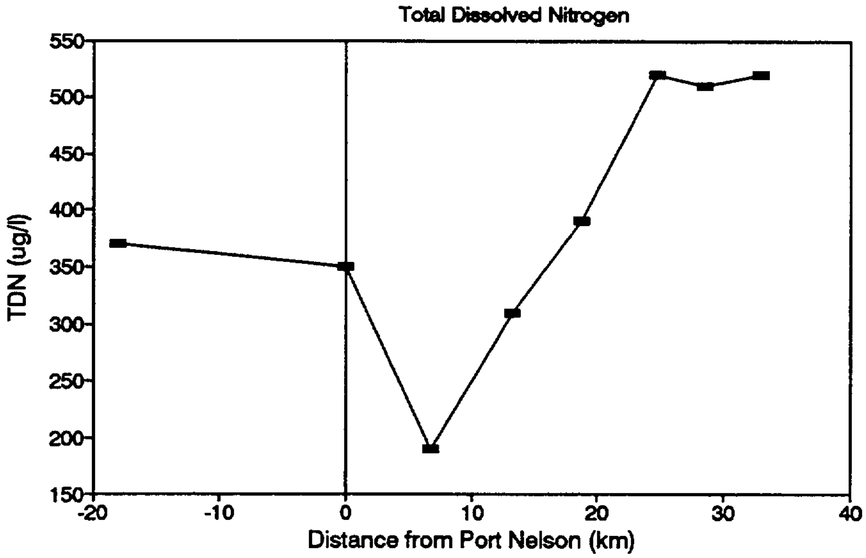


Figure 8. Relationship between total dissolved nitroben (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

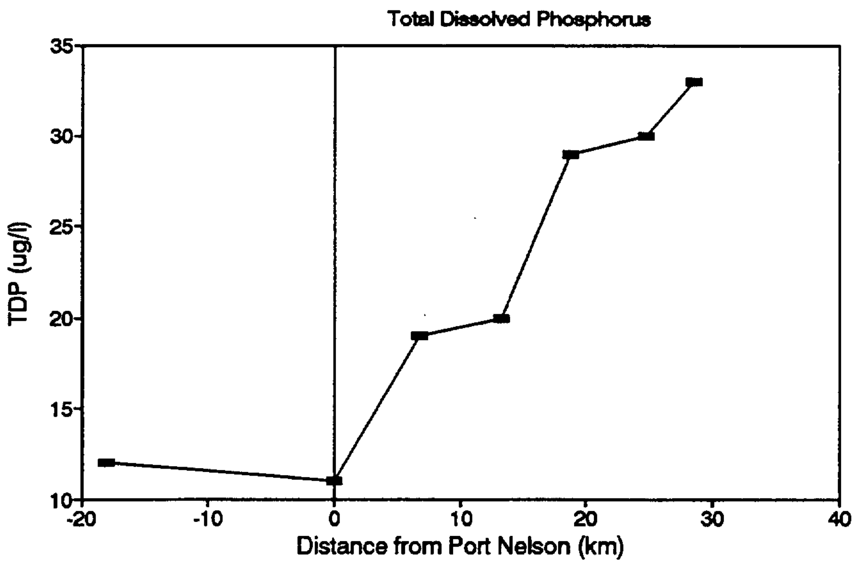


Figure 9. Relationship between total dissolved phosphorus (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

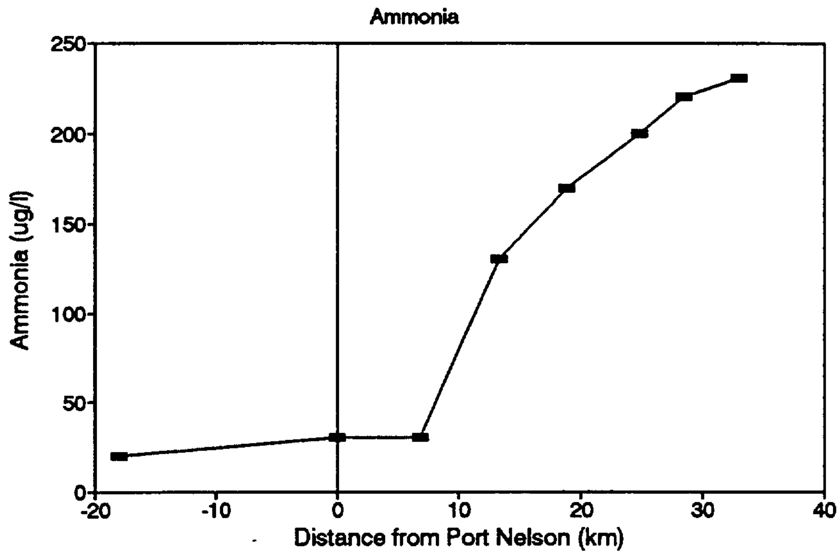


Figure 10. Relationship between ammonia concentrations (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

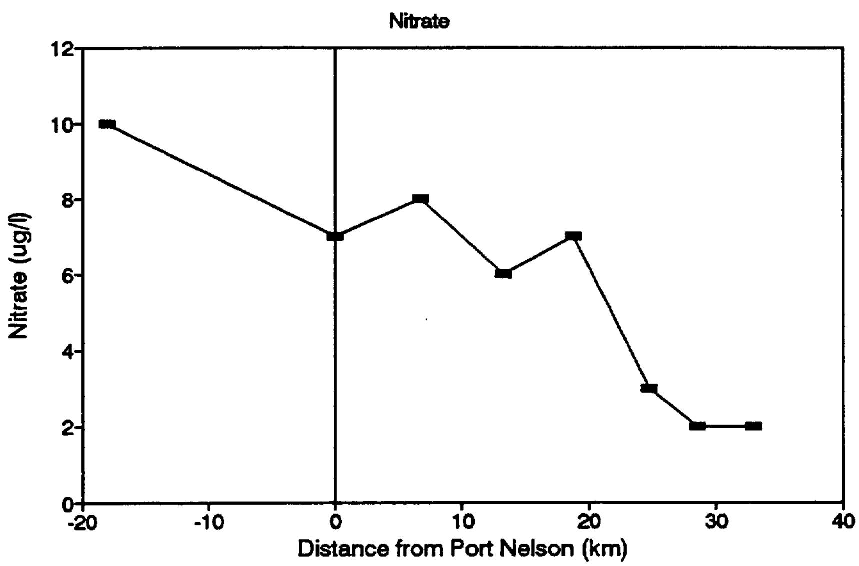


Figure 11. Relationship between nitrate concentrations (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

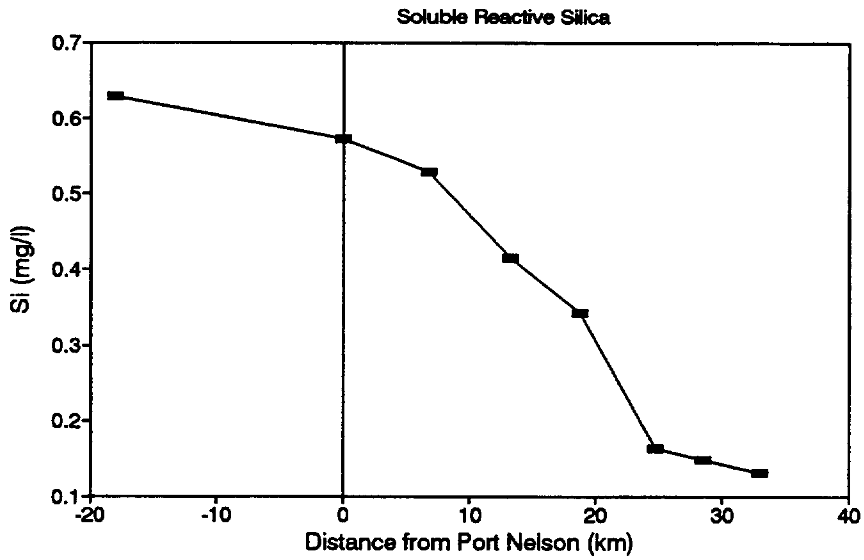


Figure 12. Relationship between soluble reactive silica (mg/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

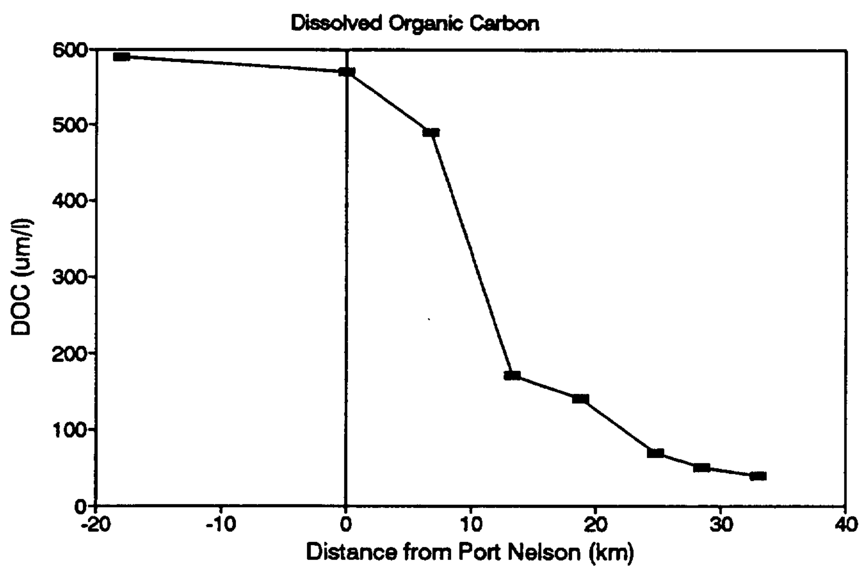


Figure 13. Relationship between dissolved organic carbon (um/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

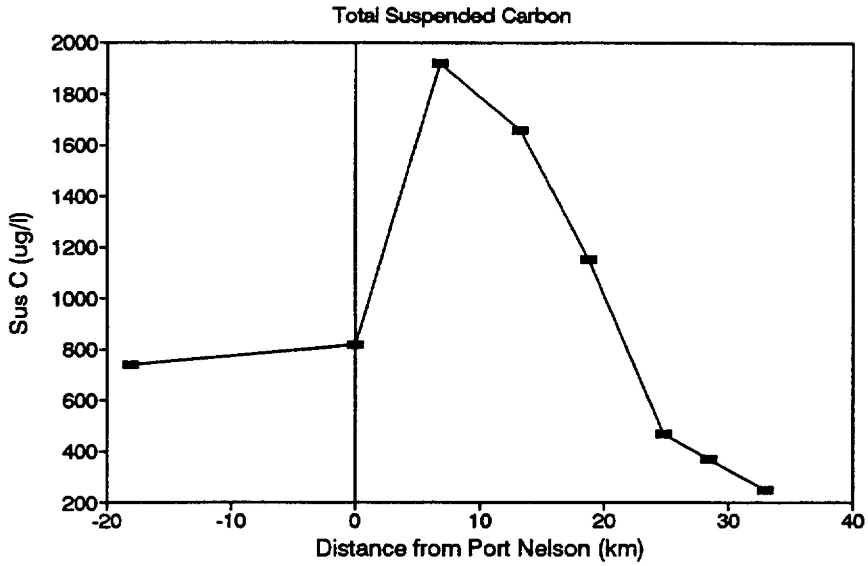


Figure 14. Relationship between total suspended carbon (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

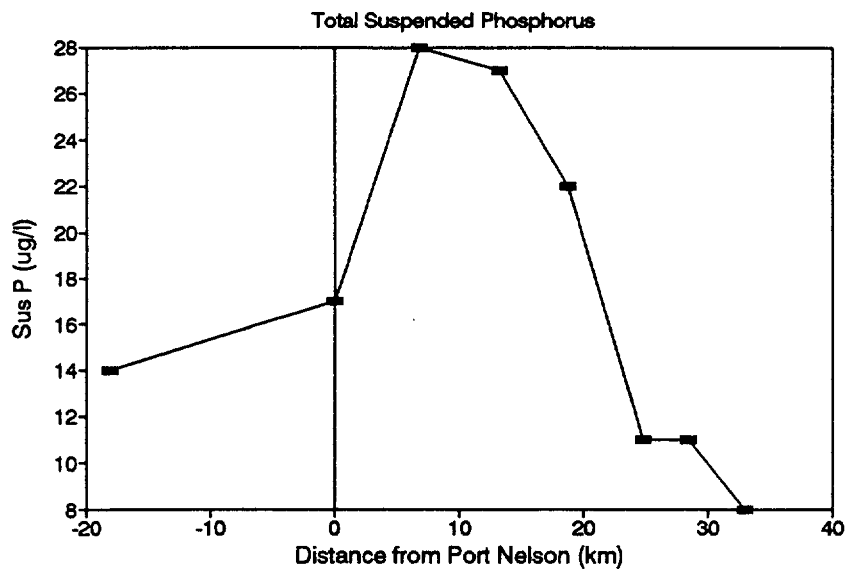


Figure 15. Relationship between total suspended phosphorus (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

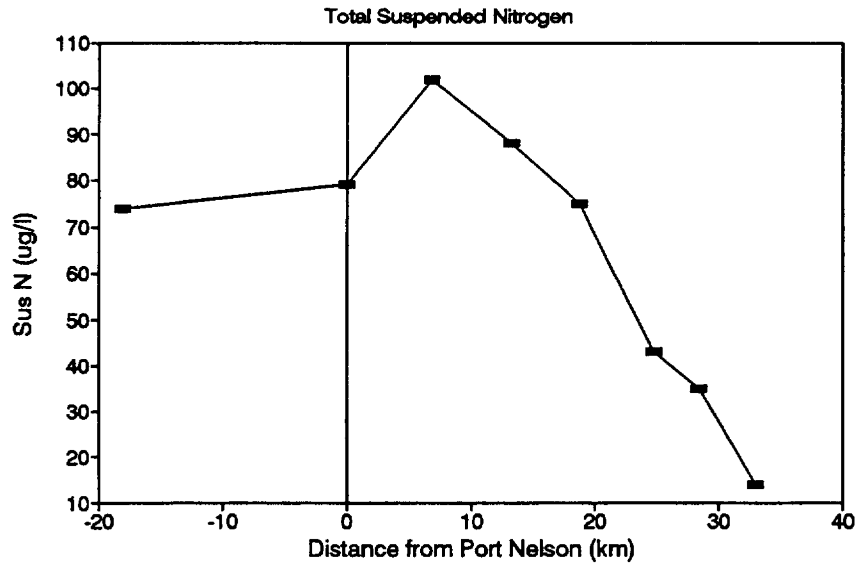


Figure 16. Relationship between total suspended nitrogen (ug/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

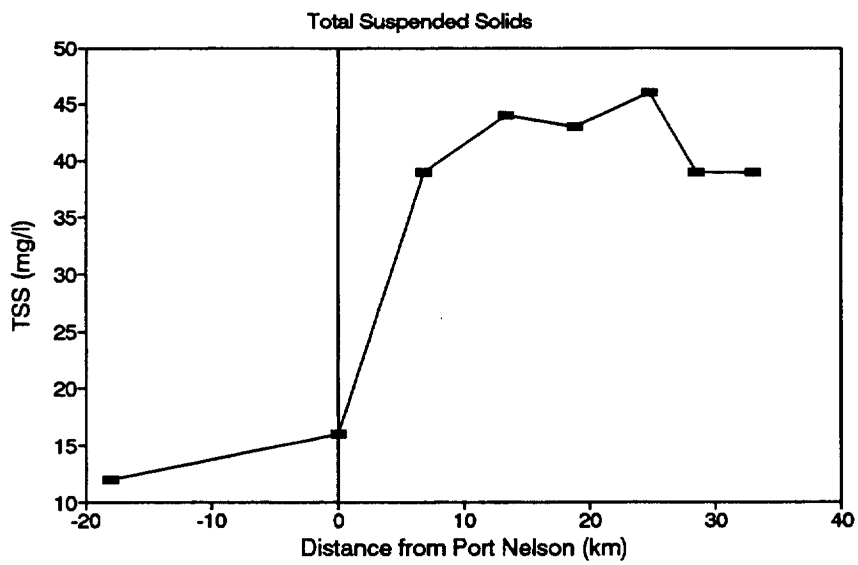


Figure 17. Relationship between total suspended solids (mg/l) and distance from Port Nelson, August 25, 1992 for samples TR1 to TR8.

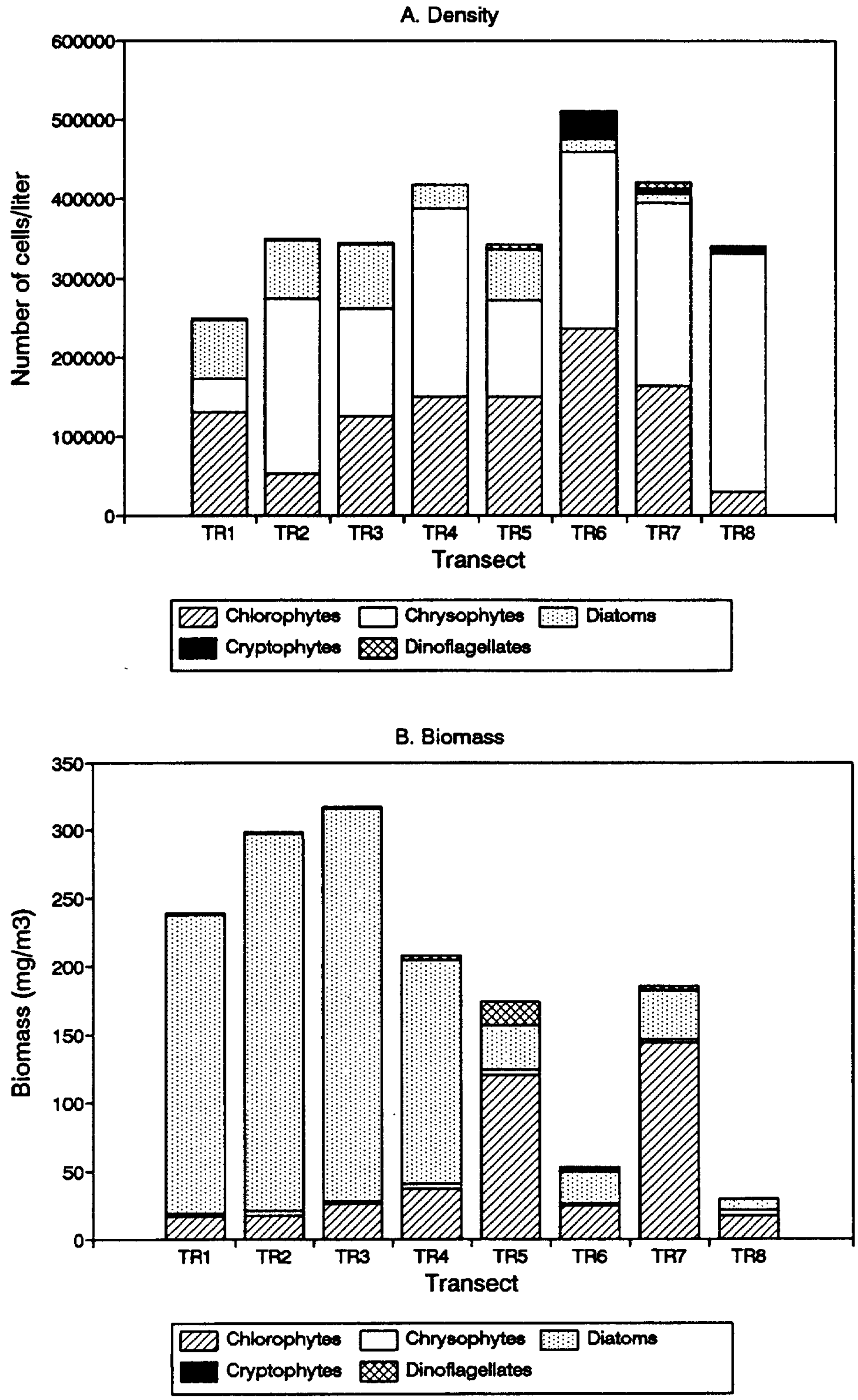
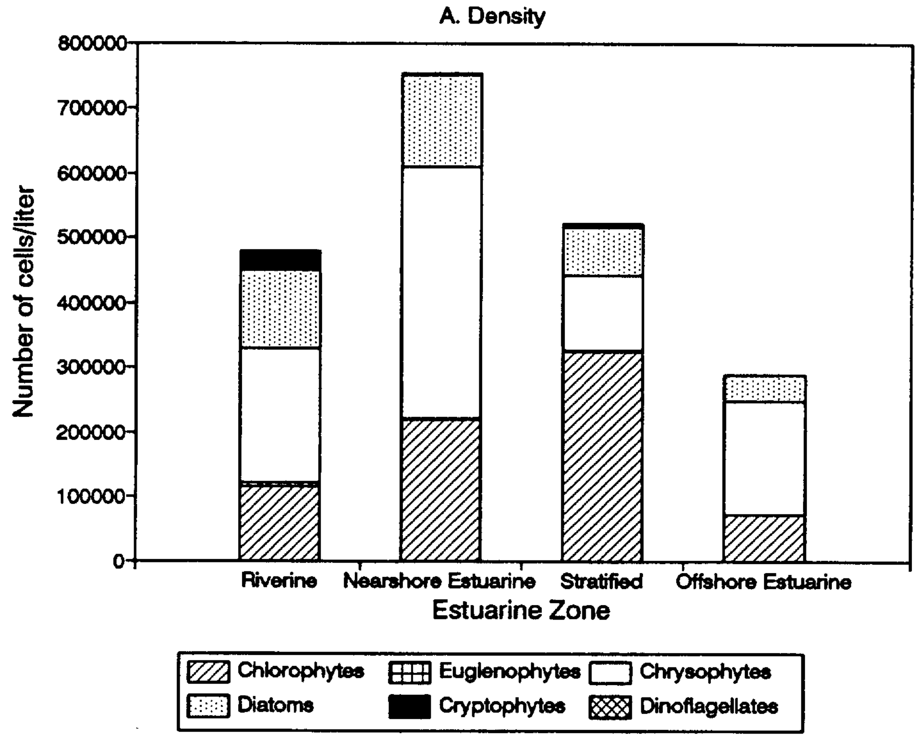


Figure 18. Phytoplankton density (cells/litre) and biomass (mg/m3) in surface water samples along transect sites TR2 to TR8, Nelson River estuary, August 1992.



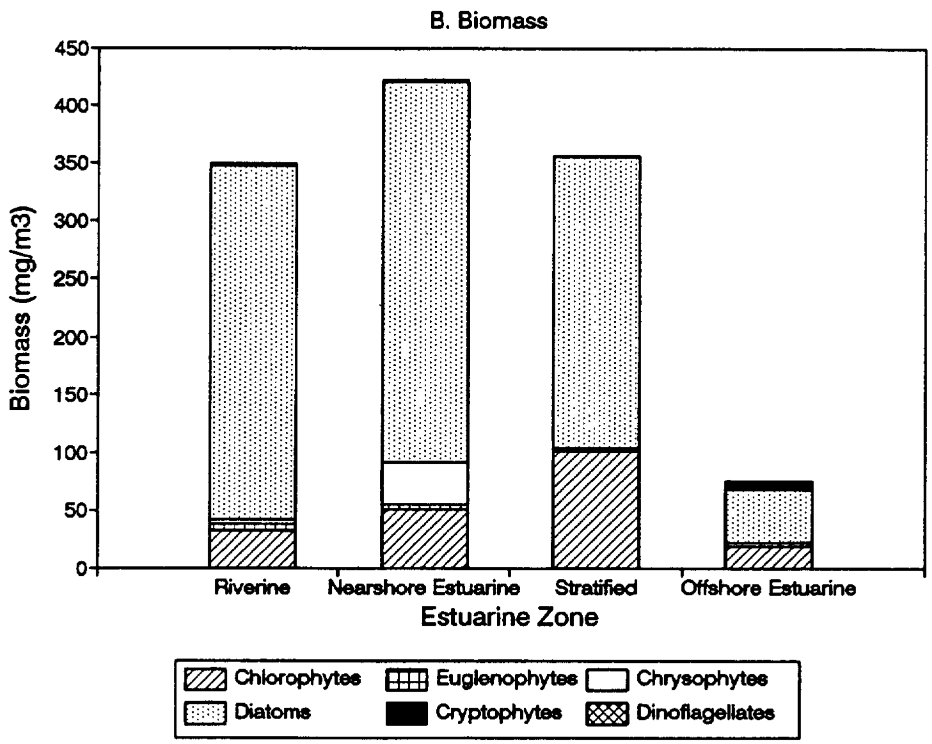


Figure 19. Phytoplankton density (# cells/l) and biomass (mg/m3) in zones of the Nelson River estuary, August 1992.

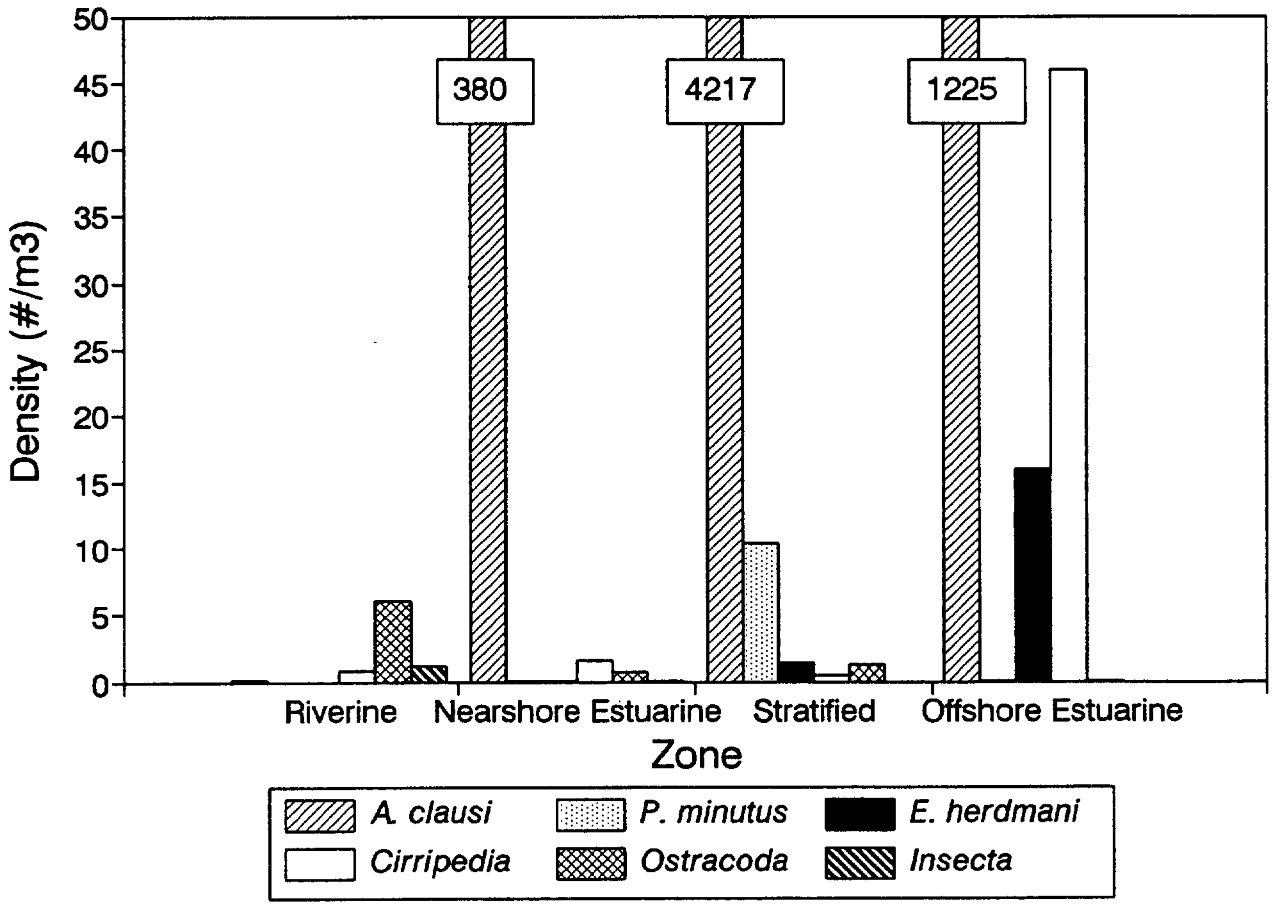


Figure 20. Density (#/m3) of zooplankters according to zones of the Nelson River estuary, August, 1992.

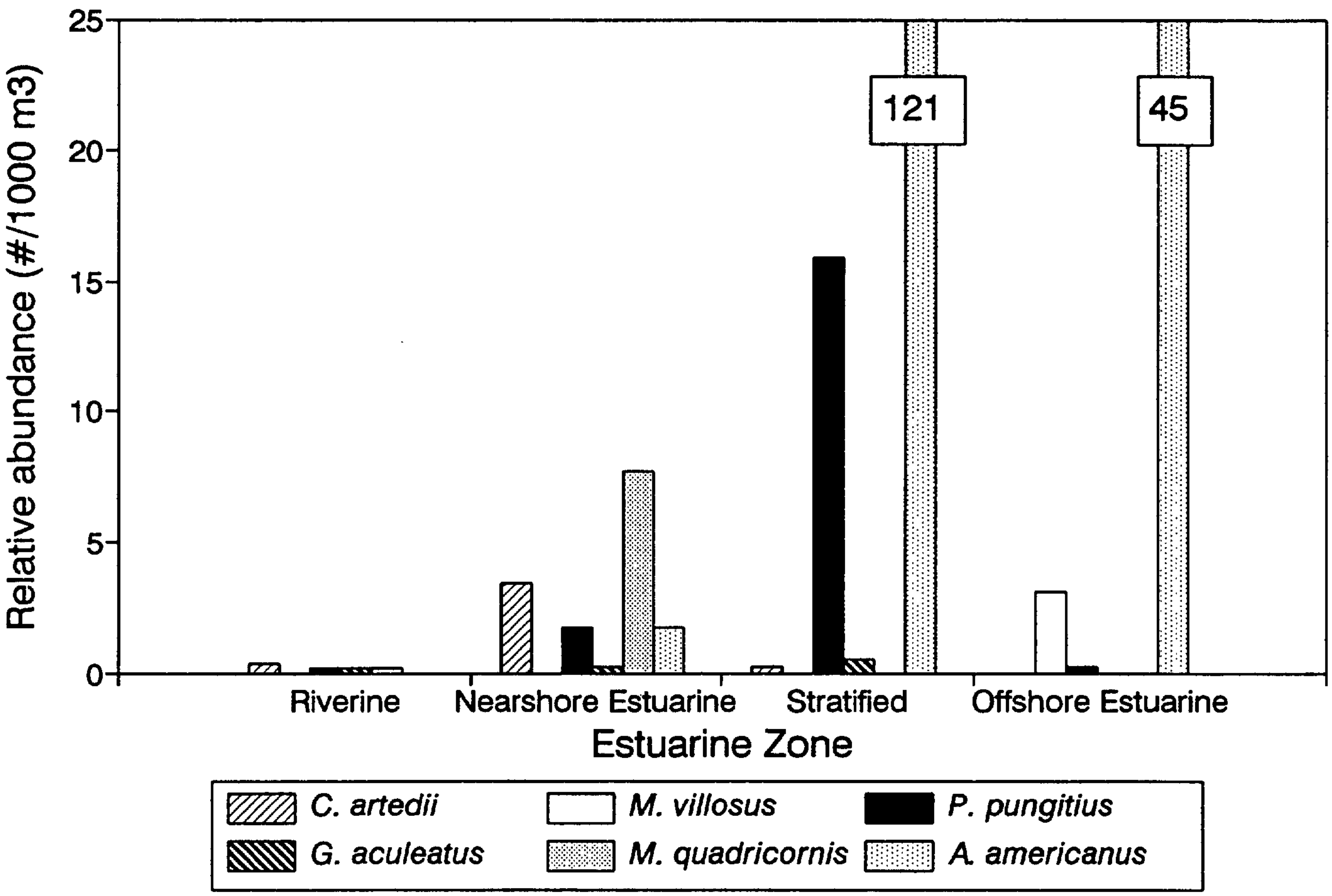


Figure 21. Density (#/1000 m3) of fish according to estuarine zone in Isaacs-Kidd trawls from the Nelson River estuary, August, 1992.

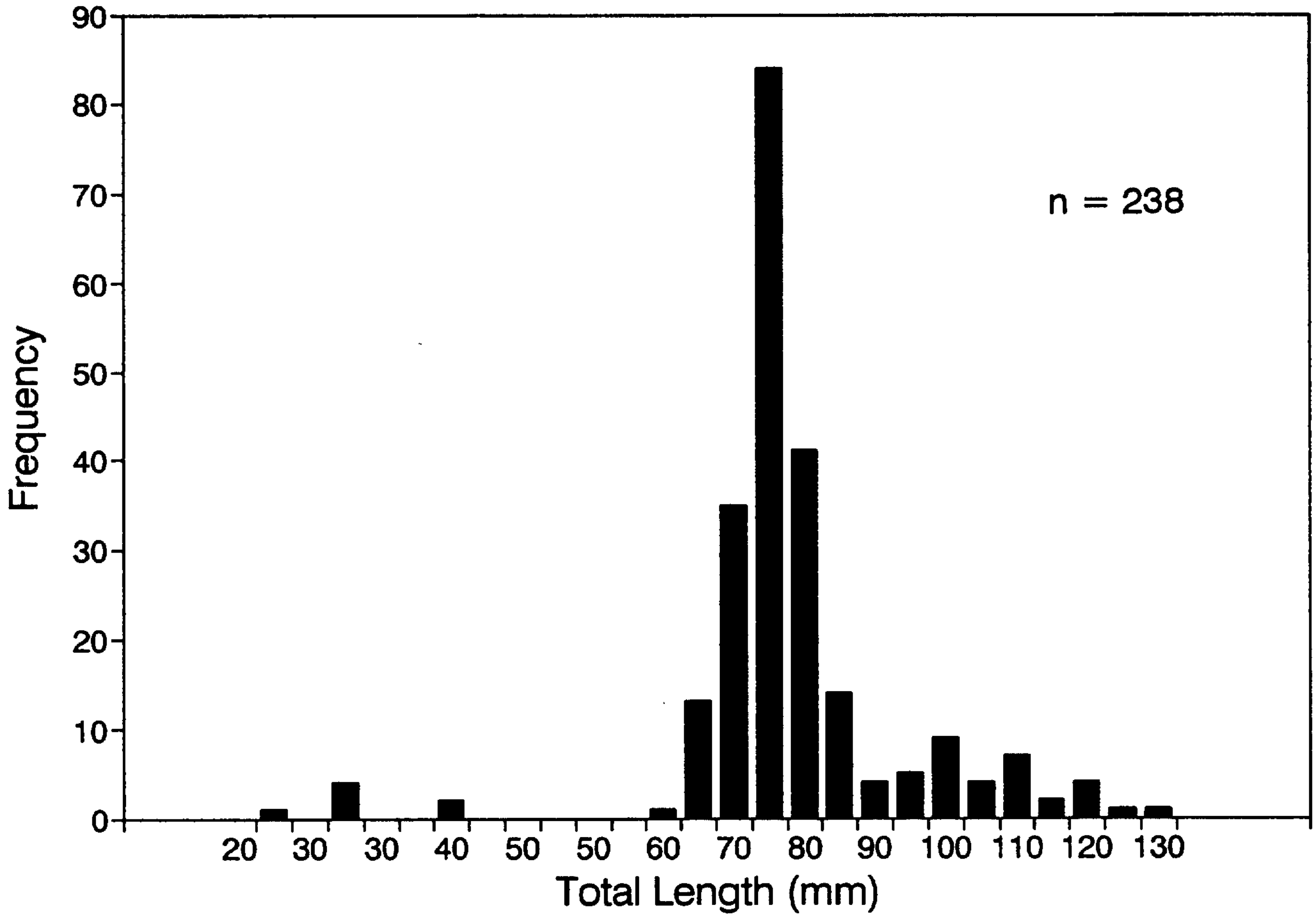


Figure 22. Length-frequency distribution of American sand lance from the Nelson River estuary, August, 1993.

Appendix 1. Date, time, location, salinity (ppt), and water depth (m) of zooplankton trawls, Nelson River estuary, August 1992. Note: location of zooplankton tows is the same as Isaacs-Kidd trawl locations.

Trawl #	Date	Time	Position (lat/long)	Salinity (ppt) (surface/bottom)	Water Depth (m)
4	Aug 19	1435	57° 09.16′ 92° 22.44′	15/19	14.0
5	Aug 22	1445	57° 03.30′ 92° 32.75′	0/0	5.0
6	Aug 22	1605	57° 05.35′ 92° 29.10′	3.7/11.7	8.5
7	Aug 22	1730	57° 04.65′ 92° 29.20′	1/4.5	3.5
8	Aug 23	1354	57° 09.71′ 92° 23.00′	4.9/10.1	5.0
10	Aug 23	1544	57° 12.11′ 92° 21.70′	26/26.2	7.0
11	Aug 23	1700	57° 10.52′ 92° 26.79′	13.5/15.2	3.6
12	Aug 23	1818	57° 06.15′ 92° 31.05′	0.5/4	3.0
13	Aug 25	1242	57° 16.90′ 92° 16.73′	26/26.7	6.0
14	Aug 25	1342	57° 13.38′ 92° 17.83′	20/23.7	6.0
15	Aug 25	1500	57° 11.22′ 92° 19.65′	5/18.5	7.0
16	Aug 25	1630	57° 07.88′ 92° 24.68′	0/15.5	24.0
17	Aug 25	1740	57° 03.96′ 92° 30.26′	0/0	6.0
18	Aug 25	1829	57° 01.53′ 92° 35.66′	0/0	5.0

Appendix 2. Date, time, location, salinity (ppt), and depth (m) of Isaacs-Kidd mid-water trawls, Nelson River estuary, August 1992.

Trawl #	Date	Time	Location In	Location Out (Direction)	Depth of Tow (m)	Salinity (ppt) (surface/bottom)	Water Depth (m)
1	Aug 19	1005	57° 09.23′ 92° 23.30′	57° 08.25′ 92° 24.51′	2.6	-/-	4.0
2	Aug 19	1105	57° 09.50′ 92° 23.16′	57° 08.45′ 92° 24.47′	2.6	1.8	5.0
3	Aug 19	1242	57° 08.45′ 92° 18.50′	57° 09.02′ 92° 18.07′	1.2	15/15	4.5
4	Aug 19	1406	57° 09.52′ 92° 21.34′	57° 09.13′ 92° 22.43′	5.3	15/19	16.0
5	Aug 22	1415	57° 02.60′ 92° 34.08′	@50-60°	4.6	0/0	5.0
6	Aug 22	1539	57° 04.67′ 92° 29.89′	@30°	2.6	3.8/8.2	8.0
7	Aug 22	1600	57° 05.12′ 92° 30.87′	@125°	3.3	1/4.3	3.5
8	Aug 23	1322	57° 09.52′ 92° 21.34′	@283°	5.3	5/10.2	12-7
9	Aug 23	1436	57° 11.81′ 92° 22.73′	@72°	3.3	-/-	4.0
10	Aug 23	1518	57° 12.15′ 92° 21 75′	@55°	4.6	26/26.2	6.0
11	Aug 23	1634	57° 11.55′ 92° 26.26′	@180°	2.6	13.5/15.2	3.0
12	Aug 23	1741	57° 06.88′ 92° 30.43′	@200°	2.6	2.3/4.0	3.0
13	Aug 25	1214	57° 16.36′ 92° 17.66′	57° 17.05′ 92° 17.22′	3.3	26/27.8	5-7
14	Aug 25	1314	57° 14.08′ 92° 18.27′	57° 13.39′ 92° 18.19′	2.6	20/23.7	6-7
15	Aug 25	1437	57° 12.18′ 92° 18.91′	57° 11.60′ 92° 19.34′	3.3	5/18.5	6-7
16	Aug 25	1542	57° 09.13′ 92° 22.97′	57° 08.33′ 92° 23.92′	4.6	0/15.5	12
17	Aug 25	1705	57° 05.27′ 92° 28.50′	57° 03.91′ 92° 30.01′	3.3	0/0	7
18	Aug 25	1805	57° 02.43′ 92° 33.84′	57° 01.53′ 92° 35.66′	1.2	0/0	5

Appendix 3. Salinity and temperature data by depth for all sites of the Nelson River estuary 1992 survey.

Zone	Site	Depth (m)	Temperature (C°)	Salinity (ppt)
Riverine	5	0.51	14.9	0
		1.77	14.8	0
		2.2	14.8	0
		2.44	14.8	0
	17	0	14.5	0
		1	14.5	0
		2	14.5	0
		3	14.5	0
		4	14.5	0
		5	14.5	0
		6	14.5	0
	18	0	16.0	0
		5	16.0	0
Nearshore Estuarine	6	0.17	13.0	3.7
		1.09	13.0	3.8
		1.94	13.0	3.9
		3.03	12.1	7.1
		3.79	12.0	7.3
		4.38	12.0	7.3
		4.89	11.9	7.7
		5.73	11.8	7.9
		6.23	11.8	8.1
		6.65	11.7	8.2
		7.41	11.7	8.2
		7.92	11.6	8.2
		8.51	11.6	8.2
	7	0.17	14.1	1.0
		0.84	14.1	1.9
		1.85	13.3	4.4
		2.78	13.2	4.5
		3.37	13.2	4.45
	12	0.17	13.4	0.59
		0.25	13.4	0.59
		0.76	13.43	2.3
		1.6	12.9	3.9
		2.44	12.85	3.95
		2.6	12.85	3.96
		2.86	12.85	3.96
Stratified	2	0	15.1	1.8
		5	15.1	1.8
Stratified (cont'd)	4	0	11.0	15.0
		2	10.5	15.3
		4	9.4	16.7
		6	9.0	17.7
		8	8.6	18.3
		10	8.5	18.3
		12	8.5	19.0
	8	0.25	12.6	4.9
		0.51	12.6	4.9
		1.1	12.6	4.9
		1.85	11.75	8.4
		2.7	10.9	9.2
		3.5	10.9	9.5
		4.3	10.66	10.1
		4.7	10.6	10.1
	15	0	13.8	5.0
		1	12.8	7.2
		2	12.1	8.3
		3	11.5	10.0
		4	10.8	11.7
		5	9.5	14.6
		6	9.2	15.2
		7	8.8	16.0
		8	8.0	18.0
		9	7.8	18.5
	16	0	14.9	0
		2	14.7	0.2
		4	14.0	2.3
		6	13.0	4.4
		8	12.8	5.9
		10	11.9	8.0
		12	11.8	8.0
		24	9.5	15.5
Offshore Estuarine	3	0	10.3	15.4
		1	10.3	15.4
		2	10.3	15.4
		3	10.3	15.4
		4	10.3	15.4

Appendix 3. (cont'd).

Zone	Site	Depth (m)	Temperature (C°)	Salinity (ppt)	Zone	Site	Depth (m)	Temperature (C°)	Salinity (ppt)
Offshore Estuarine (cont'd)	10	1	6	26.0		13	0.34	6.3	26.0
		1.3	6	26.0			0.42	6.3	26.0
		1.7	6	26.0			1	6.1	26.0
		2	5.9	26.0			2.1	5.9	26.1
		2.2	5.9	26.0			3.2	5.7	26.2
		2.6	5.9	26.1			4	5.5	26.3
		2.86	5.9	26.1			4.4	5.4	26.4
		3.2	5.8	26.1			5	5.1	26.5
		3.6	5.8	26.1			6	4.9	27.6
		4.2	5.75	26.1			6.1	4.9	27.7
		5.4	5.66	26.2					
		6.65	5.68	26.2		14	0	8.5	20.1
		6.9	5.67	26.2			6	6.5	23.7
	11	0	9.7	13.5					
		0.34	9.7	13.5					
		1.09	9.6	14.4					
		2.27	9.2	15.07					
		3	9.15	15.17					
		3.6	9.14	15.19					

Appendix 4. Results of water chemistry analysis for all samples collected in the Nelson River estuary, August 1992.

Station	Depth	NO3	NO2	NH4	SUS	TDN	Sus P	TDP	DIC	DOC	Sus C	Chl a	SRSI	Cl	SO4	TSS	Cond.	Na	K	Mg	Ca	Fe	pH	Alk
	(m)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l)	(ug/l	(um/l)	(um/l)	(ug/l)	(ug/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(uS)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)		(ueq/l
Riverine																								
17	SUR	3	1	20	90	360	21	11	1760	580	1240	5.10	0.54	10	14	22	228	11	2	8	25	0.70	8.62	1725
18	SUR	5	0	40	78	340	16	11	1730	570	890	4.70	0.59	10	14	14	225	9	2	8	25	0.60	8.59	1695
Nearshore estuarine																								
6	SUR	3	0	60	89	320	20	10	1760	390	1020	3.40	0.41	1650	250	23	5536	770	31	101	57	0.10	8.48	1768
7	SUR	2	0	20	102	210	24	12	1770	570	1390	4.70	0.49	326	58	22	1325	150	8	28	32	0.40	8.53	1740
12	SUR	2	0	20	81	260	21	13	1760	580	1120	4.20	0.48	84	23	20	485	43	3	12	26	0.40	8.60	1749
6	BOT	6	0	100	244	330	96	17	1890	190	8660	5.80	0.50	4500	620	167	13939	1760	77	220	92	0.40	8.38	2138
12	BOT	4	0	60	70	260	17	13	1760	900	920	3.60	0.48	1360	189	21	4419	470	21	70	48	0.30	8.49	1774
Stratified																								
8	SUR	4	0	60	77	270	19	12	1870	270	850	3.60	0.41	3150	500	24	9836	1480	65	202	83	0.40	8.45	1835
15	SUR	4	0	110	66	300	16	13	1870	320	700	2.70	0.48	2690	380	21	8255	1200	56	172	77	0.60	8.46	1812
16	SUR	4	0	30	78	190	17	12	1790	570	810	4.30	0.55	164	34	14	741	88	5	17	28	0.60	8.60	1747
8	BOT	3	1	120	326	340	109	16	1970	130	8070	5.10	0.43	7000	930	150	19969	3050	148	370	171	0.20	8.38	2080
16	BOT	13	1	190	277	460	100	25	1950	110	8280	6.20	0.47	8800	1150	204	24220	3430	196	420	177	0.70	8.35	2105
Offshore estuarine																								
10	SUR	6	2	310	32	590	12	34	2060	60	590	0.47	0.14	14900	1950	60	38653	6300	303	740	290	0.70	8.21	2126
11	SUR	9	1	220	54	430	18	23	2010	130	820	1.10	0.29	8000	1080	42	21748	2140	114	260	116	0.50	8.40	2033
13	SUR	2	1	230	14	520	8	33	2050	40	250	0.40	0.13	14700	1900	39	38356	6500	307	770	309	0.50	8.29	2131
14	SUR	8	1	310	70	520	14	40	2040	120	570	0.80	0.28	8300	1100	37	23923	3970	178	470	178	0.60	8.35	1990
TR1	SUR	10	1	20	74	370	14	14	1740	590	740	4.00	0.63	10	15	12	224	9	2	8	25	0.70	8.61	1690
TR2	SUR	7	1	30	79	350	17	12	1710	570	820	4.30	0.57	10	14	16	226	9	2	8	24	0.70	8.62	1707
TR3	SUR	8	0	30	102	190	28	11	1760	490	1920	4.80	0.53	1050	222	39	3500	510	22	72	43	0.90	8.49	1786
TR4	SUR	6	1	130	88	310	27	19	1860	170	1660	2.70	0.42	5200	740	44	15026	2290	102	280	117	0.70	8.39	1903
TR5	SUR	7	1	170	75	390	22	20	1980	140	1150	1.98	0.34	7200	930	43	19870	3350	143	390	155	0.80	8.35	1953
TR6	SUR	3	1	200	43	520	11	29	2090	70	470	1.60	0.16	11300	1900	46	31733	5200	255	610	265	0.70	8.32	2064
TR7	SUR	2	1	220	35	510	11	30	2060	50	370	1.06	0.15	14500	1900	39	35094	5900	278	700	285	0.60	8.29	2092
TR8	SUR	2	1	230	14	520	8	33	2050	40	250	0.40	0.13	14700	1900	39	38356	6500	307	770	309	0.50	8.29	2131