

# **Physical Oceanography of the Richibucto Estuary (New Brunswick): Autumn Conditions in 1995**

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**PHYSICAL OCEANOGRAPHY OF THE RICHIBUCTO ESTUARY  
(NEW BRUNSWICK): AUTUMN CONDITIONS IN 1995<sup>1</sup>**

by

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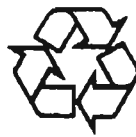
<sup>1</sup> Contribution n° 1 of the Richibucto Estuary Project

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## ABSTRACT

St-Hilaire, A., A. D. Boghen, and S. C. Courtenay. 1997. Physical oceanography of the Richibucto Estuary (New Brunswick): Autumn conditions in 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2167: vi + 28 p.

As part of a larger investigation into the capacity of the Richibucto Estuary to sustain feral and cultured finfish and invertebrates, a field survey of CTD (Conductivity, Temperature, and Depth) casts was undertaken on the Richibucto Estuary in October-November, 1995, by the Environmental Science Research Centre of the Université de Moncton, in partnership with DFO. The aim of this survey was to characterize the longitudinal and vertical stratification of the estuary during the autumn season. The survey covered the lower part of the estuary (i.e. downstream of the Highway 11 bridge and the St-Charles River) during both spring and neap tides. Generally, there was weak vertical stratification in the lower estuary. Most of the salinity gradients measured were less than  $0.2 \text{ PSU} \cdot \text{m}^{-1}$ . The longitudinal salinity gradient varied between  $0.4 \text{ PSU} \cdot \text{km}^{-1}$  on 10 October to  $1 \text{ PSU} \cdot \text{km}^{-1}$  on 28 October 1995.

Temperature profiles showed an isothermal water column on 10 October and 28 October 1995, with temperatures of  $12.5^\circ\text{C}$  and  $10.0^\circ\text{C}$ , respectively. The thermal structure was substantially different on 30 November 1995, when a thermocline was measured at 2 m from the surface and temperatures below  $0^\circ\text{C}$  were recorded at the upstream stations.

## RÉSUMÉ

St-Hilaire, A., A. D. Boghen, et S. C. Courtenay. 1997. Physical oceanography of the Richibucto Estuary (New Brunswick): Autumn conditions in 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2167: vi + 28 p.

Dans le cadre d'un programme cherchant à déterminer la capacité de l'estuaire de la rivière Richibouctou à permettre le développement d'espèces de poissons et invertébrés naturelles et cultivées, une campagne d'échantillonnage avec un CTD a été entreprise durant les mois d'octobre et novembre 1995 par le Centre de Recherche en Science de l'Environnement, en collaboration avec le ministère de Pêches et Océans. Le but de cette campagne était de caractériser la stratification verticale et longitudinale de l'estuaire durant la saison d'automne.

Le bas-estuaire de la rivière Richibouctou (c'est-à-dire en aval de la Rivière St-Charles et du pont de la route 11) a été échantillonné durant les marées de morte-eau lors de 2 sorties et de vive-eau lors d'une troisième sortie. La stratification verticale semble généralement faible dans cette partie de l'estuaire. Le gradient de salinité vertical a rarement dépassé  $0.2 \text{ USP} \cdot \text{m}^{-1}$ . Le gradient longitudinal de salinité a varié entre  $0.4 \text{ USP} \cdot \text{km}^{-1}$  le 10 octobre 1995 et  $1 \text{ USP} \cdot \text{km}^{-1}$  le 28 octobre 1995.

Les profils de températures ont montré que la colonne d'eau était isothermique le 10 et le 28 octobre avec des températures respectives de  $12.5^{\circ}\text{C}$  et  $10.0^{\circ}\text{C}$ . Une thermocline a été mesurée à une 2 m de la surface, le 30 novembre 1995. Des températures inférieures à  $0^{\circ}\text{C}$  ont aussi été enregistrées le 30 novembre 1995.



## 1.0 Introduction

The Environmental Science Research Centre (ESRC) of the Université de Moncton, in partnership with Fisheries and Oceans Canada (DFO), undertook a field survey in the fall of 1995, on the Richibucto Estuary. This survey was an initial component of the Richibucto Estuary Environmental Assessment and Resource Enhancement Project (REEAREP).

The REEAREP is a multi-phase, multi-disciplinary investigation. The main objective of the program is to maximize long-term social, recreational and economic benefits from existing and potential estuarine resources for the residents of the area. The first step in this process involves documenting the existing biota, and their ecology, in the estuary.

Other studies in neighbouring estuaries such as the Miramichi (Locke and Courtenay, 1995a, b; St-Hilaire et al., 1995) and even larger systems such as the St. Lawrence Estuary (Laprise and Dodson, 1989) have shown estuarine ecosystems to be organized with respect to salinity and temperature gradients (both vertically and longitudinally). Such data do not exist for the Richibucto Estuary. For this reason, it was felt that the initial field work for the REEAREP should concentrate on the physical oceanography of this system.

The Richibucto Estuary is a small coastal plain watershed located in southeastern New Brunswick.

The drainage basin covers 1088.5 km<sup>2</sup> and the average elevation is 45.5 m above mean sea level (Montreal Engineering Company, 1969). The shallow bay is fed mostly by two rivers: the main Richibucto River and the St. Nicholas River. Two smaller tributaries also feed the Northwest Branch: the Little Aldouane and the St. Charles Rivers (Figure 1). The mean annual freshwater discharge into the estuary is 26.0 m<sup>3</sup>·s<sup>-1</sup>. The maximum discharge is usually reached in April (mean of 91.5 m<sup>3</sup>·s<sup>-1</sup>), after which a rapid decline occurs to a monthly mean of 22.8 m<sup>3</sup>·s<sup>-1</sup> in June.

The discharge in October is usually below the mean annual flow (monthly mean of 18.2 m<sup>3</sup>·s<sup>-1</sup>),

while the monthly mean in November ( $26.0 \text{ m}^3 \cdot \text{s}^{-1}$ ) is equal to the annual mean (Gregory et al., 1993).

Richibucto Bay (also known as Richibucto Harbour) is shallow, with depths seldom exceeding 1 m, except for the 150 m wide channel where depths reach a maximum of 12 m. The bay is separated from Northumberland Strait by a system of sand dunes.

Since there are few physical data from shallow estuaries in the area and no known data specific to the Richibucto Estuary, it was decided to characterize the physical oceanography of this estuary in order to fulfill the following objectives:

- to provide background data of salinity and temperature in the lower part of the estuary
- to quantify the vertical and longitudinal stratification using salinity and temperature data
- to investigate the affect of tides and freshwater discharge on the stratification.

## **2.0 Materials and Methods**

The survey consisted of a series of CTD (Conductivity, Temperature, Depth) casts taken at 19 locations in the Northwest Branch (stations A, B, C, D, E, F), main Richibucto (stations A', B' C', D', E', F'), Richibucto Bay (stations G, H, I), and along the South Richibucto dune (stations J, K, L, M) (Figure 1). Table 1 summarizes the survey dates and tidal information. Stations sampled on 10 October 1995 concentrated on the main Richibucto, while most of the stations sampled on 28 October 1995 and 30 November 1995 were in the Northwest Branch.

The instrument used to perform the CTD casts was a SEABIRD SBE-19 (Seabird, Washington, U.S.A.) equipped with a conductivity cell, a dissolved oxygen probe, a thermistor and a hydrostatic pressure sensor. Table 2 gives the precision of the sensors. The SEABIRD is also equipped with a pump to ensure constant flushing of the conductivity cell.

At each station, the CTD was held just below the surface for 45 seconds to allow the pump to be activated and to provide constant flushing of the conductivity cell. The CTD was then lowered at a constant rate of approximately  $0.1 \text{ m}\cdot\text{s}^{-1}$  from the surface to the bottom. Measurements were taken every 0.5 seconds. The data stored in the CTD were later downloaded to a computer. A software package calculated salinity from conductivity, temperature, and pressure data, using the Practical Salinity Scale (Fofonoff and Millard, 1983). Units of the Practical Salinity Scale (PSU) differ from measurements in parts per thousand (PPT) by less than 0.001. Vertical profiles of salinity (PSU) and temperature ( $^{\circ}\text{C}$ ) were thus obtained. Oxygen data collected by the CTD were not properly calibrated and so are not included in this report.

### 3.0 Results

#### 3.1 Salinity

Salinity profiles for all stations sampled are provided in Appendix A. Salinity in the lower estuary typically varied between 25 and 29 PSU. Generally, the water column at each site showed little stratification. The largest gradient measured was on 30 November, at station A' (Figure 2). Near-surface salinity showed a sharp increase of more than 8 units in the first metre. In most cases, however, the vertical gradient was less than  $0.2 \text{ units}\cdot\text{m}^{-1}$  for the entire water column, as reflected by the near vertical lines of Figures 3, 4 and 5.

Figure 3 shows isohaline curves for the survey of 10 October in the Main Richibucto Estuary. Isohalines are curves of equal salinity. The shape of the isohalines provides additional information on the stratification of the estuary; dense horizontal isohalines indicate strong vertical stratification. The estuary appears to be relatively well mixed, with little vertical stratification and a longitudinal gradient of less than  $0.4 \text{ PSU}\cdot\text{km}^{-1}$ .

Salinity measurements in the main branch of the Richibucto (river km 7 to 9, Figure 3) showed a relatively well-mixed water column of between 25.5 and 26.5 PSU on 10 October. In the Bay

(river km 3 to 6, Figure 3), salinity varied between 27 and 28 PSU on that day. Figure 4 shows the isohaline curves for the survey of 28 October in the Richibucto Bay and the Northwest Branch. On this date, the isohalines were mostly vertical. The change in the angle of the isohalines at depth suggests a weak increase in vertical stratification (between 3 and 5 m). The longitudinal stratification in the estuary begins at river km 4 (Station H) and is strongest between river km 4 and 8 ( $1 \text{ PSU} \cdot \text{km}^{-1}$  near the surface). Salinity was higher in Richibucto Bay (river kilometer 3-6) on 28 October than 10 October by up to 2 PSU.

Conditions on 30 November were substantially different from those 28 October in the Bay and Northwest Branch (Figure 5). In the middle portion of the estuary (mouth of the Northwest Branch), the isohalines were almost horizontal near the surface (top 2 m), which is indicative of a stronger vertical gradient than on 28 October. The isohaline of 26 PSU has also migrated further upstream, touching the bottom at river km 6 on 30 November and at river km 8 on 28 October. This is an indication of an upstream migration of the more saline water. There was a steep longitudinal gradient near the bottom on 30 November. The neap tide of 30 November was less energetic than the spring tide of 28 October (Table 1). This may be a reason for the stronger stratification on 30 November than on 28 October. A vertical gradient was also present in the top 4 m of the water column in the Northwest Branch on 30 November. Station E (river km 6) showed a halocline of 4 PSU between 1 and 2 m of depth (Figure 5).

### 3.2 Temperature

Temperature profiles for all stations sampled are shown in Appendix B. The estuary was essentially isothermal on 10 October and 28 October, at approximately  $12.5^\circ\text{C}$  and  $10.0^\circ\text{C}$ , respectively. Conditions were quite different on 30 November. The downstream stations (J and M) showed a vertical temperature gradient of nearly  $3^\circ\text{C}$ . Upstream, surface water temperature decreased to below  $0^\circ\text{C}$ , reaching a minimum of  $-2^\circ\text{C}$  near the surface, near the mouth of the St. Charles River (station A). It should be noted that frazil ice was present in the top 2 m of the water column at stations A, B, and C.

## 4.0 Discussion and Conclusions

This initial survey of the Richibucto Estuary provides essential new information on its physical oceanography. The weakly-stratified conditions during the month of October 1995 may be typical for such a shallow estuary at this latitude. However, the salinity data from November show that some vertical stratification occurs and that there is longitudinal migration of the more saline water. This is partly dependent on freshwater discharge. Preliminary daily discharge from the only gauged site on the drainage basin (Coal Branch River at Beersville, lat.  $46^{\circ} 26' 37''$  N and long.  $65^{\circ} 03' 55''$  W) showed an increase from  $0.318 \text{ m}^3 \cdot \text{s}^{-1}$  (28 October 1995) to  $2.01 \text{ m}^3 \cdot \text{s}^{-1}$  on 30 November 1995 (Environment Canada, unpublished data). There may also be other factors which have yet to be quantified such as wind. Our limited sampling has already shown the importance of the spring-neap tidal cycle for providing more or less mixing energy in the estuary. Advection of more saline waters by the semi-diurnal tidal cycle should also be quantified in subsequent studies.

The surveys on 28 October and 30 November showed a rapid decrease of temperatures in the estuary during the month of November. Discharge data from the Coal Branch River at Beersville indicated ice conditions starting on 26 November in 1995. The month of November was not especially cold in New Brunswick. Predicted water temperature data calculated from air temperature data at Catamaran Brook, in the centre of the province, showed a monthly average of  $1.6^{\circ}\text{C}$  in 1995, compared to  $1.4$ ,  $1.0$  and  $2.3^{\circ}\text{C}$  for 1992, 1993 and 1994, respectively (Caissie et al., 1996). We can therefore assume that ice formation may be typical in late November. The presence of frazil ice, leading to the formation of a solid ice cover, may be a critical period for the survival of both finfish and shellfish in the estuary. This may also contribute to stratification of the estuary.

Research on the Miramichi Estuary has shown that nursery areas for finfish are defined by salinity. Larval anadromous fish (which are also present in the Richibucto Estuary) such as rainbow smelt

(*Osmerus mordax*), Atlantic tomcod (*Microgadus tomcod*), gaspereau (*Alosa aestivalis* and *A. pseudoharengus*), and striped bass (*Morone saxatilis*) were found in highest numbers at the edge of the salt wedge. In contrast, larvae of fish such as flounder (*Pleuronectes americanus* and *P. putnami*), sculpin (*Myoxocephalus* sp.) and sand lance (*Ammodytes* sp.) were distributed further downstream (Locke and Courtenay, 1995a, b; Robichaud-Leblanc et al., 1996). Juveniles of all but sculpins and sand lance occur throughout a wide range of salinities in Miramichi Estuary (Hanson and Courtenay 1995, 1996). Identification of the relationship between salinity and concentrations of juvenile fishes in Miramichi Estuary facilitates the identification of important nursery habitats in other river systems, and prediction of potential conflicts due to anthropogenic influences. Nursery habitat may exist for juvenile striped bass in the upper Richibucto Estuary. In the Miramichi Estuary, the nursery area for anadromous fish at the edge of the salt wedge places these larvae squarely in the influence of pulp and paper mill effluent and other industrial and municipal wastes during the spring. In the Richibucto Estuary, untreated sewage from cottages and agriculture, and drainage from the commercially harvested St. Charles Peat Bog, may have adverse effects on juvenile fish.

Overwintering habitats also appear to be defined by salinity and temperature. Winter flounder move from coastal waters of the southern Gulf of St. Lawrence into the Miramichi Estuary in the fall and remain there in the relatively warm, brackish water until spring (Hanson and Courtenay, 1996). Their exodus from the estuary in spring may be triggered by rapidly declining salinities during the spring freshet. Richibucto Estuary may well provide a similar thermal refuge for overwintering fish. Young of the year striped bass have been caught in beach seines, 3 km upstream of the study area, during the fall of 1996 (unpublished data). It is unknown whether these juveniles were migrants from nearby estuaries or were actually from spawning grounds within in the Richibucto River. It appears quite possible that these fishes overwinter in the upper estuary. In recent years, a hoop net fishery took many large striped bass during the winter in the Brown's Yard area of Richibucto River.

## 5.0 Acknowledgements

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**Table 1. Survey dates and tidal information (from predicted tides)**

Date	Semi-diurnal cycle	Spring-neap cycle	Stations
10 Oct 95	Flood	Spring	A', B', E', H, J, K
28 Oct 95	Flood	Spring	A, C, F, H, I, J, L
30 Nov 95	Flood	Neap	A, C, E, J, M, A', E'

**Table 2. Sensor Precision (SEABIRD CTD)**

Sensors	Precision
Pressure (Depth)	0.25% of full range (25 cm)
Conductivity	0.01 mS·cm <sup>-1</sup>
Temperature	0.01 °C

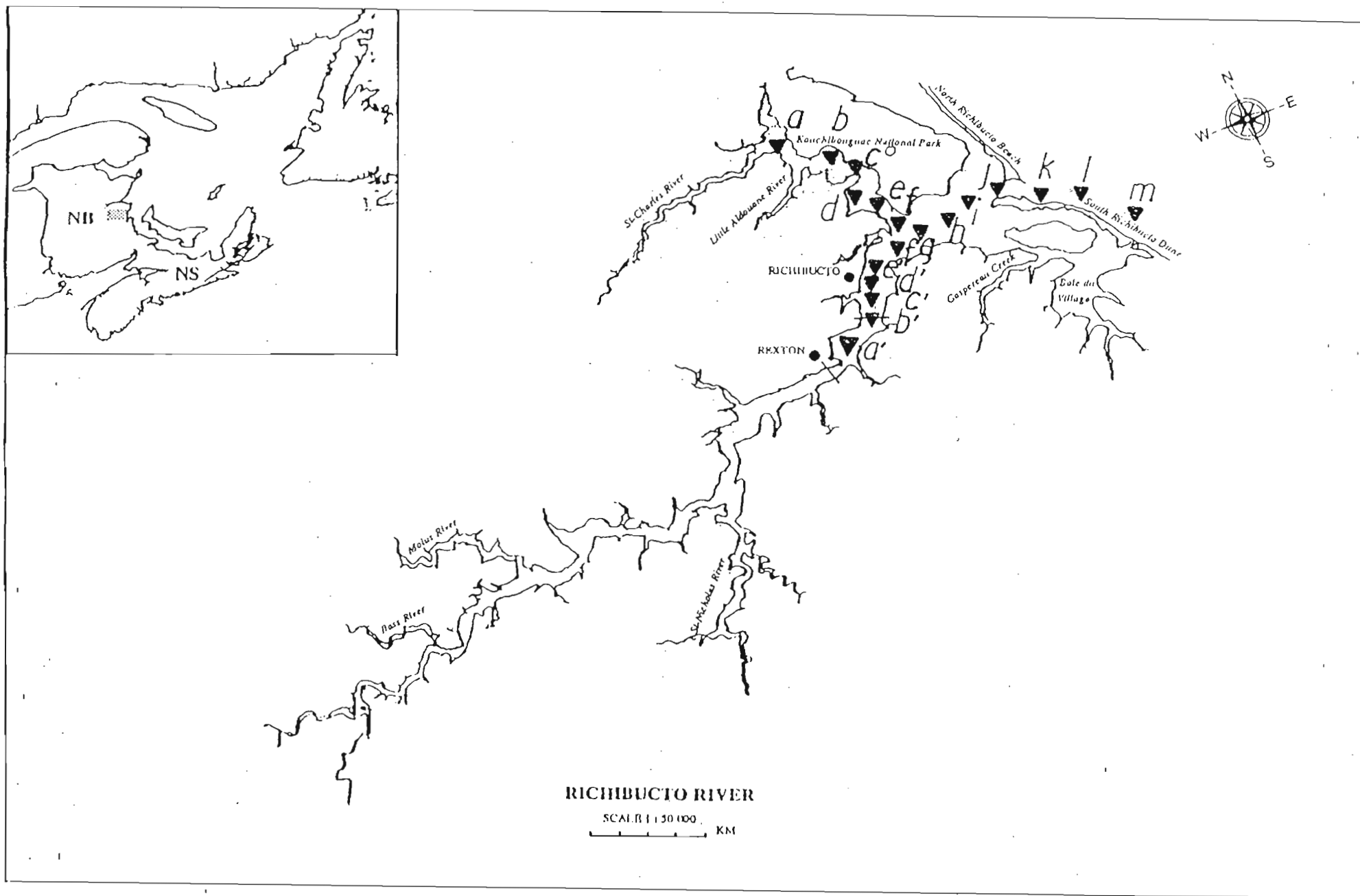


Figure 1. Map of the Richibucto Estuary showing sampling stations.

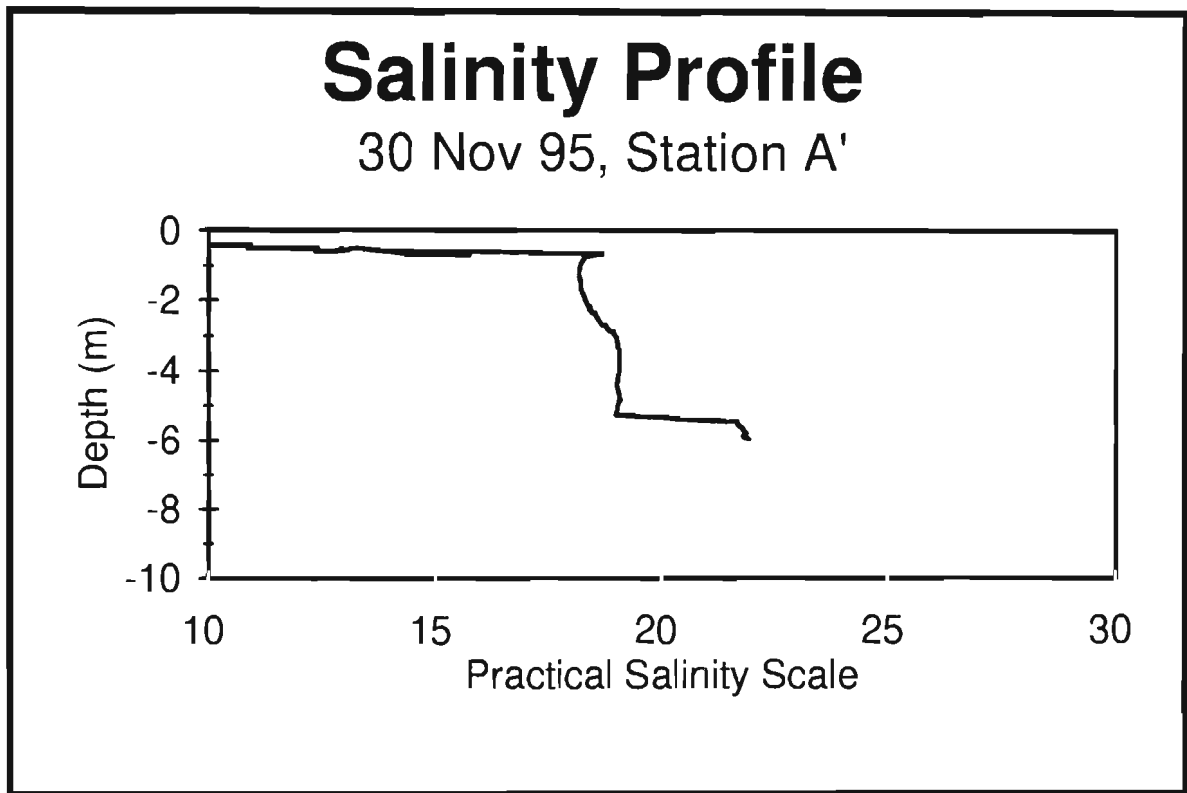


Figure 2. Salinity profile with the highest vertical gradient, taken at site A', on 30 November 1995, in the Richibucto Estuary.

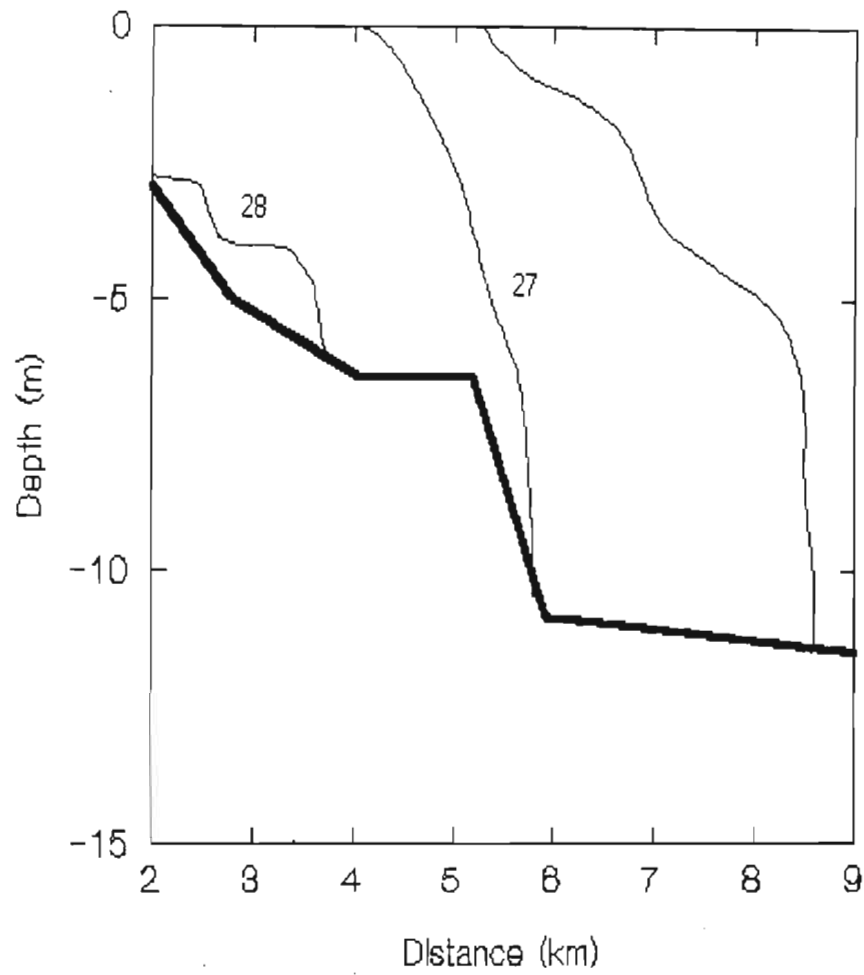


Figure 3. Isohaline curves (PSU), Richibucto Estuary, 10 October 1995. The darker line represents the bottom. The distances are measured from station M (South Richibucto dune, km 0), going upstream, up to the highway bridge on the Richibucto River (station A', km 9).

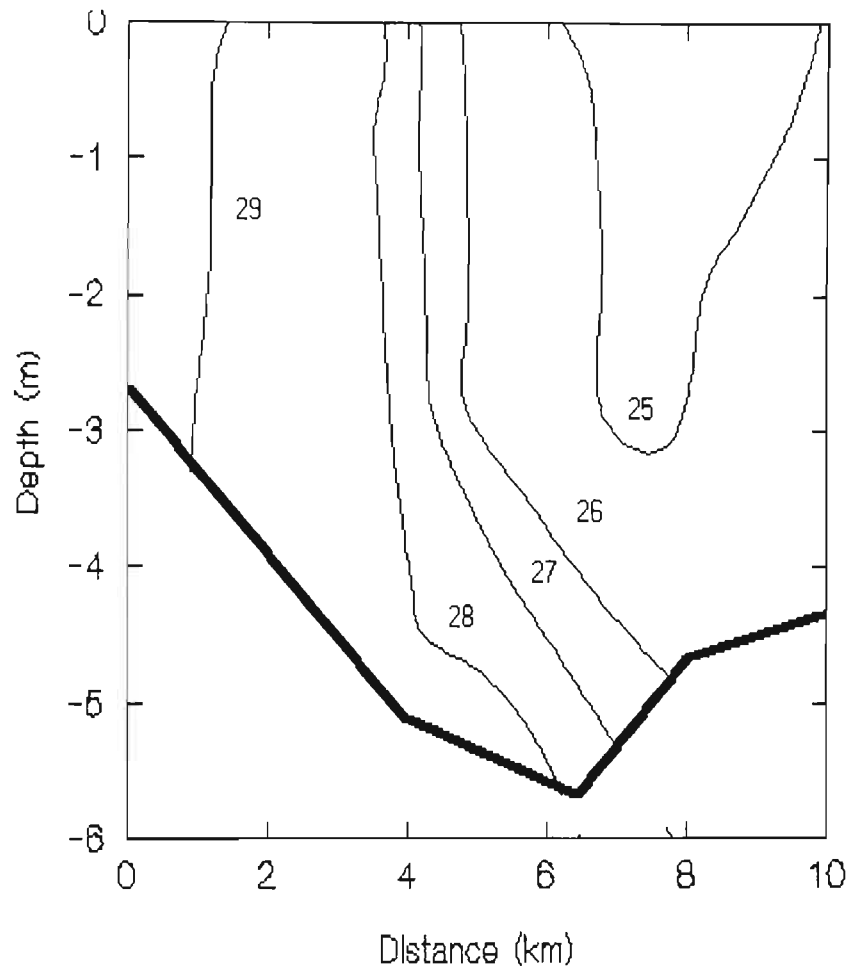


Figure 4. Isohaline curves (PSU), Richibucto Estuary, 28 October 1995. The darker line represents the bottom. The distances are measured from South Richibucto dune (station M, km 0), going upstream to the mouth of the St. Charles River, in the Northwest Branch (station A, km 10).

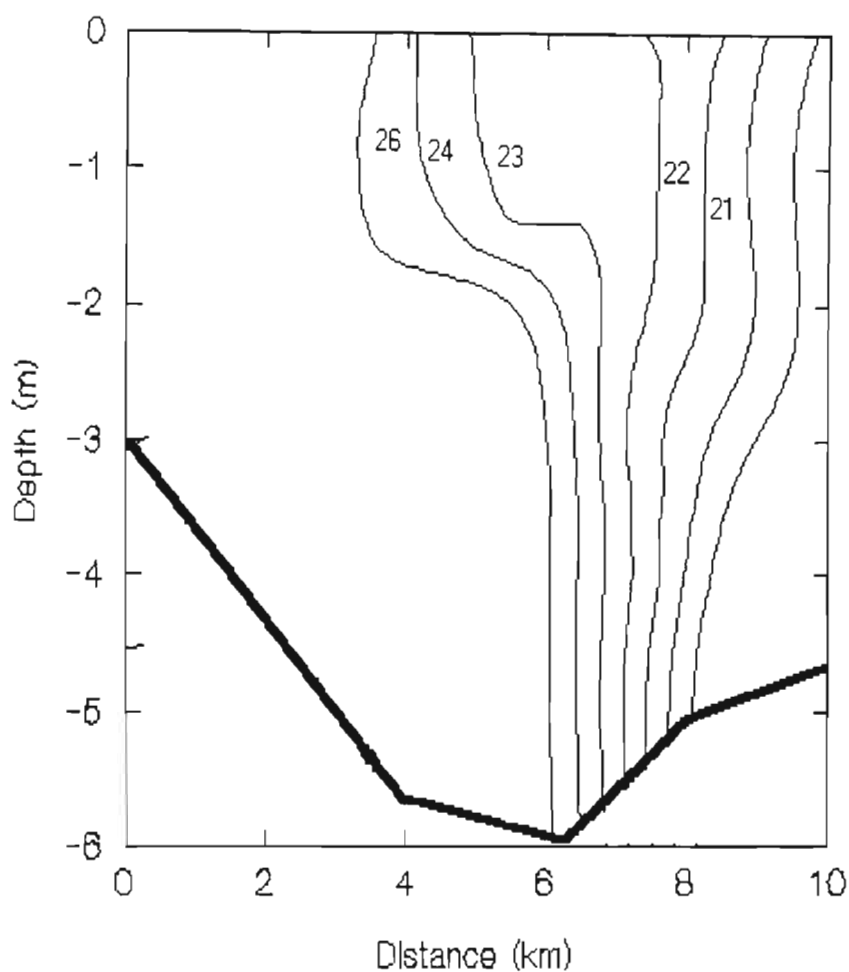
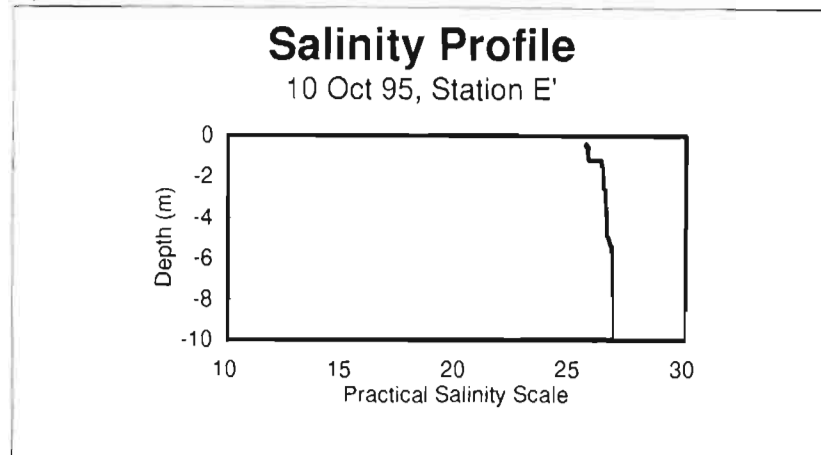


Figure 5. Isohaline curves (PSU), Richibucto Estuary, 30 November 1995. The darker line represents the bottom. The distances are measured from South Richibucto dune (station M, km 0), going upstream, up to the mouth of the St. Charles River, in the Northwest Branch (station A, km 10).

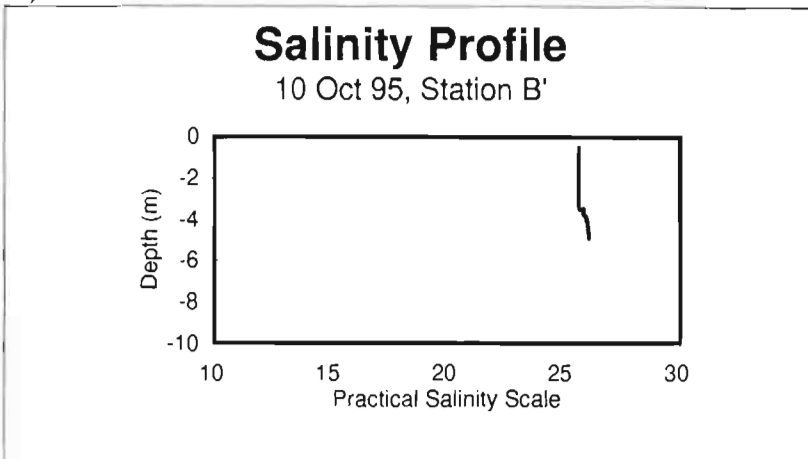
## **Appendix A**

### **Salinity Profiles**

a)



b)



c)

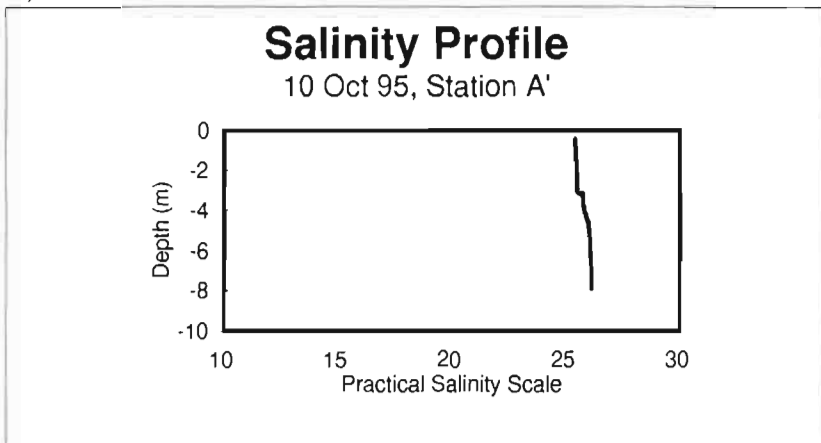
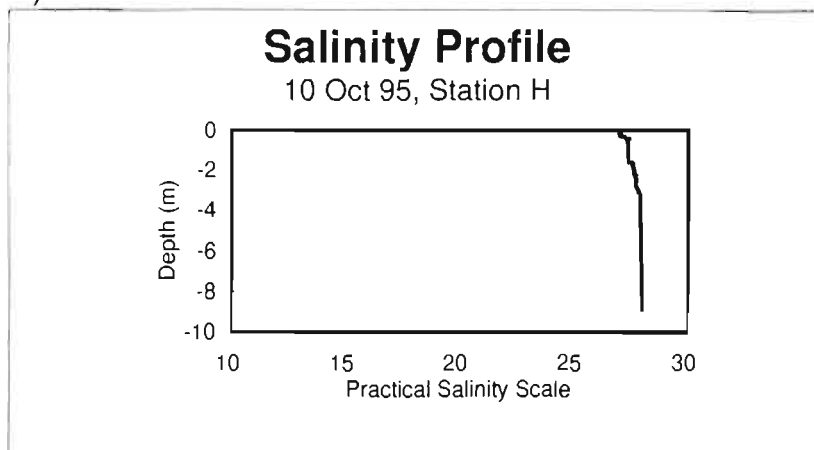


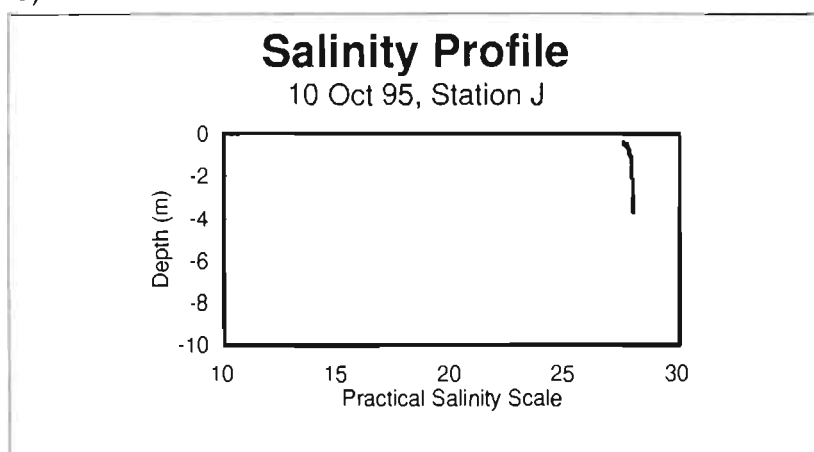
Figure A1. Salinity profiles at stations E', B', and A' in the Richibucto Estuary (10 Oct 1995).



a)



b)



c)

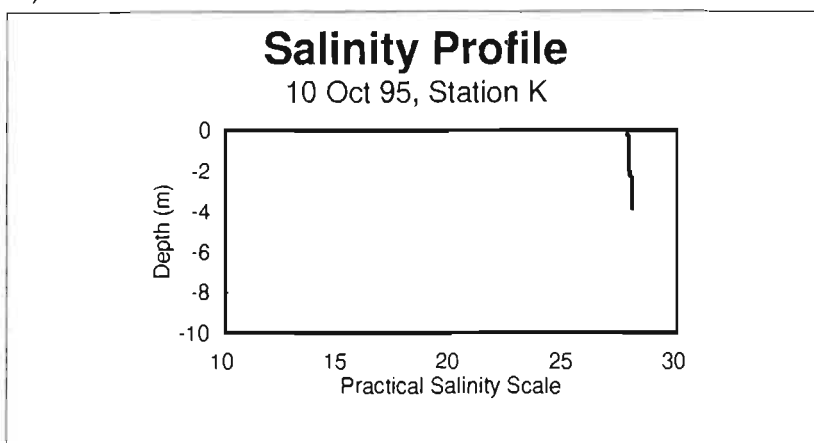
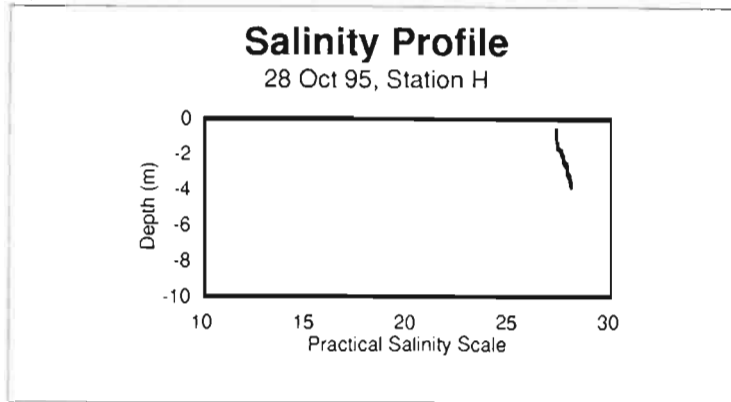
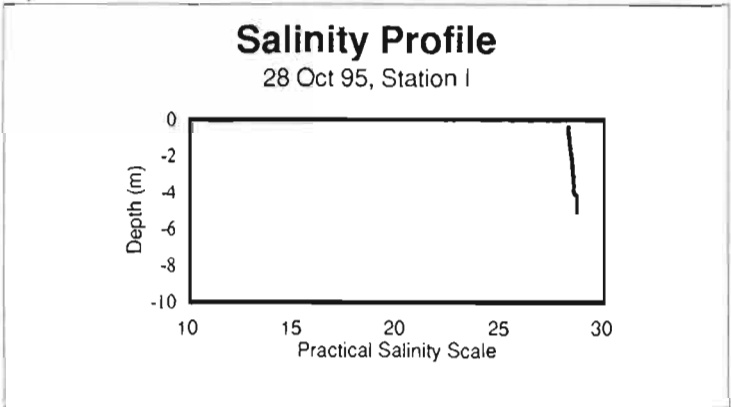


Figure A2. Salinity profiles at stations H, J, and K in the Richibucto Estuary (10 Oct 1995).

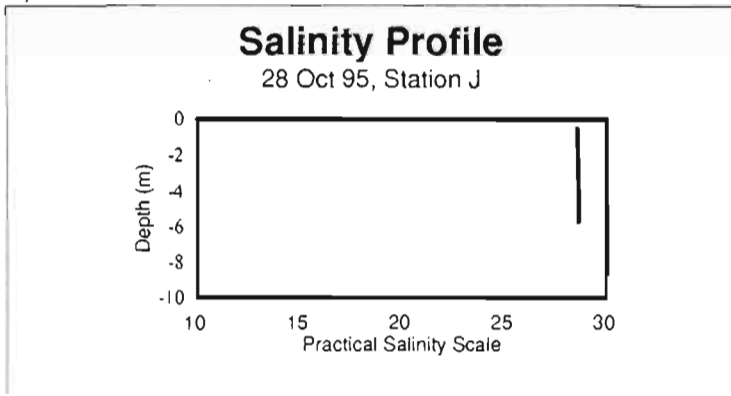
a)



b)



c)



d)

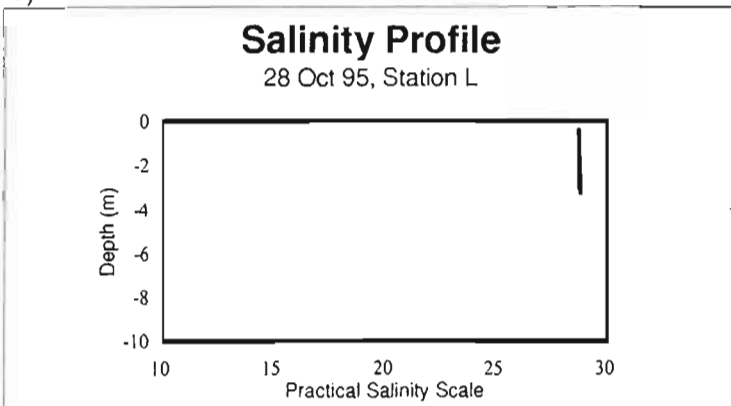
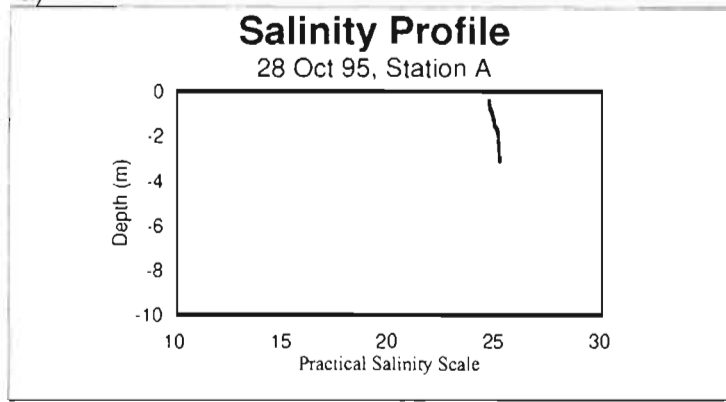
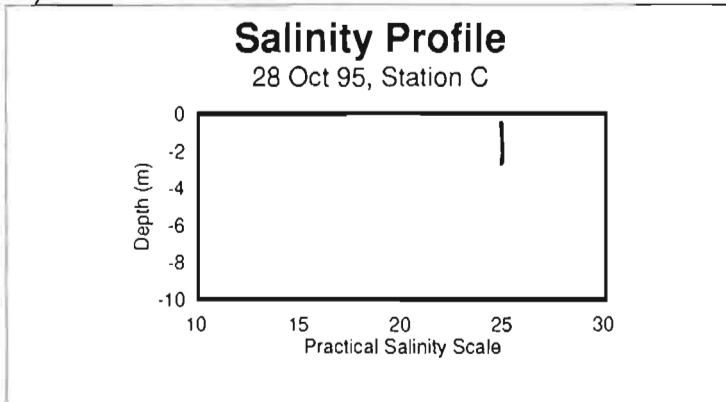


Figure A3. Salinity profiles at stations H, I, J, and L in the Richibucto Estuary (28 Oct 1995)

a)



b)



c)

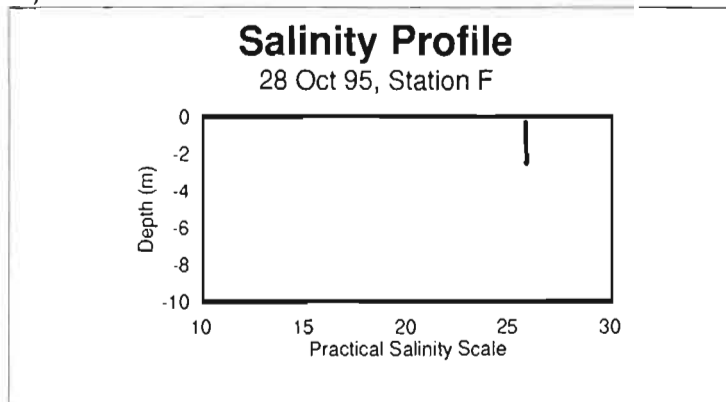
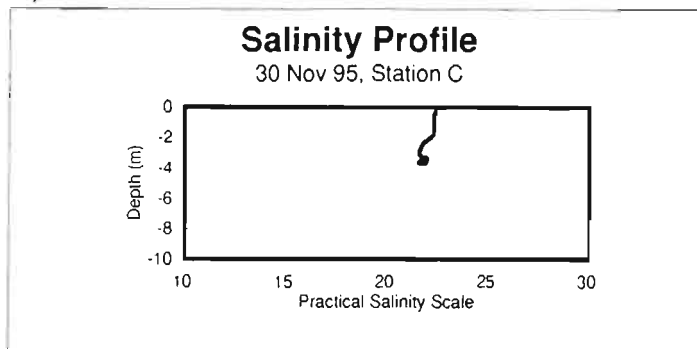
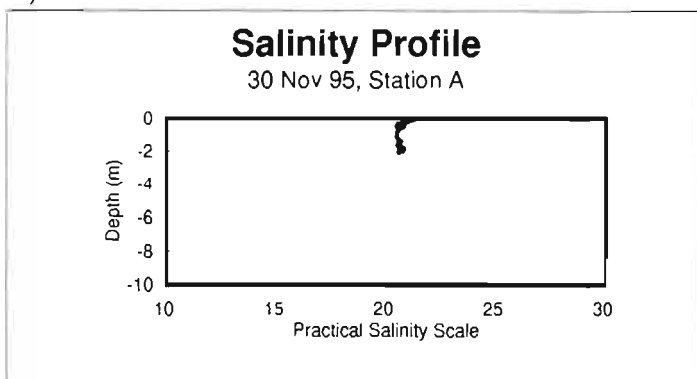


Figure A4. Salinity profiles at stations A, C, and F in the Richibucto Estuary (28 Oct 1995)

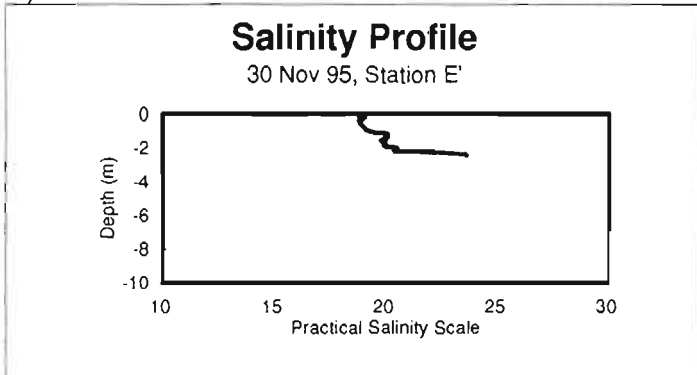
a)



b)



c)



d)

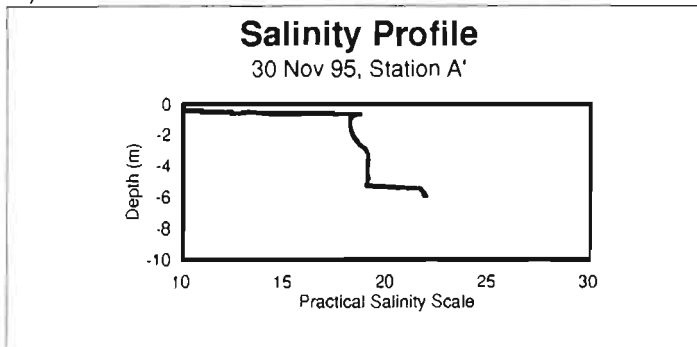
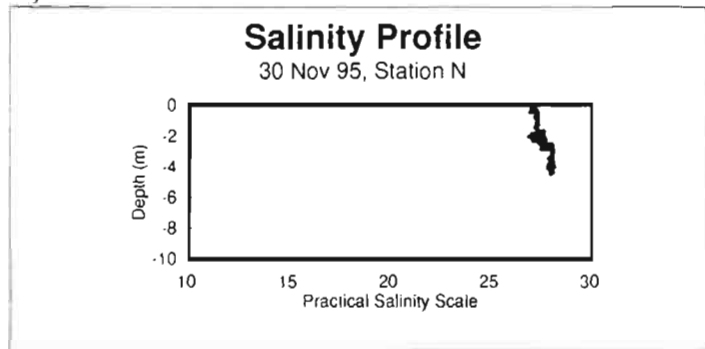
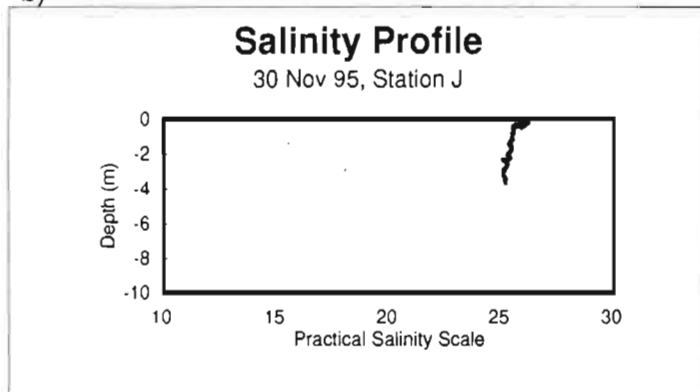


Figure A5. Salinity profiles at stations A, C, E', and A' in the Richibucto Estuary (30 Nov 1995).

a)



b)



c)

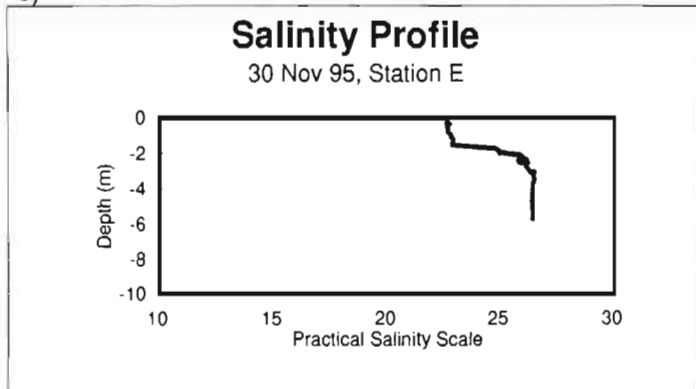
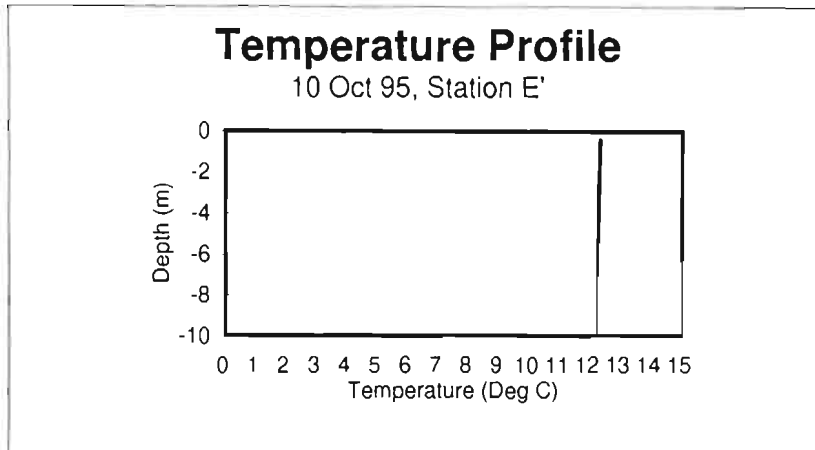


Figure A6. Salinity profiles at stations N, J, and E in the Richibucto Estuary (30 Nov 1995).

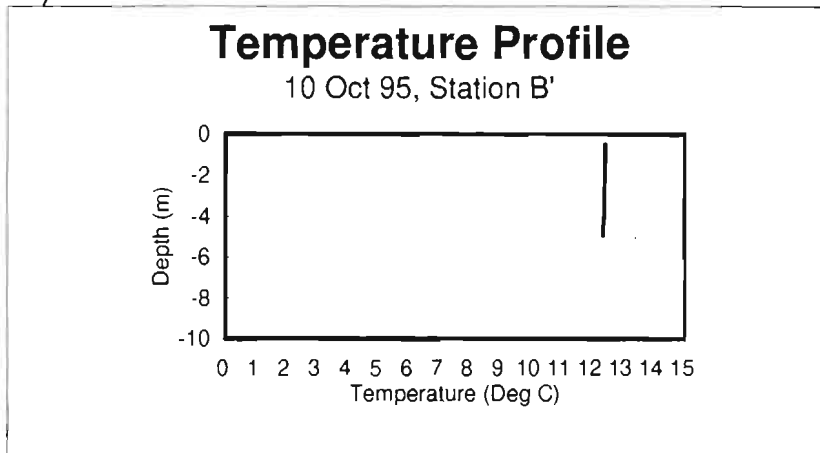
## **Appendix B**

### **Temperature Profiles**

a)



b)



c)

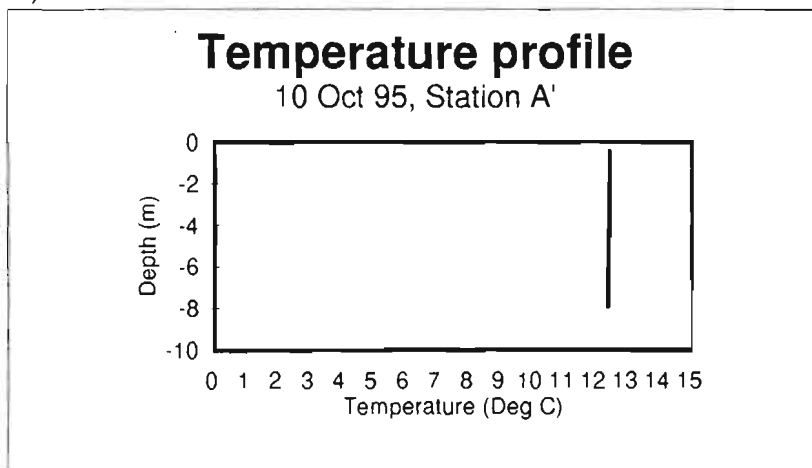
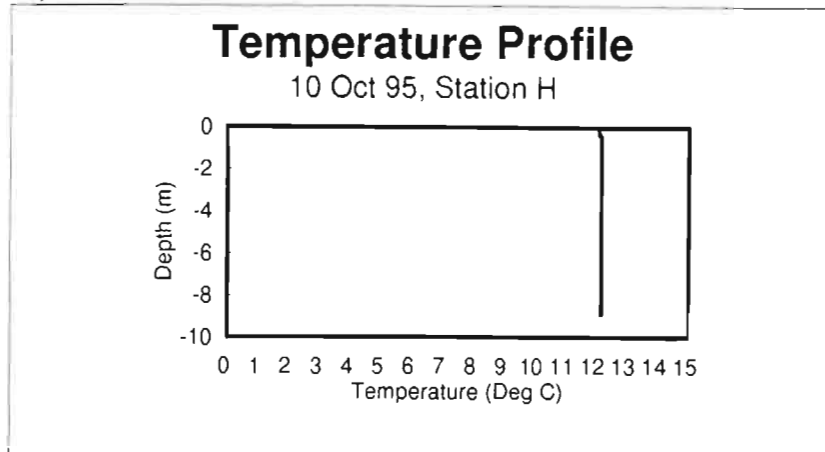
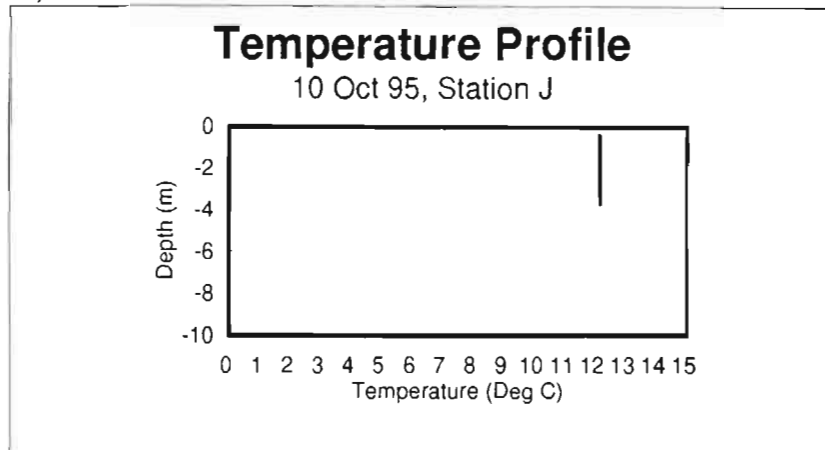


Figure B1. Temperature profiles at stations E', B', and A' in the Richibucto Estuary (10 Oct 1995).

a)



b)



c)

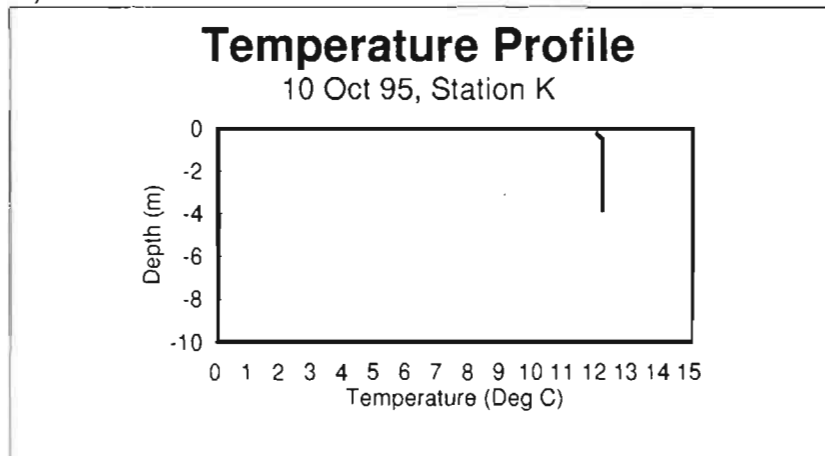
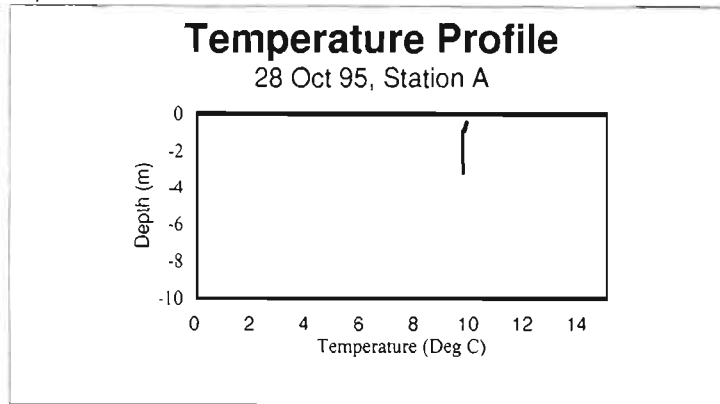


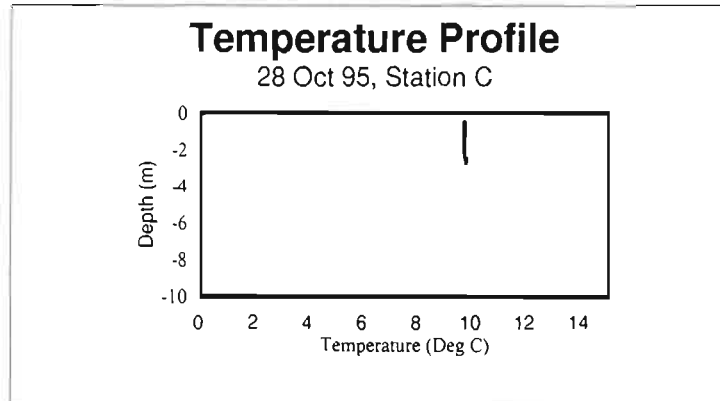
Figure B2. Temperature profiles at stations H, J, and K in the Richibucto Estuary (10 Oct 95).



a)



b)



c)

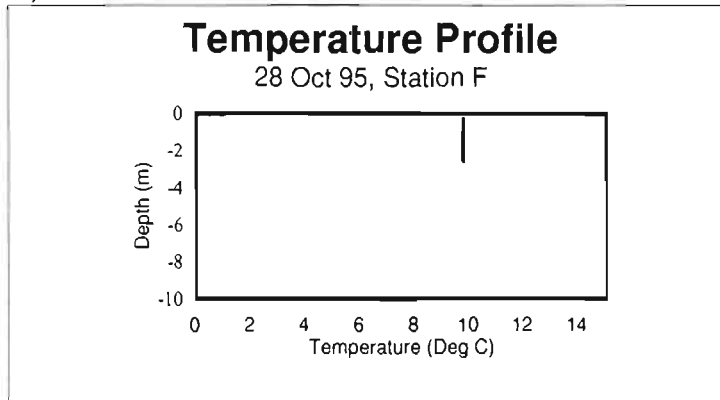
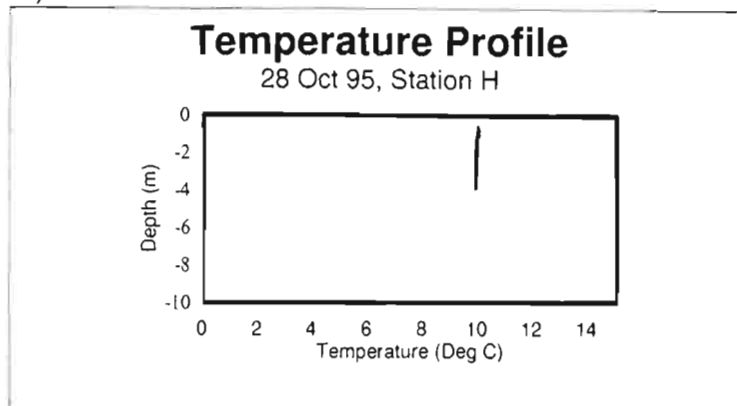
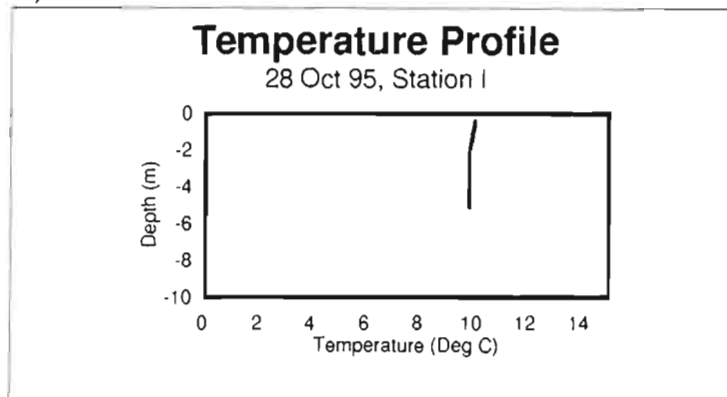


Figure B3. Temperature profiles at stations A, C, and F in the Richibucto Estuary (28 Oct 1995).

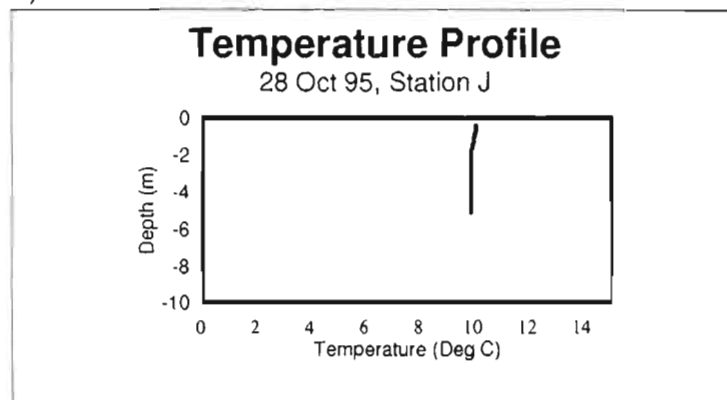
a)



b)



c)



d)

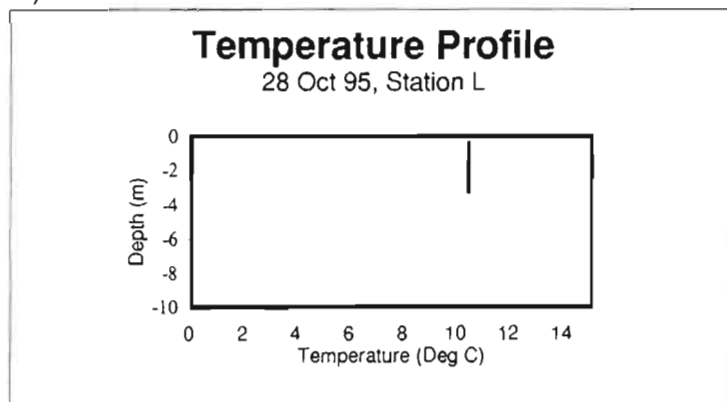
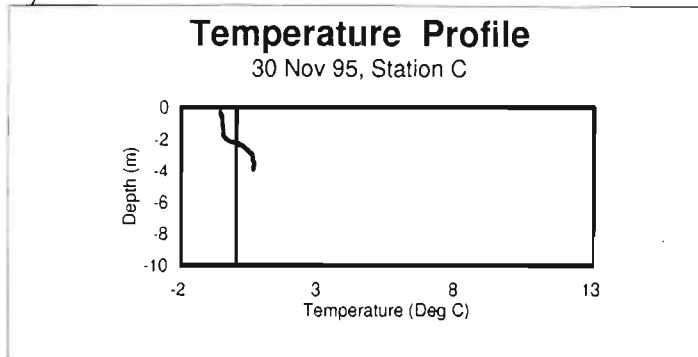
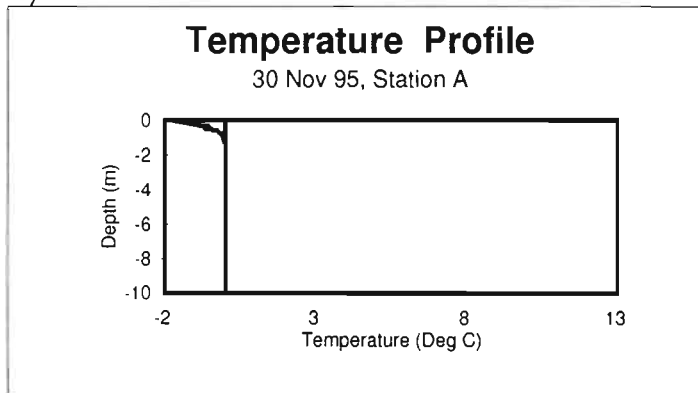


Figure B4. Temperature profiles at stations H, I, J, and L in the Richibucto Estuary (28 Oct 1995).

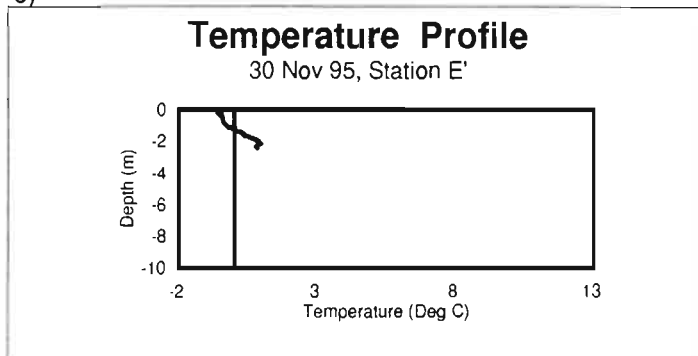
a)



b)



c)



d)

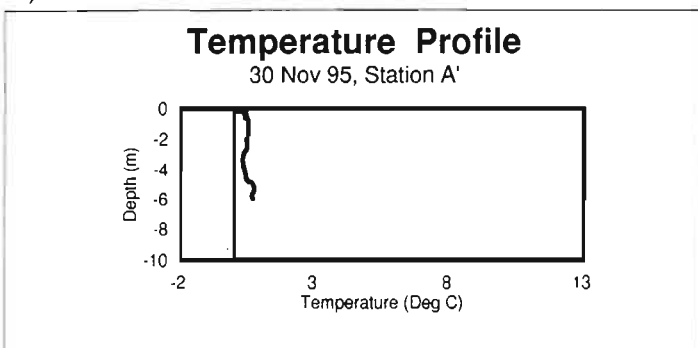
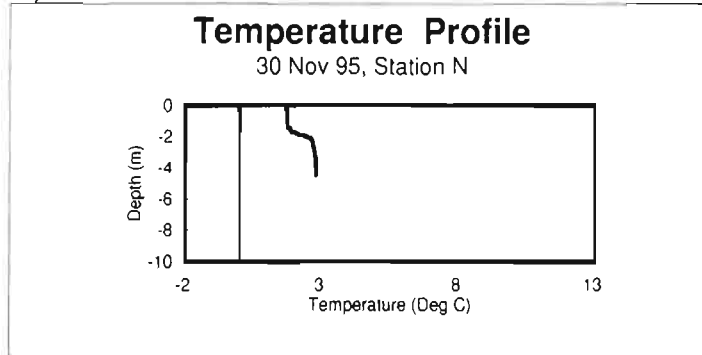
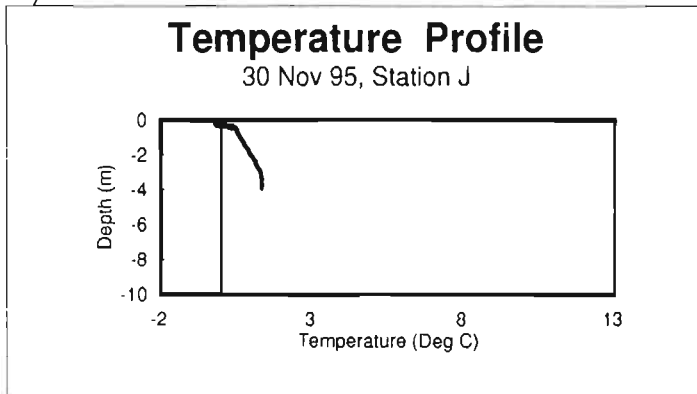


Figure B5. Temperature profiles at stations A, C, E', and A' in the Richibucto Estuary (30 Nov 1995)

a)



b)



c)

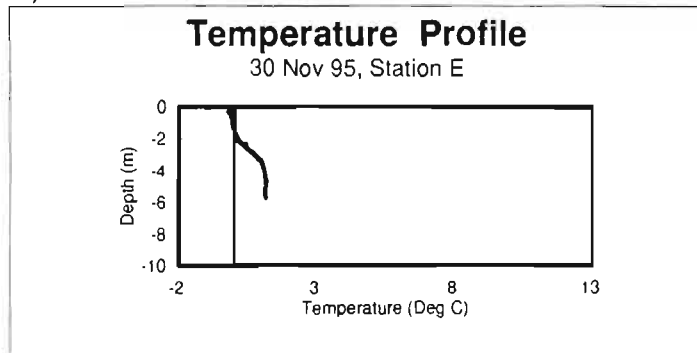


Figure B6. Temperature profiles at stations N, J, and E in the Richibucto Estuary (30 Nov 1995)