MARINE RESOURCE INVENTORY OF THE SEASIDE ADJUNCT, KEJIMKUJIK NATIONAL PARK

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December, 1987

Publication No. 6

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1. SUMMARY

The marine resources of the Seaside Adjunct to Kejimkujik National Park are contained within two large tidal lagoons located behind sand beach-dune complexes which partially isolate them from the sea. These systems, along with four small brackish-water headponds, have been described in terms of their origin, geology, physiography, morphology, sediment types and sedimentation processes, biology and input/output relationships. The major emphasis has been placed on identification and documentation of the biological habitats and communities present, and the factors responsible for their development and maintenance, with a view to making recommendations for monitoring, conservation, and preservation of these resources.

The major habitat types within the lagoon consists of high salinity coastal oceanic water, salt marshes, intertidal sand and mudflats and subtidal mud flats. The pelagic community is primarily oceanic in nature there being little freshwater input, relative to tidal exchange, to allow development of typically estuarine communities. Salt marsh habitats exist primarily on a narrow band along the shore zone, but occasionally occur on isolated islands on the higher intertidal flats and, where streams enter the lagoon, as larger meadows. Intertidal sand and mud habitats are poorly developed as a result of the unstability of substrates caused by high tidal current velocities and the coarse nature of sedimentary materials. The subtidal benthic community is dominated by eel grass beds located primarily in the upper reaches of the basins.

The physical factors associated with these habitats, particularly the high current velocities and resulting unstable substrates, leads to high community diversity but low species diversity and presents an extremely interesting environment for both interpretive and recreational activities.

2. INTRODUCTION

The Seaside Adjunct to Kejimkujik National Park was acquired by Environment Canada Parks in 1984. As part of the information required for development of a Park Management Plan, the Acadia Centre for Estuarine Research of Acadia University was commissioned to provide an inventory of the marine resources contained within the Adjunct. This report presents the results of our investigations, which were carried out on three separate site visits during October 18-20, 1986; February 13-14, 1987; and June 8-14, 1987.

2.1 Study Objectives

The major objective of the Marine Resource Inventory was to document the types of marine habitats present in the Adjunct and to describe the major communities associated with each habitat. In addition, it was deemed desirable to provide information, where possible, on the functional aspects of the marine environments, with particular reference to the factors responsible for development and maintenance of the biological resources. Information of this type is essential for future development of realistic management plans. The specific objectives of the study can be summarized as follows:

(1) to document, map and describe the marine habitats and communities present;
(2) to describe the geological, physical and chemical characteristics of the marine habitats;
(3) to identify and describe the principal geomorphological and oceanographic processes responsible for development of the major marine habitats and the communities associated with them;
(4) to evaluate the marine resources in terms of their ecological significance, scientific importance, interpretive value and recreational potential and constraints;
(5) to make recommendations with regard to management, preservation and conservation of the marine resources; and,
(6) to make recommendations on factors that should be monitored in future to provide indices of change in processes and consequently in marine resources.

2.2 Complementary Studies

Although there are no published scientific studies dealing specifically with the marine resources of the Seaside Adjunct, a number of reports have been prepared as a result of studies commissioned by various government agencies prior to and after acquisition of the Adjunct property by Environment Canada Parks.

An early study, conducted jointly by Environment Canada Parks and the Nova Scotia Department of Lands and Forests (Anon, 19??), presents a brief description of the resources of the Woods Property, as the Adjunct was then called, and an analysis of its potential for development, particularly in terms of recreation and interpretation. Mailman (1979) provided an initial biophysical classification of the Adjunct. This dealt primarily with classification of terrestrial vegetation types, but also included information on beach substrate types, sand dune character and stability, location of clam flats, potential bathing areas and access sites to boatable waters. A more intensive biophysical analysis by Hunter and Associates (1987) produced an Ecological Land Classification of the Adjunct. Although this study also concentrated on the terrestrial systems of the Adjunct, it provides some information on marine ecological units, marine geology, coastal physiography, climate and intertidal vegetation types. The only study dealing exclusively with the marine resources of the Adjunct was conducted by Newell (1985) who provided an analysis of the distribution, abundance and age structure of clam (*Mya arenaria*) populations in Port Joli and St. Catherines Basin. Newell's study provides the primary data base for assessing the extent of this resource and makes recommendations for management and monitoring of the clam beds.

There have also been a number of studies which, although not specific to the Adjunct, provide useful information relevant to an evaluation of its marine resources. In a study designed to give a general description of the Atlantic coastline of Nova Scotia, Monroe (1982) provides information on the morpho-dynamics, shoreline types and beaches of the Port Mouton peninsula. A series of studies by Piper (1980) and Piper *et al.* (1986) discusses substrate types, offshore sediment characteristics and sediment budgets for the offshore area of the Adjunct.

A study of the winter feeding ecology of geese by Smith (1985), although not conducted within the Adjunct, provides information on the distribution and abundance of *Zostera* communities in Port Joli which borders part of the Adjunct.

2.3 Acknowledgements

Mike Brylinsky was principal investigator for this project. Peggy Crawford Kellock coordinated the field work and laboratory analyses of field samples and aided in data tabulation and report preparation. Reg Newell was responsible for the bathymetric and subtidal benthic field surveys and Ruth Newell conducted the survey and identification of benthic macrophytes. Graham Daborn assisted in project management and report preparation.

The field crews consisted of the above plus Peter Comeau, Mike Shaffelberg, Jerome Mazier, Diane Amirault and David Waterbury. Because of the extremely difficult access to study areas, much unproductive time was spent transporting personnel and the large quantities of essential equipment from site to site. Special thanks are due to the members of this group who, despite often inclement weather, long portages over rough terrain

carrying overloaded packs and awkward field equipment, performed the necessary tasks with high morale and spirit making even the worst of chores pleasurable.

Cliff Drysdale, Dan Reive and Barb Hellemann of the Kejimkujik Park Staff aided in project design and field work. We extend our thanks to each of these.

3. STUDY AREA

3.1 Location and Access

The Seaside Adjunct is located on the southwestern shore of Nova Scotia (Figure 1) in Queens County, approximately 25 km southeast of the town of Liverpool (45° 52′ N and 64° 50′ W). It forms the outermost part of a peninsula bordered by Port Joli Bay on the southwest, Port Mouton Bay on the Northeast and the Atlantic Ocean on the southeast.

The major marine systems of the Adjunct consist of Little Port Joli Basin and St. Catherines Basin. Little Port Joli Basin occupies a total area of 124.7 hectares, and St. Catherines Basin 141.8 ha (Table 3), representing approximately 4.5 and 5.1% respectively of the total area of the Adjunct. Both basins are located along the southeast border of the peninsula and are accessible mainly by foot or all-terrain-vehicles from trails originating at Southwest Port Mouton and St. Catherines River. Access to both basins is also possible by small watercraft from the Atlantic Ocean via channels leading into each basin.

In addition to these major basins, four small coastal brackish water ponds are located within the Adjunct. These include Port Joli Headpond, Port Mouton Headpond and two ponds at Boyd's Cove. Each of these ponds is situated adjacent to the ocean shoreline and is accessible by foot along trails bordering the shoreline.

3.2 Recent History

Ms. Judith Tulloch, a Historian for Environment Canada Parks, has documented the Human History of the Seaside Adjunct. Despite early ownership of the property dating back to the early 1780's, little development of the lands took place until 1912 when William A. Kinney attempted to develop a large working sheep farm in the area of St. Catherines Basin. He is reported to have constructed a dyke at the east end of St. Catherines Basin in an attempt to drain and reclaim the salt marsh behind the dune beach. This appears to have met with early failure, however, and in 1928 the property passed into the hands of the Port Joli Sportsmen's Club whose charter maintained that the lands were to provide sporting, hunting, angling and social activities for its members. There is also some indication that this group intended to develop the property for sheep and horse breeding, but this apparently never occurred and in 1936 the property was sold at a tax sale to Edward and Frederick Burgess of Port Mouton. The Burgesses harvested pulp but made little other use of the property. In 1949 it was sold to Bourdette Wood who used the property as a summer home until his death in 1957, after which his son raised sheep on the lands and sold pulp to nearby mills. In 1974 the property was expropriated by the provincial government and in 1984 it became federal property.

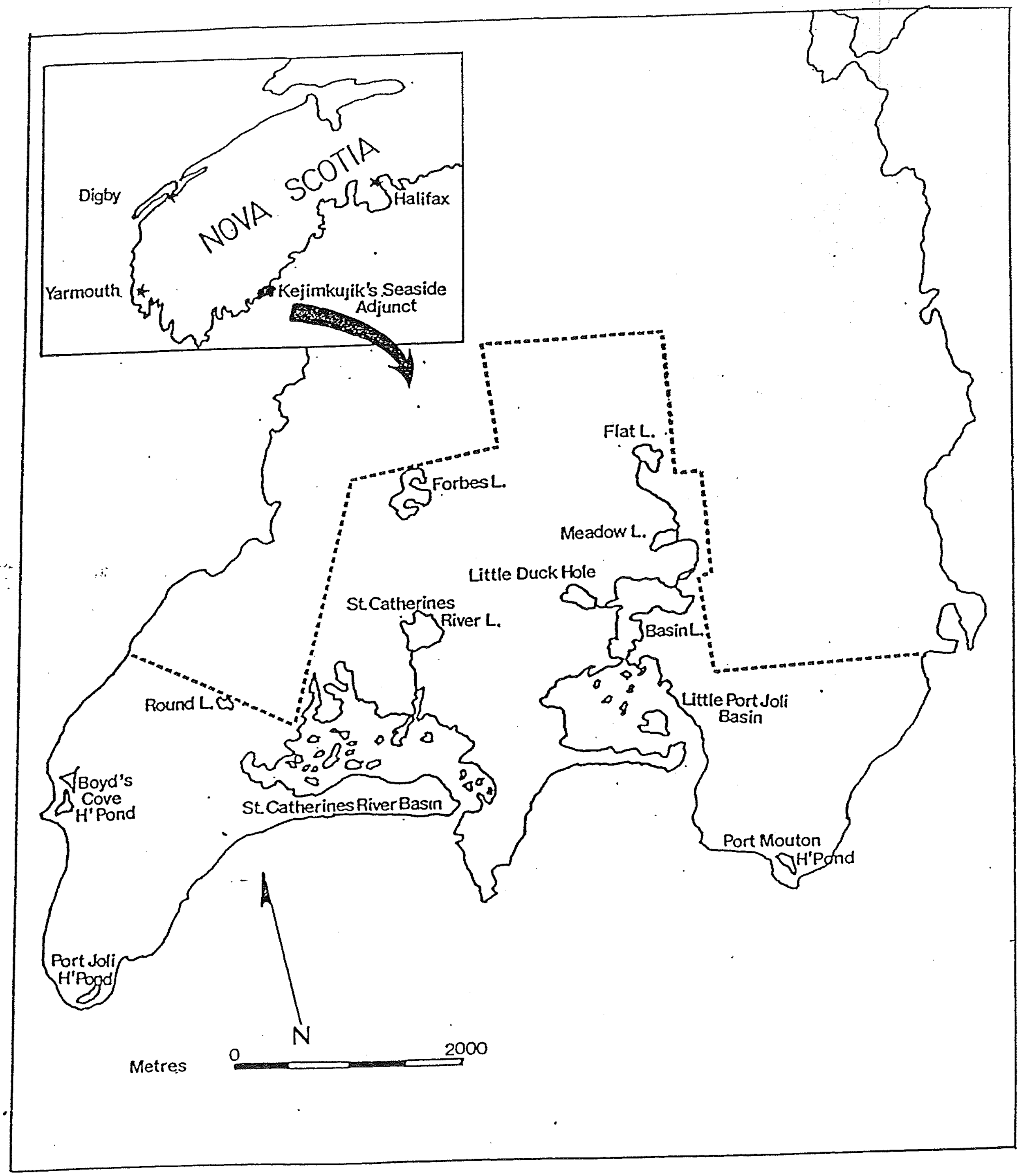

Figure 1. Overview of Seaside Adjunct to Kejimkujik National Park

Table 3. Marine habitats of the Seaside Adjunct, Kejimkujik National Park.

Habitat Type	Little Port Joli Basin Area (ha)	Little Port Joli Basin % Total Area	St. Catherines Basin Area (ha)	St. Catherines Basin % Total Area
Salt Marsh	29.4	23.5	41.9	29.6
Coarse Sand	21.8	17.4	22.8	16.1
Fine Sand	25.8	20.7	6.3	4.4
Eel Grass	34.5	27.7	38.9	27.4
Mudflat	13.4	10.7	31.9	22.5
Totals	124.7	100	141.8	100

Despite private ownership dating back to the early 1780's, the Adjunct property appears to have been used for many years by local residents for recreational purposes. Although it does not appear that any of the marine resources present were ever extensive enough to be commercially important, recreational harvesting of soft-shelled clams and waterfowl hunting in the area probably have a long history. There is also some indication that illegal harvesting of lobsters in the Basin Lake area was a common practice prior to acquisition of the property by Parks Canada.

3.3 Geological Features

The major geological features of the Adjunct have been summarized by Hunter and Associates (1987). The Adjunct is situated on the tilted erosion surface of the Southern Upland of Nova Scotia, which is composed primarily of slates, greywackes and granites. This is underlain primarily by undeformed, Permo-Carboniferous plutonic rocks. A small area near Port Joli is underlain by older, Cambrian greywacke and slates of the Goldenville Formation which Piper (1986) has suggested is merely a large roof pendant. This type of formation is actually more characteristic of the immediate area surrounding the Adjunct (Kepple, 1979).

A thin rubbly layer of glacial till covers the bedrock. Bedrock granite is visible in many areas where it forms outcroppings through the overburden. Drumlins are rare. This shallow moraine is presumed to extend offshore as well (Piper, 1986).

3.4 Coastal Physiography

The Adjunct is located along the southern edge of a tilted peneplain which rises from sea level along the Atlantic Coast to 600 m in Cape Breton. The landscape of the Adjunct is strongly glaciated, but of low relief. The bedrock surface in the immediate area of the Adjunct is rough, showing an abundance of overdeepened basins oriented south-southwest, corresponding to a major set of high angle faults (Fryson, 1966). Three small overdeepened basins occur at Port Mouton and a fourth small basin occurs south of Mouton Head. These features are thought to be the results of sculpturing by fluvial processes during the Tertiary and glacial quarrying and meltwater erosion during the Pleistocene (King, 1972).

The coastline of the Adjunct is irregular and rocky, sloping gently landward and to the sea. The most seaward shoreline contains two large sandy beaches separated from each other by a granite headland. The development and maintenance of these beaches appears to be associated with the presence of protruding headlands that provide "anchor" points and protection from erosion processes associated with longshore transport. The remainder of the shoreline consists mostly of exposed cobble beaches interrupted with pebble-cobble pocket and steep shingle beaches (Monroe, 1979) reflecting the low availability of sedimentary materials available for sand beach formation in the area (Piper, 1986).

The two large tidal lagoons forming the major marine systems of the Adjunct are almost completely separated from the sea by sand beach-dune complexes which appear to be slowly migrating landward in response to rising sea levels. These dunes are in an early successional stage and consist of only a primary dune backed on the landward side by tidal flats. There are no secondary dunes present. A single tidal channel through the dune connects each lagoon to the sea. Both lagoons contain extensive sediment deposits, much of which have been built up to intertidal positions and large areas become exposed tidal flats at low tide. In some areas these flats have become covered by emergent salt-water vegetation and form marsh systems.

3.5 Origin of Coastal Lagoons

The origin and development of the marine lagoons of the Adjunct is most likely a result of rising sea level in combination with the development of a barrier beach.

Slowly rising sea levels over the last 10,000 years have resulted in the overall form of the Atlantic coastline of Nova Scotia being one of submergence, with drowned river valleys and mid-bay barrier beaches, and an embayed shoreline morphology (Piper *et al.*, 1986). Nova Scotia has experienced a variable rate of sea level rise over the last 7000 years. In the region of the Adjunct relative sea level rise has been estimated at about 30 cm/century. Most of this rise has been the result of the subsidence of land relative to the sea, the rise in eustatic sea level being only about six cm per century (Grant, 1987).

At the height of the last glaciation, some 20,000 years ago, Nova Scotia and its present continental shelf were completely ice covered. During the Holocene transgression, which began about 18,000 years ago, the ice gradually retreated and by 11,000 BP had receded behind the present coastline. During this transgression glacial till was deposited beneath the retreating ice. This till was composed of relatively unconsolidated sediment and was easily eroded. However, as sea level rapidly rose in response to the retreating ice cover, the supply of new sediments necessary to maintain the beaches was insufficient and the beach systems began a landward transgression which still continues today in response to the rising sea level (Piper, 1980). Evidence that this process is still occurring within the Adjunct can be seen in drowned tree stumps, submerged peat and overriding barrier beaches along the the shorelines of both St. Catherines and Little Port Joli beaches.

The landward migration of the beach-dune complexes has probably been slowed somewhat as a result of the protection afforded by the adjacent granite headlands which modify the effects of strong storm waves and hinder longshore transport of sediments away from the beaches. There is evidence from aerial photography that the lagoons periodically become isolated from the sea by sedimentation of littoral drift at the tidal inlets. However, as a result of strong storm events, breakthroughs occur and strong tidal currents, in combination with a paucity of sediments, prevent the openings from becoming permanently closed.

3.6 Climatic Conditions

Climatic conditions at locations near the Adjunct (Table 1) have been summarized by Hunter and Associates (1987). Air temperatures range from a mean daily maximum of about 11.5 °C to a mean daily minimum of about 2.7 °C. The annual mean is about 7 °C. Total annual precipitation averages about 130 cm of which approximately 110 cm falls as rain and the remainder as snow. The proximity of the ocean results in high humidity and frequent fog and is significant in moderating climatic conditions to produce a prolonged gradual transition between seasons. Winters are relatively mild and short, summers cool and short and both spring and fall tend to be long and cool.

Seawater temperatures reach their maximum of 10-13 °C in late July and August. The sea is generally ice free during winter months but some drift ice occurs offshore from April to May. Prevailing winds blow from the northwest quadrant during the winter and early spring and from the southwest during summer and early autumn. Wind velocities vary seasonally, with mean velocities of 20-25 km/hr during the winter declining to about 15 km/hr during late summer (Table 2 and Figure 2).

3.7 Offshore Oceanic Surface Currents

Offshore surface sea water circulation in the area immediately adjacent to the Adjunct is dominated by a southwest drift along the shore which has a distinct seasonal pattern (Bumpus and Lanzier, 1965). The southwest drift is most fully developed during the spring and tends to break down during the summer, when a northeast drift extends inshore from the area of Browns Bank. The southwest drift is again formed during the autumn and winter, but is somewhat less distinct than during the spring. Surface current velocities are generally low, ranging from less than one to about three knots. Further offshore, over the edge of the continental shelf, the surface circulation is characterized by a general off-shelf movement in a northeast or easterly drift.

3.8 Marine Habitats

Despite their relatively small size, the marine systems of the Adjunct contain a surprising variety of marine habitats. This diversity primarily results from the low topography, the strong tidal mixing that occurs, and the effect that tidal

Table 1. Climatic conditions at Western Head, Nova Scotia (from Environment Canada Atmospheric Environment Service)

WESTERN HEAD (AUT) 43° 59'N 64° 40'W 9 m	JAN JAN	FEB FÉV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEP SEPT	OCT OCT	NOV NOV	DEC DÉC
Daily Maximum Temperature	1.0	0.6	3.5	7.7	11.6	15.2	17.5	18.7	17.3	13.5	8.6	3.5
Daily Minimum Temperature	-6.9	-7.3	-3.7	0.3	4.3	7.6	9.9	10.9	9.7	5.4	1.4	-4.5
Daily Temperature	**-3.0**	**-3.4**	**-0.1**	**3.9**	**8.0**	**11.3**	**13.8**	**14.8**	**13.6**	**9.4**	**5.0**	**-0.5**
Standard Deviation, Daily Temperature	1.7	1.6	0.9	0.8	0.8	1.2	1.0	1.2	1.0	1.2	1.2	1.7
Extreme Maximum Temperature	11.1	10.6	14.4	23.3	27.8	33.9	33.9	30.0	30.0	27.2	20.0	12.2
Years of Record	16	16	16	16	16	16	16	16	17	17	17	17
Extreme Minimum Temperature	-22.2	-23.3	-16.7	-8.3	-4.4	1.7	4.4	5.0	0.0	-4.4	-10.0	-18.3
Years of Record	16	16	16	16	16	16	16	16	17	17	17	17
Rainfall	108.6	75.7	83.3	95.8	104.0	80.8	78.5	100.5	98.1	117.6	154.0	111.7
Snowfall	40.8	56.1	36.1	14.0	2.3	0.0	0.0	0.0	0.0	2.3	3.9	41.8
Total Precipitation	**141.5**	**123.4**	**115.6**	**107.6**	**106.1**	**80.8**	**78.5**	**100.5**	**98.1**	**121.1**	**158.4**	**150.6**
Standard Deviation, Total Precipitation	40.8	47.4	40.7	37.1	48.9	27.3	45.2	61.1	71.5	67.2	86.3	47.6
Greatest Rainfall in 24 hours	42.7	48.0	75.2	77.5	50.3	63.5	53.6	172.7	108.7	122.2	92.5	76.5
Years of Record	16	16	16	16	16	16	16	16	17	17	17	17
Greatest Snowfall in 24 hours	33.0	59.2	40.4	27.4	27.2	0.0	0.0	0.0	0.0	41.9	10.4	44.2
Years of Record	16	16	16	16	16	16	16	16	17	17	17	17
Greatest Precipitation in 24 hours	42.7	53.3	81.5	77.5	50.3	63.5	53.6	172.7	108.7	122.2	92.5	76.5
Years of Record	16	16	16	16	16	16	16	16	17	17	17	17
Days with Rain	9	7	9	12	13	12	10	12	10	11	13	12
Days with Snow	10	8	7	4	0	0	0	0	0	0	2	8
Days with Precipitation	16	13	13	13	13	12	10	12	10	11	14	17

Table 2. Summary of wind velocity and direction at Western Head, Nova Scotia (from Environment Canada Atmospheric Environment Service)

WESTERN HEAD (AUT) N.S.

PERIOD 1963-80 PERIODE

Lat. 43°59′N Long. 064°40′W

Elevation 9 m Altitude

	JAN JANV	FEB FEV	MAR MARS	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOUT	SEP SEPT	OCT OCT	NOV NOV	DEC DEC	YEAR ANNUEL	
PERCENTAGE FREQUENCY / FRÉQUENCE EN %														
N	7.8	6.3	7.7	7.3	6.1	4.2	3.3	4.4	6.7	8.6	9.5	9.1	6.8	N
NE	11.3	12.3	15.0	19.1	18.9	16.4	9.9	10.2	14.8	11.8	13.1	11.7	13.7	NE
E	3.1	5.2	4.7	4.7	5.2	2.9	2.1	1.7	3.5	2.5	5.0	4.1	3.7	E
SE	5.8	5.9	7.2	6.7	5.2	3.9	4.1	3.9	6.5	5.6	8.0	8.2	5.9	SE
S	5.4	6.5	7.5	9.5	13.0	12.5	10.2	9.6	9.4	9.5	6.8	6.1	8.8	S
SW	14.5	15.3	18.7	20.2	30.3	41.6	53.7	46.5	28.2	24.7	16.6	13.7	27.0	SW
W	17.6	18.5	14.6	10.8	7.8	7.9	7.1	9.6	10.2	15.1	16.1	15.3	12.6	W
NW	34.5	29.9	24.6	21.6	13.4	10.5	9.4	13.7	20.5	22.0	24.9	31.8	21.4	NW
Calm	0.0	0.1	0.0	0.1	0.1	0.1	0.2	0.4	0.2	0.2	0.0	0.0	0.1	Calme
MEAN WIND SPEED IN KILOMETRES PER HOUR / VITESSE MOYENNE DES VENTS EN KILOMÈTRES PAR HEURE														
N	17.1	15.9	17.1	18.9	16.6	12.3	9.7	9.8	11.9	15.7	16.6	16.0	14.8	N
NE	26.4	27.8	23.5	23.0	20.5	16.8	13.2	14.6	16.7	20.6	25.7	25.6	21.2	NE
E	24.0	30.8	21.3	19.7	15.0	13.0	9.9	9.2	14.1	19.1	27.6	29.4	19.4	E
SE	28.0	27.6	24.0	19.3	15.5	13.6	11.6	11.7	19.0	22.4	27.1	33.6	21.1	SE
S	27.7	28.9	22.6	18.6	19.7	18.8	15.7	18.1	20.8	23.6	28.9	30.3	22.8	S
SW	25.4	24.6	23.8	21.4	20.3	18.5	15.8	15.5	19.5	21.5	25.2	25.1	21.4	SW
W	17.7	18.3	19.2	17.7	16.1	14.7	12.3	13.2	13.7	15.2	15.9	18.4	16.0	W
NW	20.0	19.7	21.3	19.9	20.3	18.4	15.5	17.2	16.6	17.8	17.7	19.1	18.6	NW
All Directions	21.8	22.6	21.8	20.3	19.2	17.3	14.7	15.1	17.2	19.3	21.6	22.6	19.5	Toutes directions
Maximum Hourly Speed	82 N	85 NE	80 SVL	72 SW	63 SE	68 NE	72 SE	71 NE	84 S	101 S	77 NE	76 S	101 S	Vitesse horaire maximale

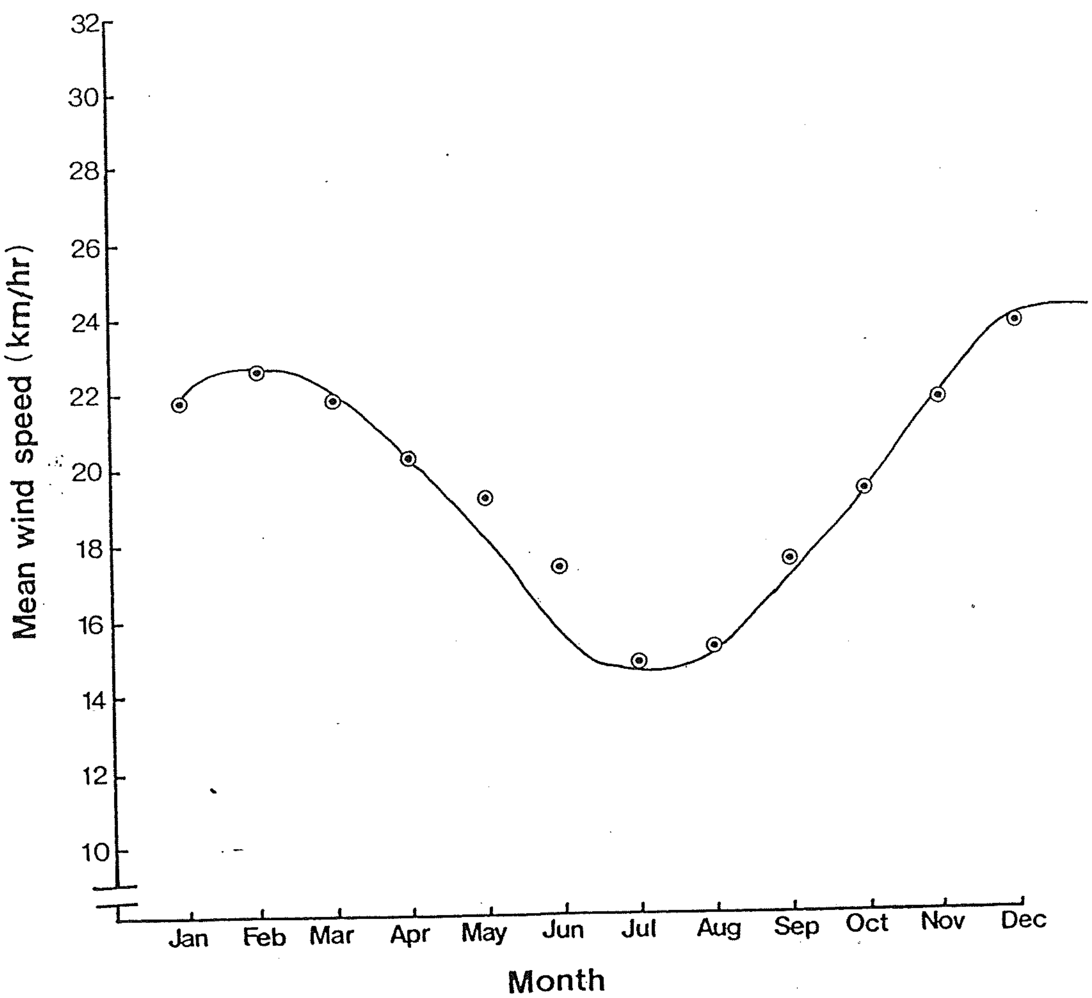

Figure 2. Seasonal variation in wind velocity at Western Head, Nova Scotia (from Environment Canada Atmospheric Environment Service - 1963 to 1980 average)

turbulence has on the sorting and distribution of sediment types. This is particularly evident in intertidal areas where sediment types range from fine silts to coarse sands.

Bordering the shoreline of each lagoon is a narrow intertidal salt marsh habitat characterized primarily by *Spartina alterniflora* near the low water level and *Spartina patens* along the upper shoreward regions. This habitat reaches varying levels of development depending on the slope of the intertidal zone and stability of the underlying sediments. Salt marsh habitats also occur in intertidal areas where tidal flats are relatively high and sediments are composed of fine sands and muds. The remainder of the intertidal area is characterized by the presence of tidal sand- or mud-flat habitats and a large diversity of community types corresponding to the variety of sediment types. In areas where sediments are stable and relatively fine grained, benthic algae colonize the surface, in some cases forming dense algal mats. These areas also contain the greatest abundance of benthic infauna. Epifauna however are generally rare. Areas dominated by coarser sediments indicative of stronger tidal currents, tend to be less stable, and this prevents any extensive development of benthic communities. Such communities are dominated by animals with shorter life cycles and greater colonizing ability.

The sub-tidal habitats range from bedrock and boulders exposed by tidal scouring in the main channels, to very fine mud sand bottoms in the innermost areas of the lagoons. Macroscopic algal communities develop when there are suitable rocky substrates for attachment and the mud-sand bottoms are colonized by eelgrass communities.

The pelagic habitats of the lagoons, in contrast to the benthic, exhibit much less diversity and are primarily oceanic in nature. The lack of any significant freshwater input and the large tidal exchange prevent the development of extensive estuarine or brackish water habitats, and strong tidal mixing results in little vertical or horizontal heterogeneity in the pelagic system between different areas of the basin.

Table 3 lists the major marine habitats identified during this study, together with the area occupied by each, and Figures 27 and 28 present maps of each basin illustrating the distributions of the various habitat types.

4. METHODOLOGY

4.1 Site Visits

Three site visits were made to the Adjunct. The first, on October 18-20, 1986, involved sampling at 15 different stations to provide a general evaluation of the major morphological, physical, chemical and biological characteristics of each site. Particular emphasis was placed on determining the potential for stratification of the water column and identification of pelagic and benthic habitats and community types at each station. This information was used to design the sampling programme and logistics for a more intensive site visit that took place from June 8-14, 1987 when most of the field work was carried out. An additional site visit was made on February 14-15, 1987 to evaluate winter habitat conditions, primarily with regard to development and extent of ice cover.

4.2 Field Procedures

4.2.1 Selection of Sample Sites and Transect Locations

Sampling sites and transect locations were selected on a non-random basis and designed to include measurements and collections at a minimum of one station within each of the major habitat types. Potential sampling sites were initially identified by examination of aerial photographs and finalized during site visits. A total of 49 stations were sampled throughout the survey. Appendix B presents a series of maps indicating the location of sample stations. At most stations duplicate samples were taken for analysis, but at three stations, corresponding to the inlets of each of the major basins, a time-series analysis of physical, chemical and biological parameters of the water column over a tidal cycle was conducted to provide an input-output analysis of the pelagic system.

4.2.2 Morphological Characteristics

A bathymetric survey, necessary for determination of the morphological characteristics of each basin, was conducted on site using a metered rod and/or marked leadline. The deeper areas of channels and shallower soft-bottom areas were traversed by small watercraft. Shallow areas with hard bottoms were traversed by foot. For the tidal lagoons, depth soundings were converted to datum using tide tables, times of soundings and reference depths obtained from time-series measurements of depths during tidal cycles. The data obtained were used to produce bathymetric maps from which the morphological characteristics of each were determined using standard cartometric and planimetric techniques.

4.2.3 Physical, Chemical and Biological Variables

Table 4 lists the major physical, chemical and biological variables measured and summarizes the techniques employed. Figures 3a-j illustrate the field procedures associated with these techniques.

The particular variables measured at each sampling station varied depending on the type of habitat being sampled. Most measurements of physical and chemical factors were confined to the pelagic system. Physical factors measured for the benthic habitats consisted primarily of determination of sediment types using a subjective classification based on visual inspection which included the following five categories: fine muds; fine sand; coarse sand; pebbles and bedrock. Additional physical factors examined for sediments included processes associated with beach and tidal flat development dynamics, and erosion and accretion processes.

The type of biological samples taken also varied with the habitat type being studied. Sampling of the pelagic system included water samples for phytoplankton and chlorophyll analysis, horizontal zooplankton tows and beach seines for nekton. Benthic samples for infauna on exposed tidal flats were taken with a 232 cm^2 box cover to a depth of 20 cm and sieved through a #20 (850 um) screen. A general survey of the distribution of subtidal benthic fauna and flora was conducted in conjunction with the bathymetric survey using a viewing box.

General habitat types were documented using 35 mm color photography.

4.2.4 Preservation Techniques

All biological collections of animals were labelled at the site and preserved using 10 % buffered formalin. Representative samples of algal macrophytes were preserved by drying and pressing.

Samples taken for water quality analysis were either processed the same day or frozen for subsequent analysis in the laboratory.

Table 4. Summary of variables measured and techniques employed for data collection and sample analysis

Morphological Variables	Measurement Technique
Drainage Basin Area	Planimetry on appropriately scaled topographic maps
Surface Area	Planimetry on aerial photographs and/or field survey measurements
Volume	Hypsographic curves constructed from bathymetric surveys conducted with a recording depth sounder
Shoreline Length	Cartometric measurement from aerial photographs and/or land survey measurements
Maximum Length	Cartometric measurement from aerial photographs and/or land survey measurements
Maximum Breadth	Cartometric measurement from aerial photographs and/or land survey measurements
Maximum Depth	Bathymetric survey
Mean Depth	Calculation from surface area and volume
Relative Depth	Calculation from maximum depth and surface area
Development of Volume	Calculation from mean and maximum depth
Shoreline Development	Calculation from shoreline length and surface area
Physical Variables	
Light Attenuation	Secchi disc; underwater irradiometer
Euphotic Zone Depth	Calculation from irradiometer measurements
Water Temperature	Portable YSI temperature probe
Specific Conductance	Portable conductivity meter
Suspended Particulate Matter	Gravimetric on filtered water samples

Table 4 Continued

<u>Chemical Variables</u>	
Salinity	Portable salinometer
pH	Portable pH meter
Alkalinity	HACH kit (H_2SO_4 titration)
Dissolved O_2	Winkler Titration (w/ azide modification)
Nitrate	HACH kit (Cadmium Reduction Method)
Phosphate	HACH kit (Stannaver Method)
Silica	HACH kit (Heteropoly Blue Method)
<u>Biological Variables</u>	
Chlorophyll	Acetone extraction/spectrophotometric measurement
Phytoplankton	Horizontal and vertical tows with 64 um nets/microscopic counting
Zooplankton	Horizontal and vertical net tows with 160 um nets/microscopic counting
Aquatic Macrophytes	Visual sightings using shoreline surveys
Benthos	Benthic dredge sampling along transects/sieving, sorting and counting
Fish	Beach seines at selected sites/sorting and counting
Waterfowl	Visual sightings during site visits

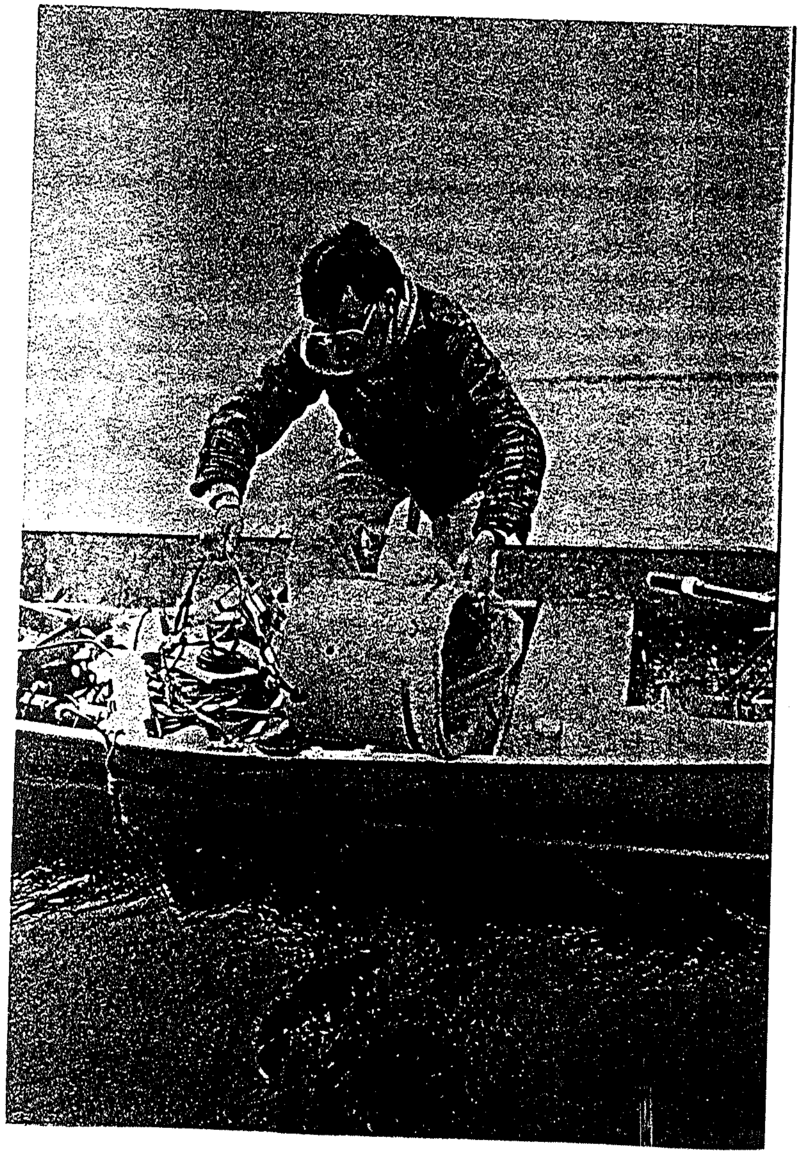

Figure 3a. Collection of zooplankton

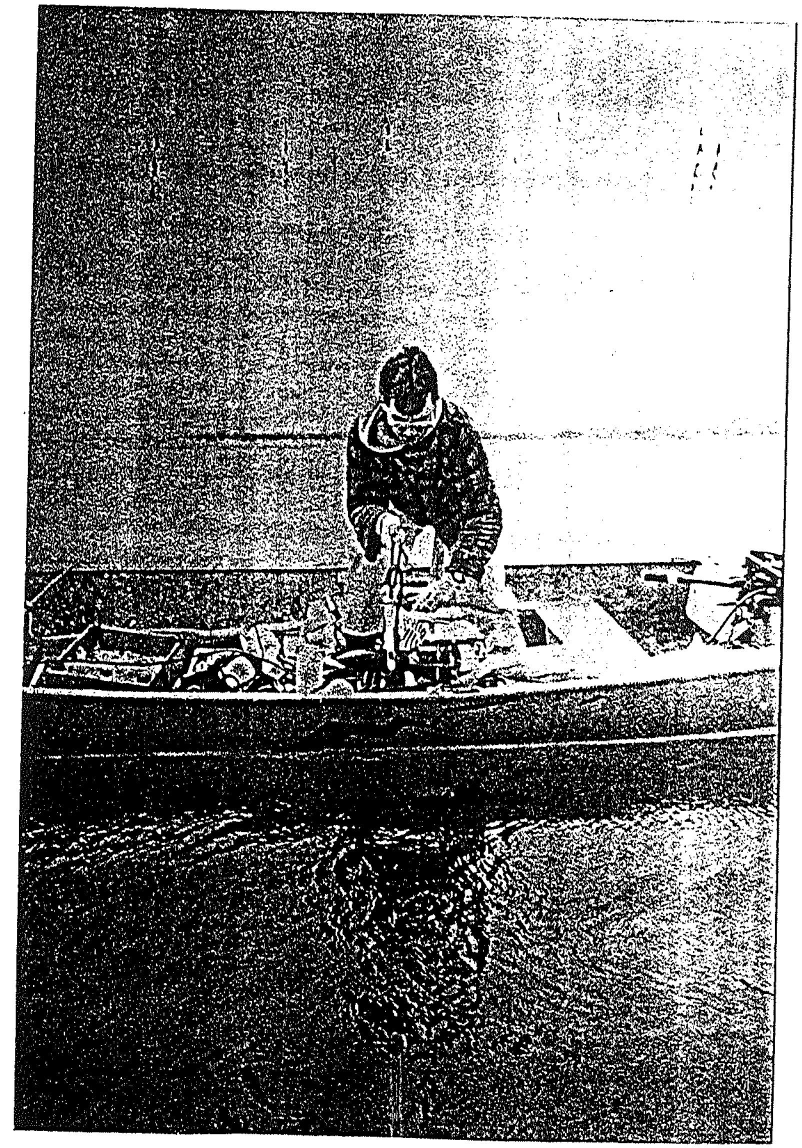

Figure 3b. Measurement of current velocities using a TSK current meter

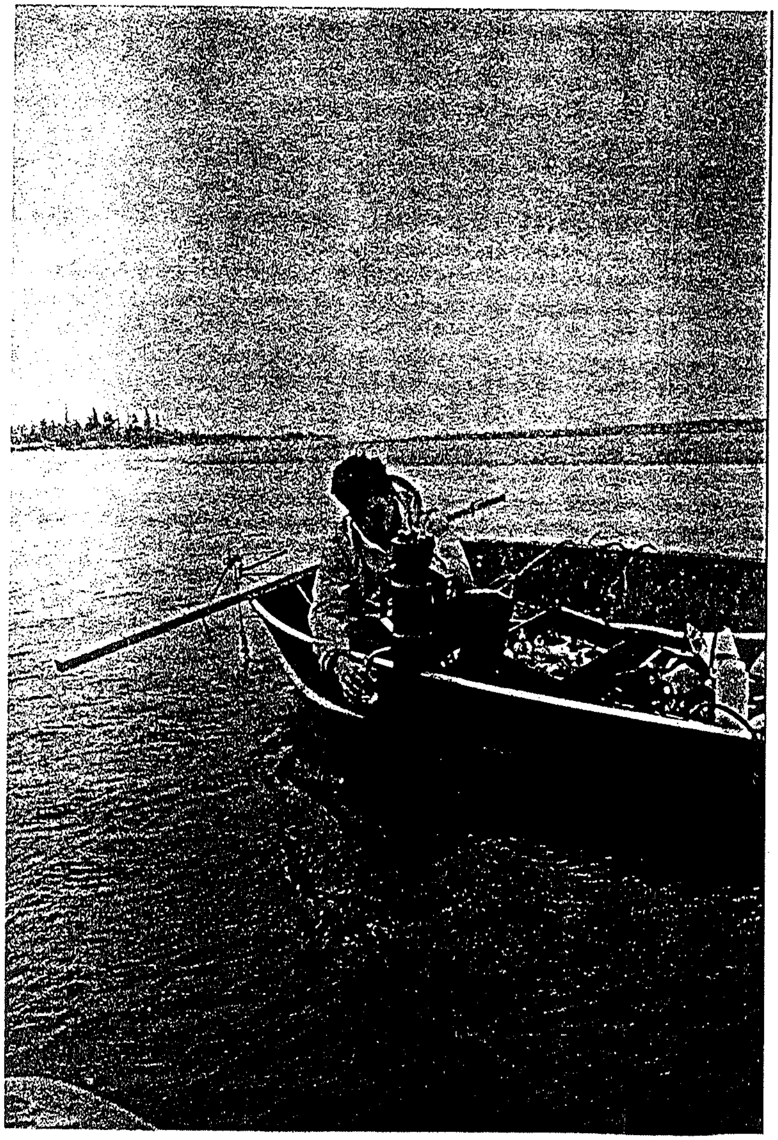

Figure 3c. Collection of water samples for chemical analyses

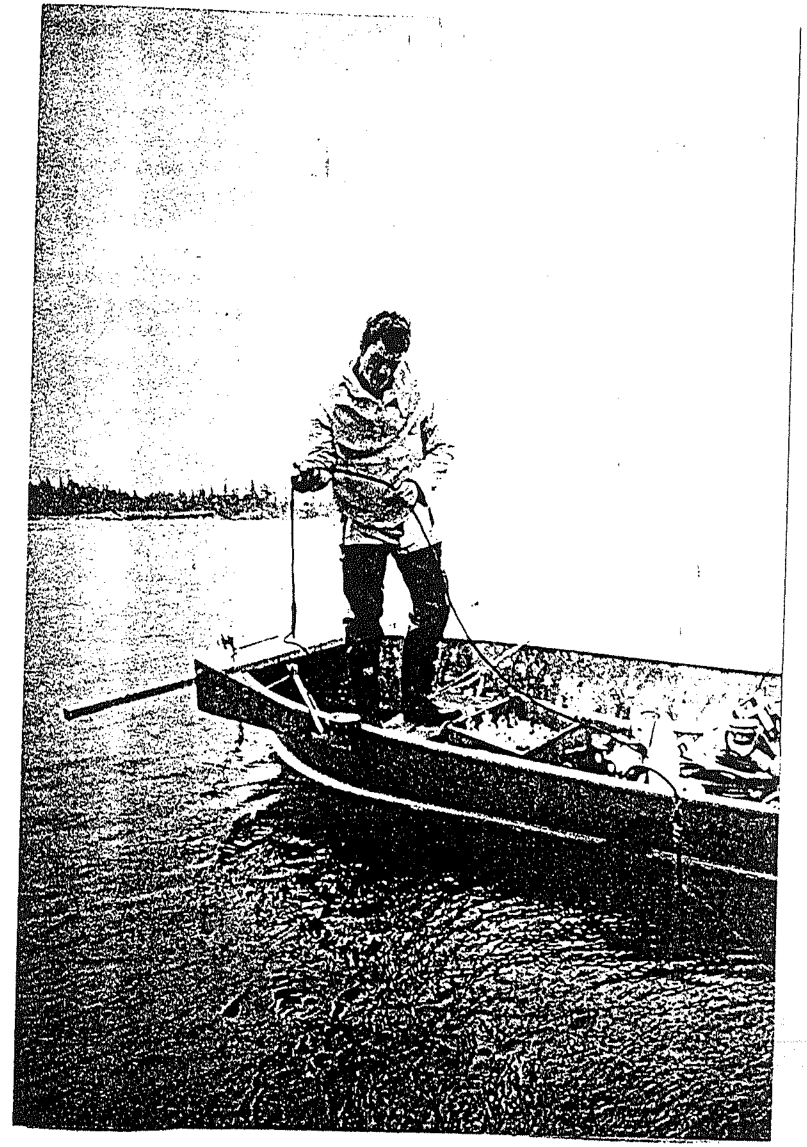

Figure 3d. Measurement of light transmission using an underwater irradiometer

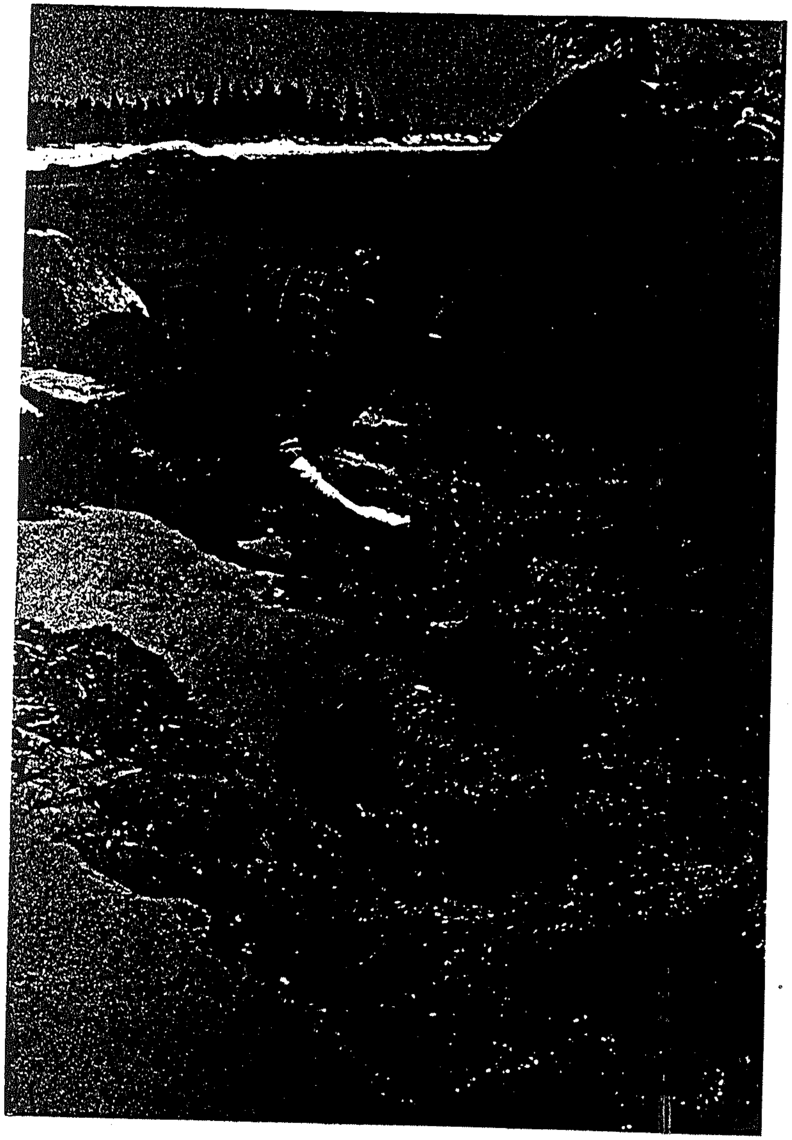

Figure 3e. Hand collection of macrophyte samples

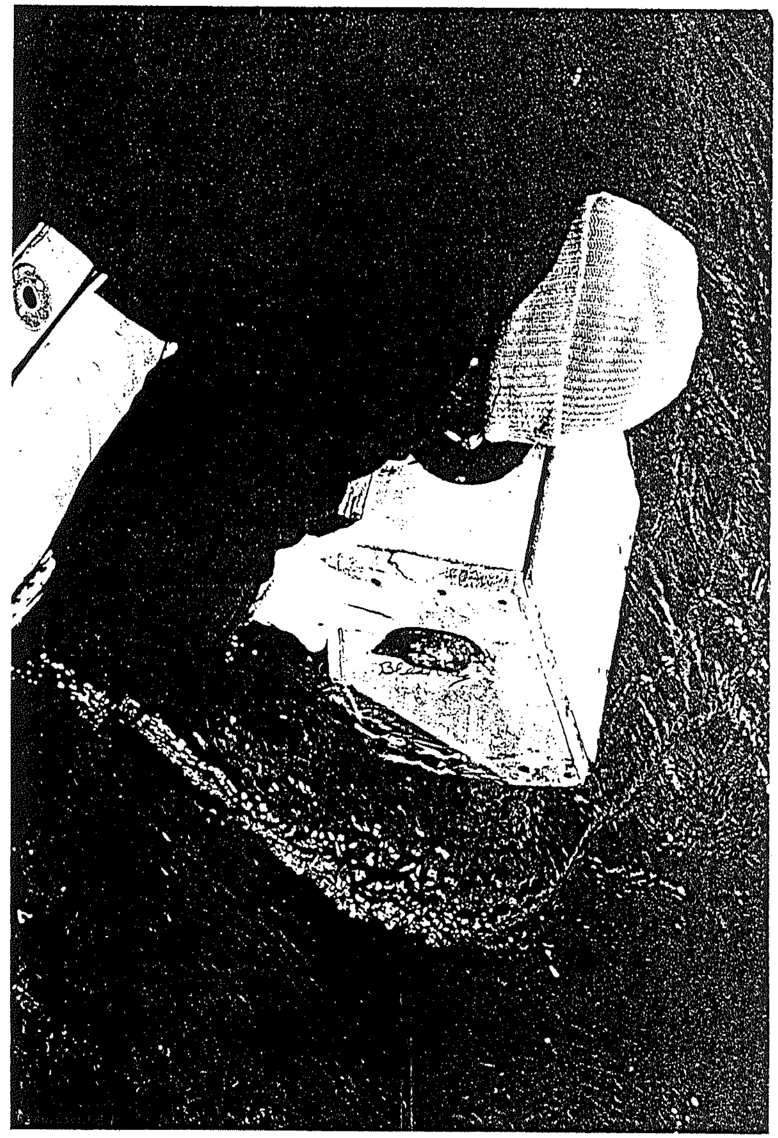

Figure 3f. Benthic macrophyte survey using a "looking box"

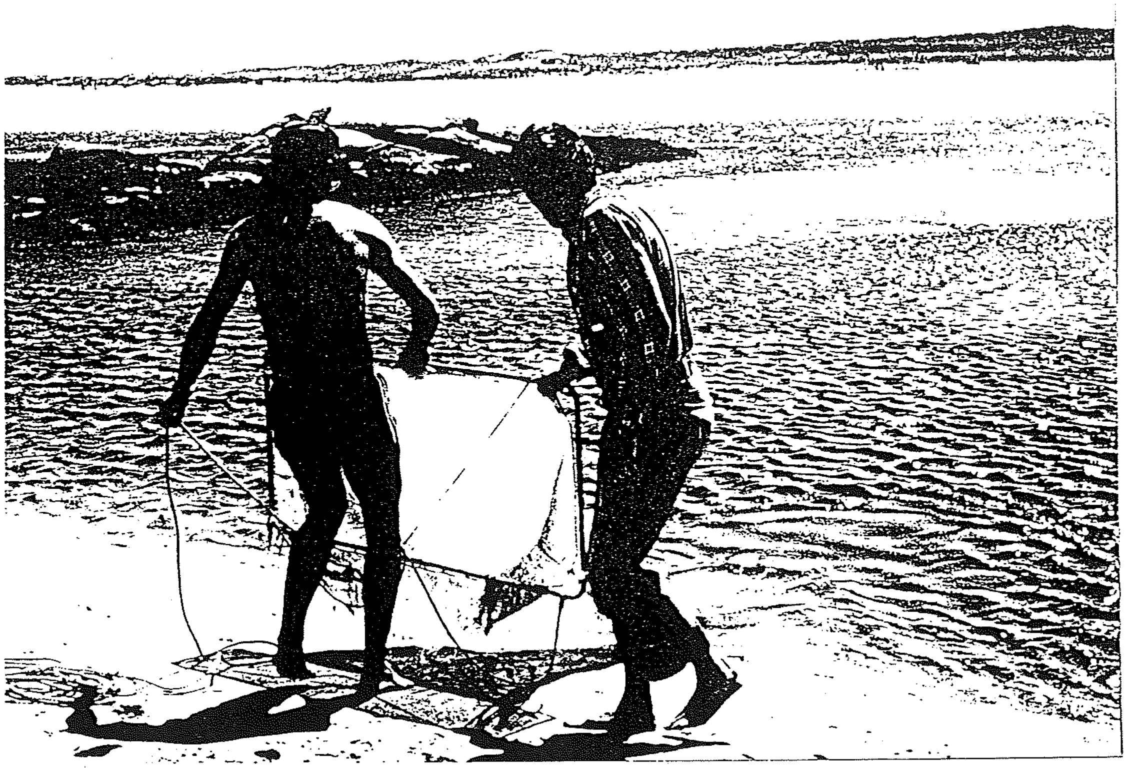

Figure 3g. Shrimp seine collections

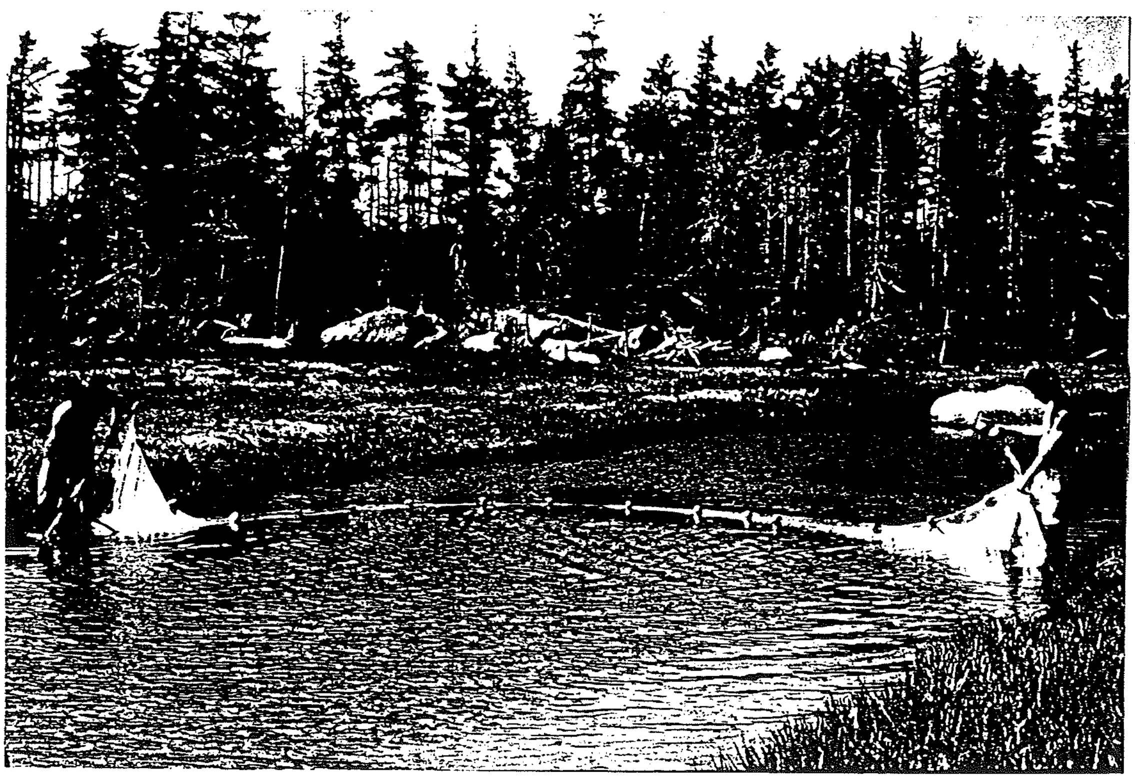

Figure 3h. Beach seine collections

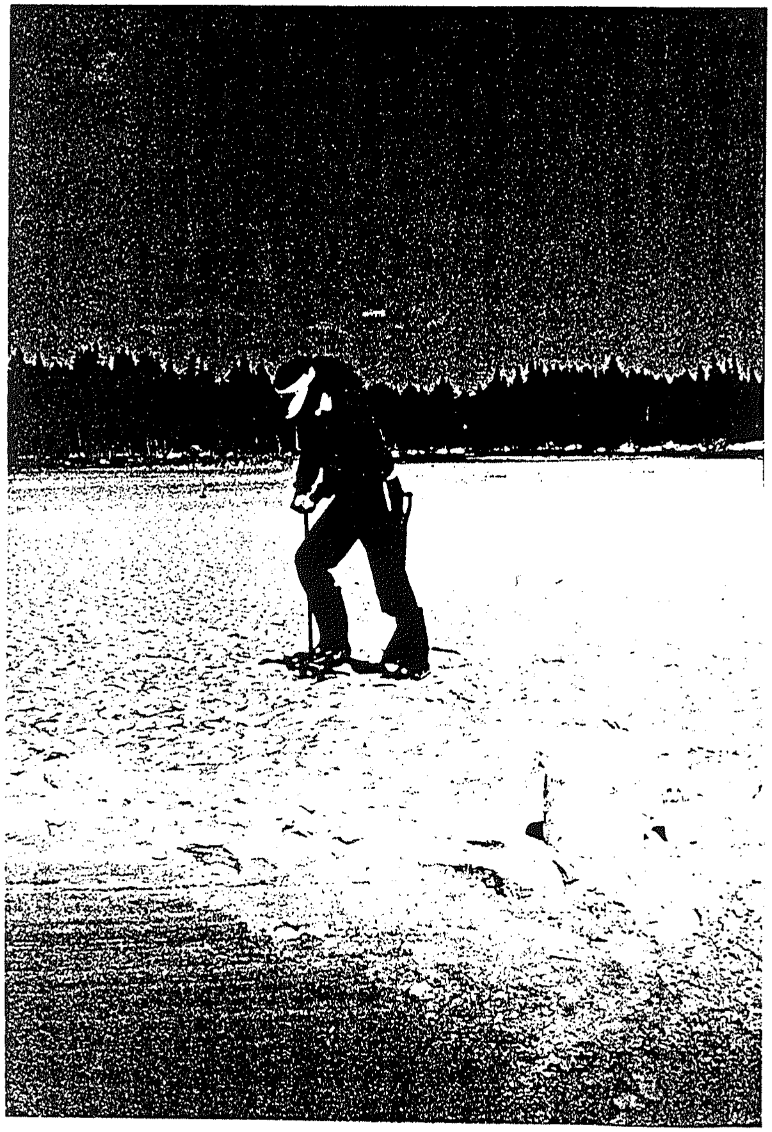

Figure 3i. Benthic box core sampling technique

Figure 3j. Sieving benthic core samples

5. RESULTS

5.1 Marine Lagoons

5.1.1 Physical Characteristics

5.1.1.1 Bathymetry and Morphology

A bathymetric map of each study site is presented in Figures 29 and 30. Although sufficient depth information was obtained to allow characterization of the major topographic features of each basin, the large variations in tidal states at different points within each basin made correction for depth to a common elevation difficult. More adequate resolution would require an intensive programme for obtaining simultaneous tide records at several points within each basin. As a result, the depths reported here should be considered approximate (the error is estimated to be 10-20%).

The morphology and resulting bathymetry of both Little Port Joli and St. Catherines Basin are complex but very similar. They represent classic examples of flood-tidal delta-systems formed in mesotidal inlets (Boothroyd, 1985). Flood-tidal deltas are characterized by an accumulation of sand landward to the inlet throat, followed by meandering channels, sandy point bars and tidal flats distal to the inlet. The more inland reaches are sites of mud deposition.

Figures 4 and 5 are aerial photographs of St. Catherines and Little Port Joli Basins, indicating the morphological characteristics typically associated with systems of this type. The major components include: (1) a <u>flood ramp</u> with a seaward dipping surface dominated by flood-tidal currents, (2) a <u>flood channel</u> extending into the lagoon as a continuation of the flood ramp, (3) an <u>ebb shield</u>, a topographically high landward margin of the delta that protects portions of the tidal flats from modification by ebb-tidal currents, (4) an <u>ebb spit</u> formed by ebb-tidal currents with some interaction by flood currents and (5) <u>spillover lobes</u> which are bowlike features formed mostly as a result of ebb-tidal current flow over low areas of the ebb shield.

Further away from the inlets meandering tidal channels and small tributary channels predominate. A large proportion of the tidal prism of water that covers the flats at high tide travels via the larger channels that tend to follow the landward border of the lagoon. Minor channels adjoin these larger channels and act as both tributaries and distributaries meandering around the tidal flats. Flats vegetated with salt-marsh grasses are characterized by channels that wind around them producing roughly circular shapes. Observation of historical aerial photographs indicate that these channels migrate over a period of several years causing considerable variation in the location of the vegetated flats. There is little evidence of buildup of natural

igure 4. Tidal delta morphology of Little Port Joli Basin (see test for explanation)

ıgure 5. Tidal delta morphology of St. Catherines Basin (see text for explanation)

levees along the edges of these flats, which is characteristic of more traditional salt-marsh systems, perhaps because of the relatively large current velocities present and the coarse nature of the sedimentary material available.

Eventually, in areas most distal to the inlet, channels become less distinct. At the upper end of Port Joli Basin a major tidal channel continues through a narrow constriction into a long neck that leads to Basin Lake. Shortly after entering Basin Lake the channel terminates in a relatively deep hole, the origin of which is unclear.

Depths at mean low water are variable within different areas of the Basins. The tidal channels are generally the deepest area and must be closely adhered to when travelling by boat at low tide. There is considerable variation in elevations of the tidal flats, but on average they are less than 0.5 m above mean low water.

5.1.1.2 Sediments

5.1.1.2.1 Sources and Sinks

Processes that might yield sediment for the lagoon systems of the Adjunct include erosion of offshore shoals and shoreline cliffs, longshore transport, river inputs and wind transport of sand-dune materials.

Although the immediate coastline of the Adjunct is well exposed to the ocean wave climate, the lack of easily erodable drumlins along the coast results in low shoreline erosion rates and a limited supply of unconsolidated material available for beach development (Piper *et al.*, 1986). Existing beaches are composed mainly of relic sediment. There is little evidence that shoreline erosion within the lagoons contributes significantly to available sediments; most of the shoreline consists of rocky materials and the small amount of erodable material present is stabilized by salt marsh vegetation. Sediment contribution by stream inputs also appears to be minor. The drainage basins of the lagoon are not easily erodable and there is little evidence of sediment accumulation where streams enter the lagoons.

The main source of sediment appears to be sand originating from the seaward side and being moved by longshore transport to the tidal inlets where it becomes trapped and washed into the lagoons on flood tides to form tidal deltas. Although the strong tidal currents within the entrance of each lagoon tend to keep these systems open, it appears that under certain conditions, perhaps mostly associated with strong storm events moving large quantities of sediment, the lagoon entrances periodically become filled isolating the lagoons from the sea. Aerial photographs show that this occurred about 1955 at the entrance to St. Catherines Basin (Figure 6).

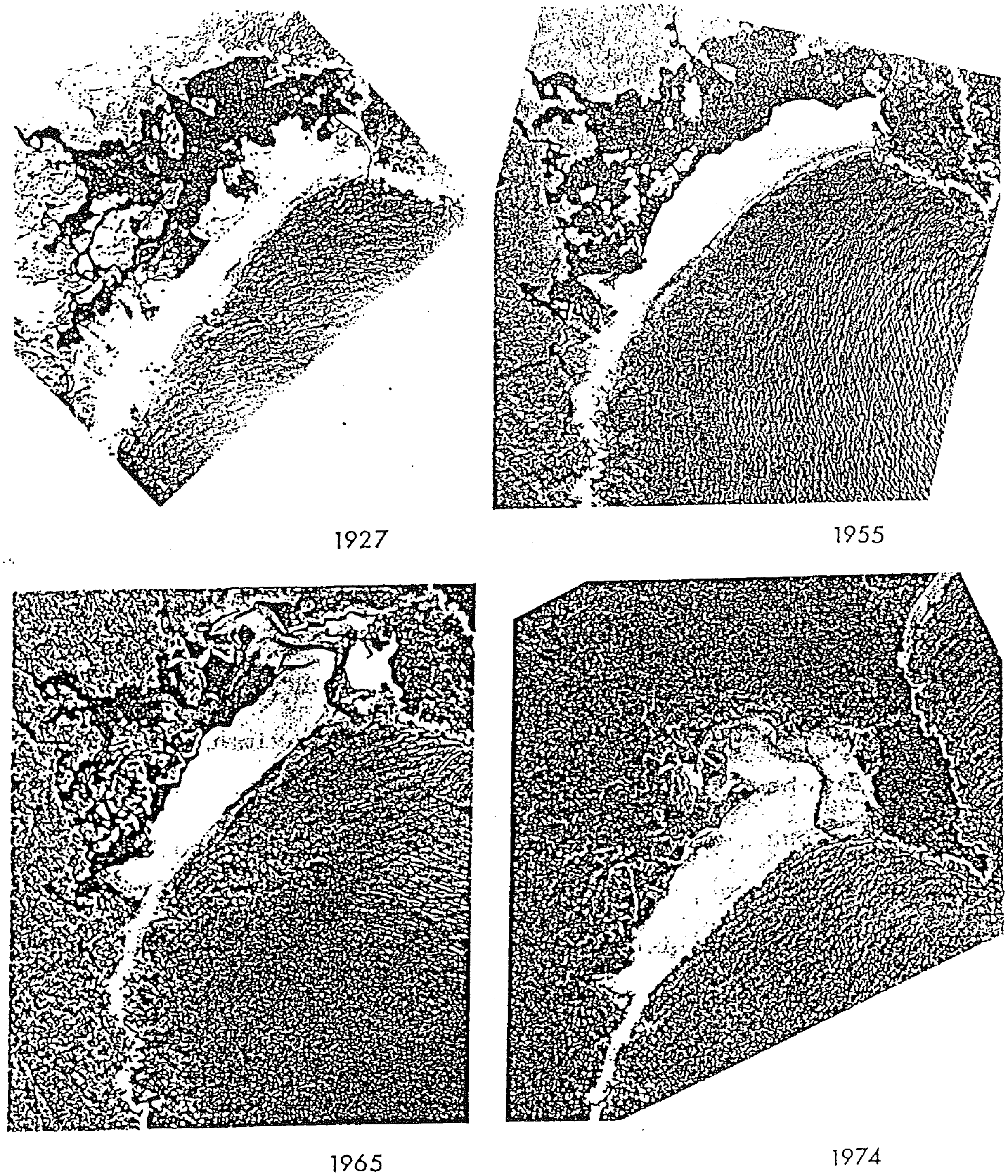

Figure 6. Evolution of the beach at St. Catherines Basin, 1927 to 1974

Wind-borne sediments originating from the beach dune systems are also probably important sources of sediment accumulating in the lagoons. There is evidence that the coastal dunes were much larger at one time (letter of Windsor Wood, 1986), and are now slowly eroding, with deposition occurring within the lagoon just behind the dune complexes.

5.1.1.2.2 Sediment Types and Distribution

The large variations in current velocities resulting from tidal cycle flushing, in combination with the complex morphology of the lagoons, creates a heterogenous environment with respect to sediment types and distribution. Sediment types are typically distributed as those of a flood tidal delta system (Boothroyd, 1978); sediment size decreases progressively up the inlet proceeding from the major channels and also with increasing elevation on the tidal flats. Figures 7 and 8 illustrate the sediment types and distributions for Little Port Joli and St. Catherines Basin respectively.

The non-vegetated intertidal zone can be subdivided into two main sedimentary domains: (1) upper intertidal flats which are relatively low sloping features completely exposed at low tide and containing fine sands consolidated to varying degrees by benthic algal and bacterial communities; (2) low intertidal sand bodies composed of relatively unconsolidated medium to coarse sands exposed for about one-half of the tidal cycle and thereby experiencing near equal periods of suspension and sedimentation and reworking by tidal currents.

The inlet channels tend to be scoured out, leaving a gravelly bottom containing very coarse sands, shells and pebbles. Further up the channels where current velocities are somewhat less, the bottom often consists of a bare compacted sand which appears to be partly organic and contains a layer of benthic diatoms at the surface. Benthic diatom "slicks" are important in diminishing resuspension of sediments.

Fine sands and muds are most prominent in the subtidal upper reaches of the lagoons, primarily where eel grass beds tend to trap sediments. In many of these areas the sediments are very soft and malodorous because of anaerobic conditions resulting from the decay of large amounts of organic matter, and the production of hydrogen sulphide and other marsh gases.

5.1.1.3 Water Movements

5.1.1.3.1 Tides

Water circulation in the lagoons is dominated by tidal exchange with offshore oceanic water. Although a number of small streams and creeks enter the lagoons, their contribution is small

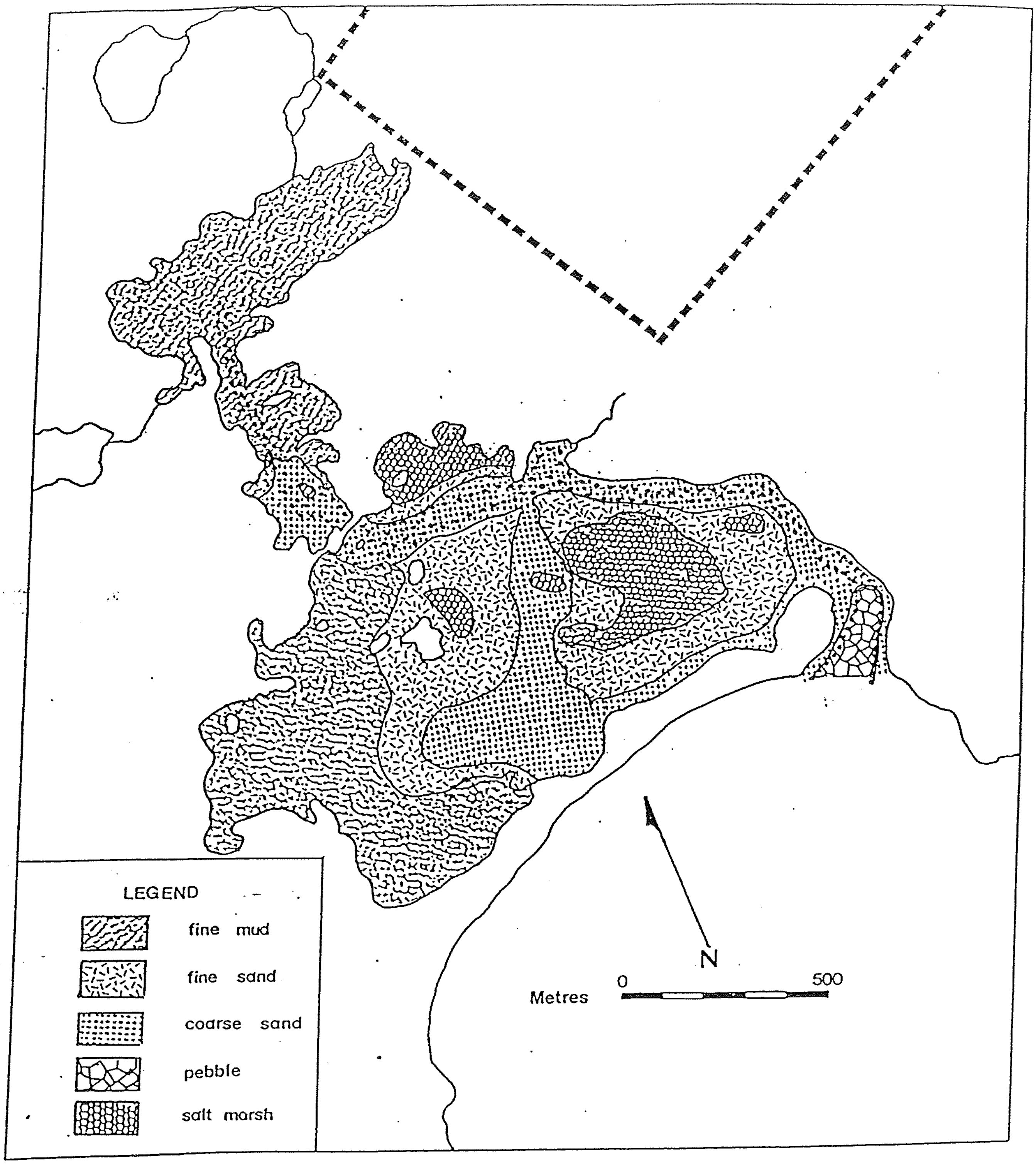

Figure 7. Sediment distributions in Little Port Joli Basin, 1987

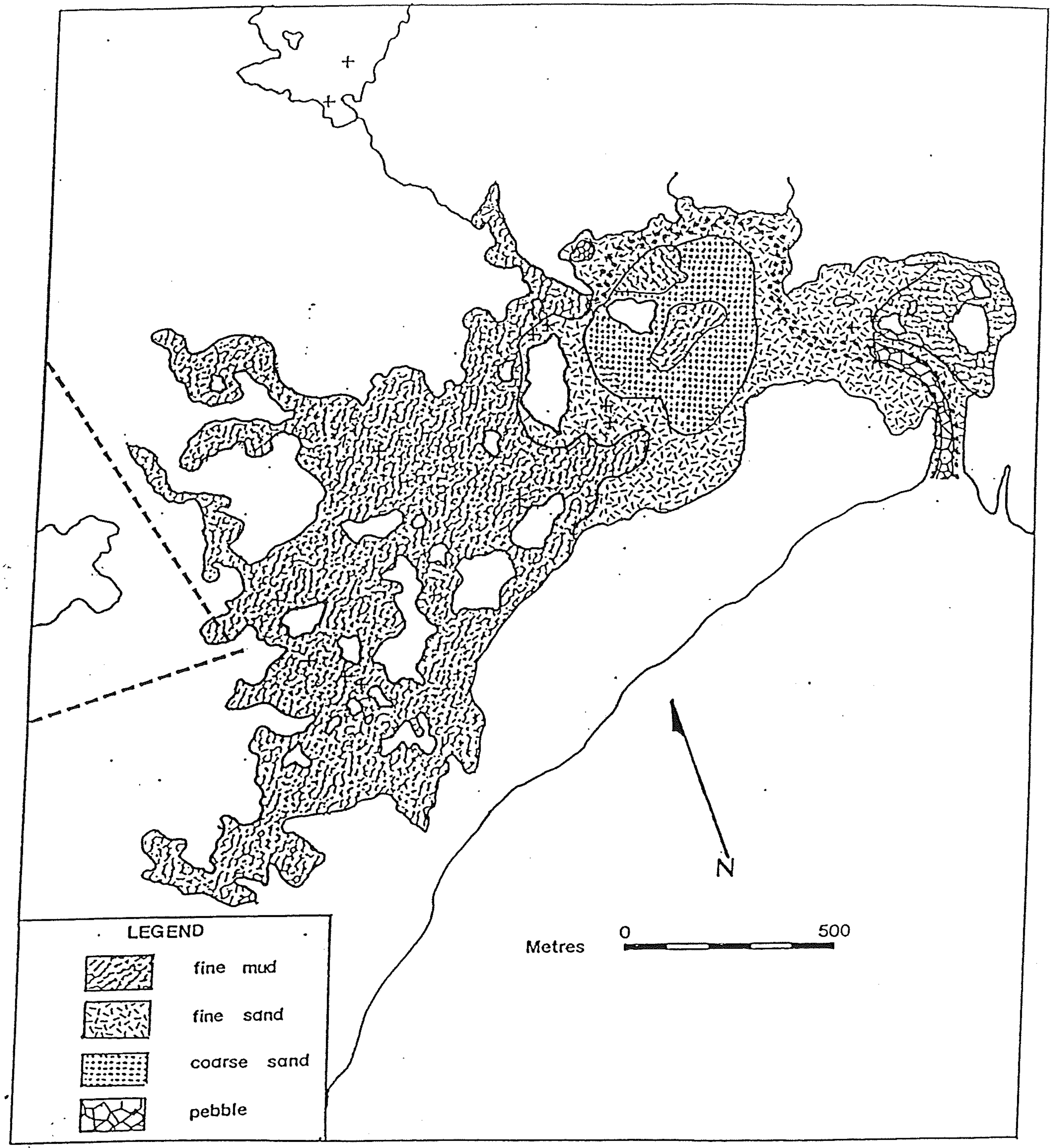

Figure 8. Sediment distributions in St. Catherines River Basin, 1987

and has little influence on circulation patterns. Furthermore, the shallow nature of the lagoons, combined with a limited fetch and lack of large expanses of open water, make wind-induced circulation insignificant.

The tidal regime is semi-diurnal. Tidal amplitude in the immediate area, based on tide table data for Port Mouton, averages 1.5 m with a maximum of about 2.2 m. This indicates that the system is at the lower end of the mesotidal range. There appear to be considerable differences, however, between the tidal amplitudes predicted for Port Mouton and those that occur within the Basins of the Adjunct. Measurements of tidal amplitudes at the three anchor stations corresponding to the inlets of each basin (Table 5) indicate that tidal amplitudes were only 30 to 50% of those predicted for Port Mouton. The difference is greater for Little Port Joli Basin than for St. Catherines Basin. Measurements of times of low and high tides at these same stations also indicate significant differences between these Basins and Port Mouton, as well as between each Basin. At the inlets to Little Port Joli Basin and Basin Lake, the times of low and high tide lagged approximately 2 and 3 hours, respectively, behind times predicted for Port Mouton. At the inlet to St. Catherines Basin, the time difference was less, about one hour, but occurred in the opposite direction, i.e., the times of low and high tide preceeded those predicted for Port Mouton. These variations are probably a reflection of the complex morphology of the area within each Basin and perhaps also the offshore topography near the entrance of the Basins.

5.1.1.3.2 Currents

The bathymetry of the Basins generally reflects the current patterns and velocities, the deeper areas appearing wherever currents are strongest and the shallower areas where currents are weakest. Most of the water moving into and out of the lagoons travels along well-defined channels and spills over onto the tidal flats only during a short period near high water.

Direct measurements of current velocities made at the anchor stations over tidal cycles indicate that near the inlets, where velocities would tend to be greatest, current speeds in excess of 1 m/sec are common. The largest velocities were recorded at the bridge between Little Port Joli Basin and Basin Lake where values greater than 2 m/sec were observed. It is likely that current velocities here are greater than anywhere else due to the narrow constriction leading into Basin Lake. An exception may be the outermost area of St. Catherines Basin just within its narrow entrance. Although no current measurements were made at this site, primarily because of the difficulty of establishing an anchor station in the rapidly moving water, it is probable that current velocities are comparable, if not greater, than those observed at the Basin Lake bridge.

The variations in current velocities measured during tidal cycles are indicated in Figures 9 to 13. As with tidal

Table 5. Comparison of times of high and low water and tidal amplitudes at various locations in the marine basins of the Adjunct with those predicted for Port Mouton by tide tables.

Date	Location*	Time of Low Tide	Time of High Tide	Tidal Amplitude (m)
June 8, 1987	Station A	15:15	–	0.4
	Port Mouton	11:41	–	1.2
June 9, 1987	Station B	–	15:45	0.4
	Port Mouton	–	19:02	1.4
June 10, 1987	Station A	–	07:52	0.6
	Port Mouton	–	10:15	1.2
June 12, 1987	Station C	14:30	–	0.6
	Port Mouton	15:26	–	1.3
June 15, 1987	Station C	12:00	–	1.0
	Port Mouton	12:22	–	1.7

* Station A – Port Joli – Basin Lake Bridge
Station B – Entrance to Port Joli Basin
Station C – Entrance to St. Catherines Basin

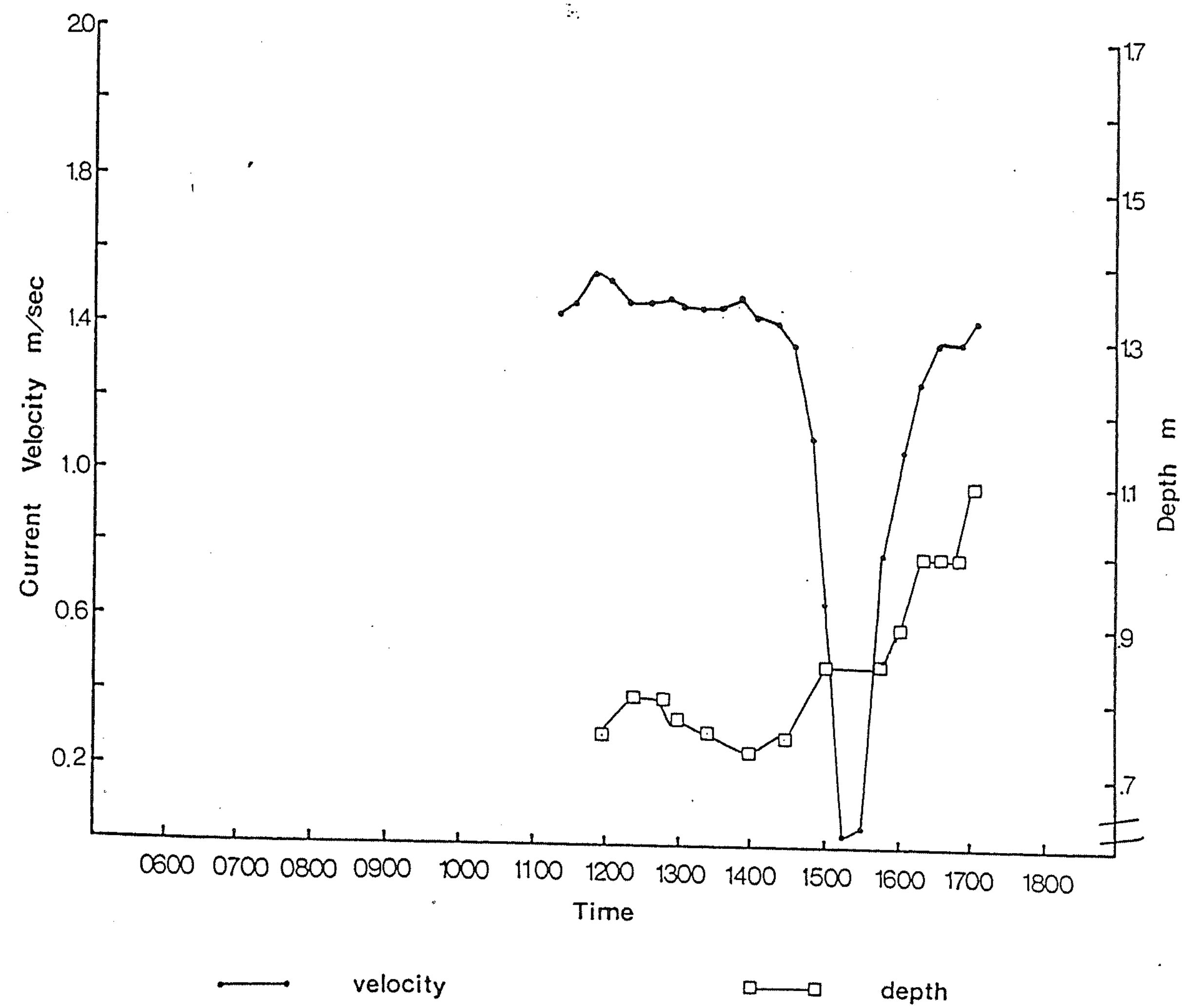

Figure 9. Variations in current velocity and depth at Little Port Joli Bridge, June 8, 1987

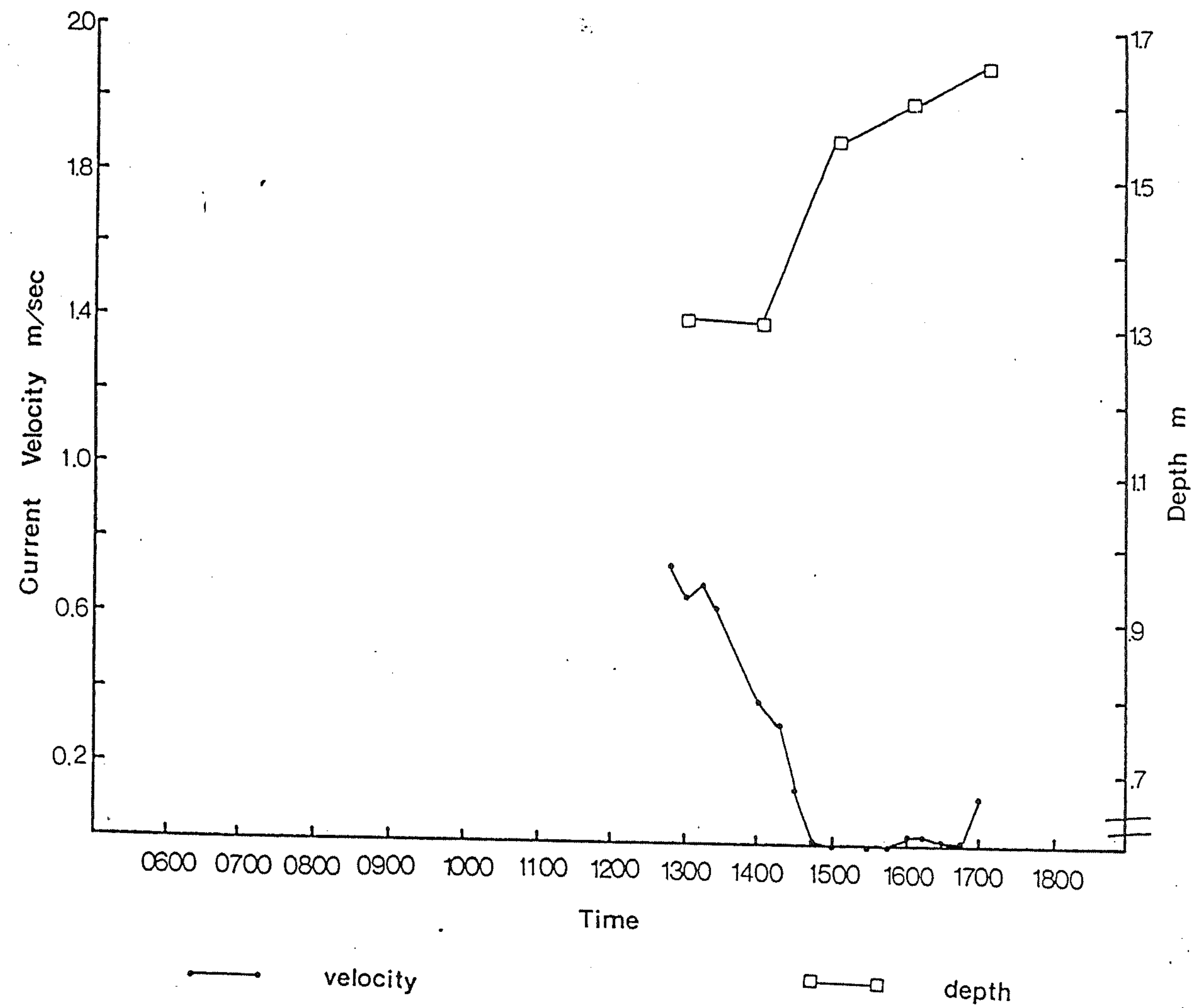

Figure 10. Variations in current velocity and depth at entrance to Little Port Joli Basin, June 9, 1987

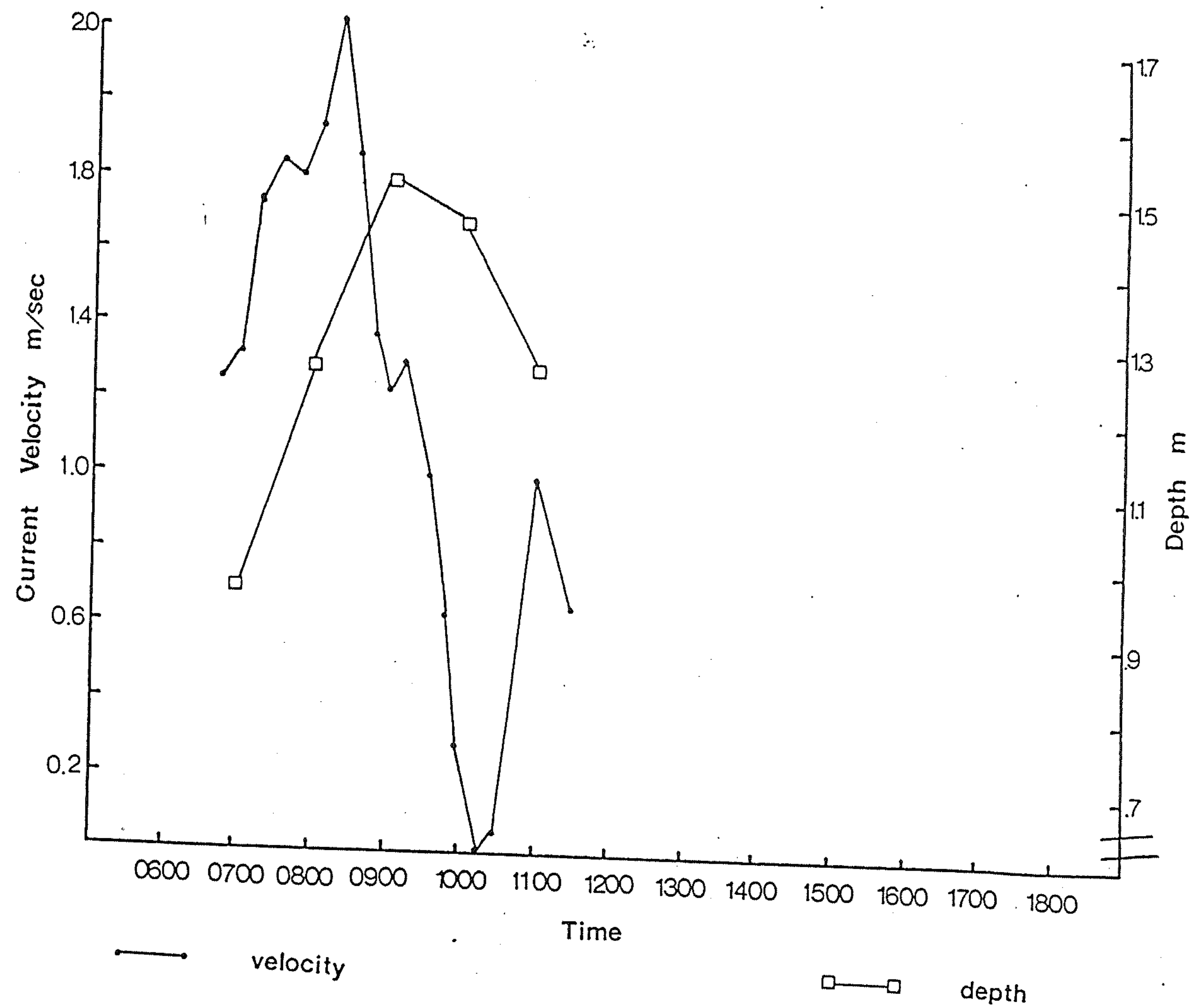

Figure 11. Variations in current velocity and depth at Little Port Joli Bridge, June 10, 1987

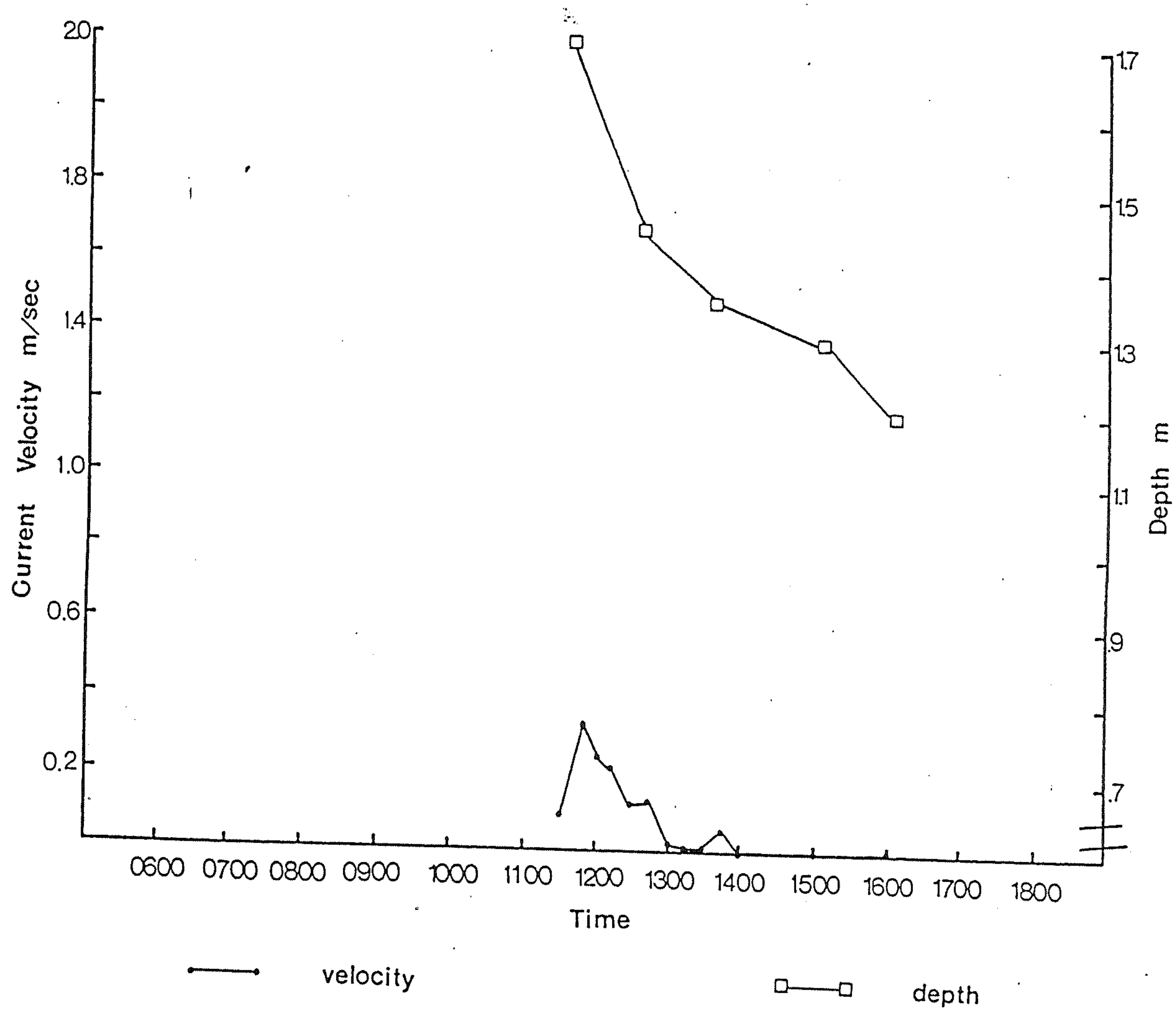

Figure 12. Variations in current velocity and depth at entrance to St. Catherines Basin, June 12, 1987

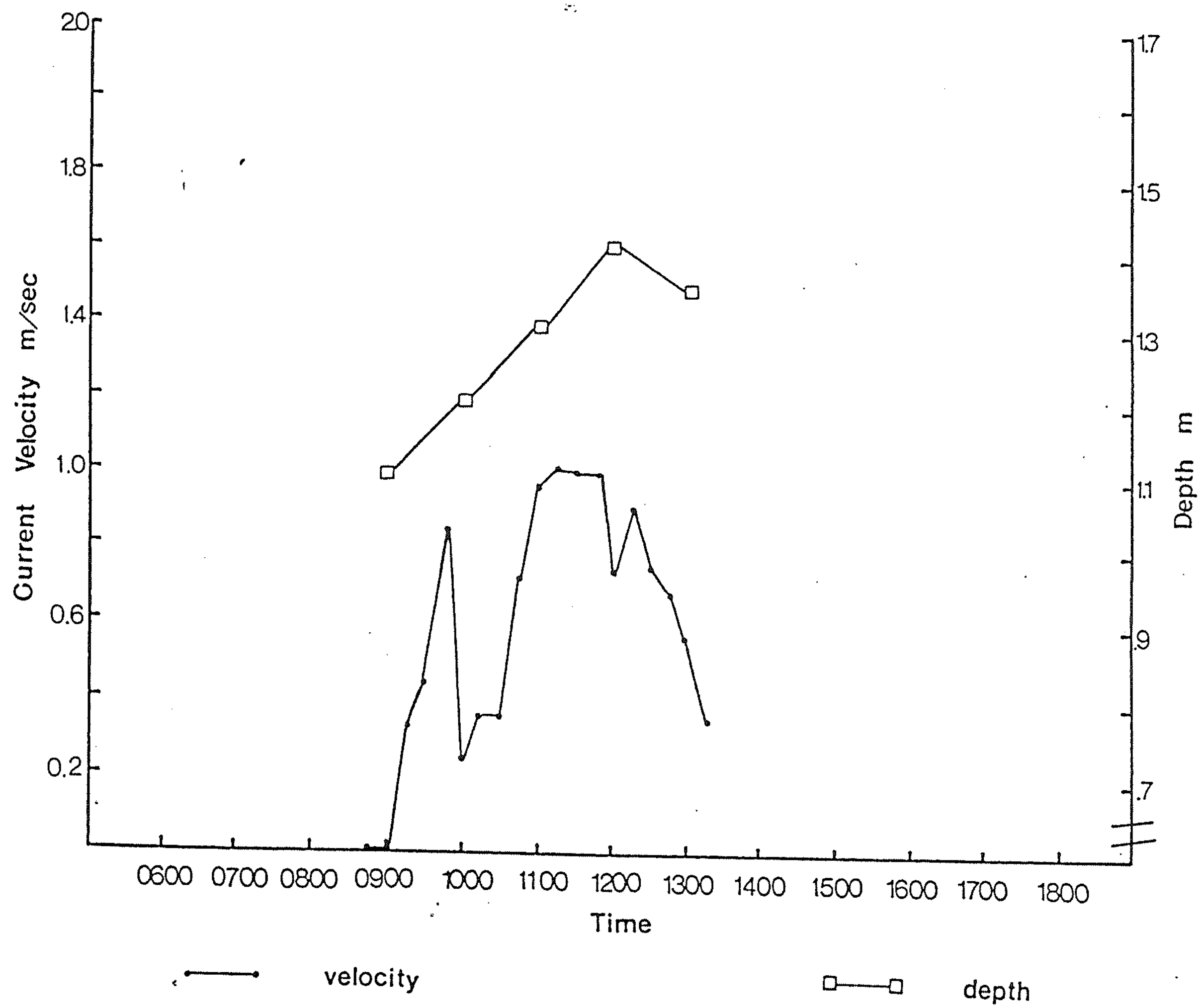

Figure 13. Variations in current velocity and depth at entrance to St. Catherines Basin, June 14, 1987

amplitudes, there is considerable variation between the stations. At the Basin Lake bridge station the cycle is very asymmetric--a relatively constant ebb tide velocity lasting 3-4 hr is followed by a short (<0.5 hr) slack low water, after which current velocity quickly climbs to a maximum at mid-flood and then decreases to high slack water. The latter is also short (<0.5 hr). At the Little Port Joli and St. Catherines Basin inlets the tidal cycle is more traditional but shows some asymmetry in that maximum current velocities tend to occur just prior to and just after slack tide rather than at mid-tide. These characteristics, like the differences in tide times, probably relate to the complex morphology of the basins.

For tidal flat areas exposed at low tide, an attempt was made to make indirect observations of current velocities based on bedform microtopography using criteria commonly employed by sedimentologists. There is a strong relationship between bedform types and current velocity (Figure 14). In general, the surface of most tidal flats were of the flat bed type indicating current speeds in excess of 0.6 m/sec. Along the sides of smaller tributaries eminating from the main channels, complex cuspate ripples were common which are characteristic of current velocities in the range of 0.4 - 0.6 m/sec.

5.1.1.3.3 Waves

As mentioned earlier, the short fetch and lack of large open water expanses prohibits development of any significant wave action within the lagoons. The inlets to the Basins are exposed to incoming waves as they approach the shoreline in relatively deep water, but most of this wave energy is dissipated on the exposed headlands and beaches bordering the inlets.

5.1.1.4 Winter Ice Conditions

One site visit during mid-February, 1987 was made to the Adjunct in order to make observations on winter conditions. A number of sites were visited and photographs taken (Figures 15a-c). In general, ice cover was extensive along the shores of both lagoons but the main channels were clear. Shore ice was generally thin and was not safe for travel by foot. In some areas, particularly within embayments and quieter areas, ice rafting along the edges was common. It is probable that the amount of ice present is significant in modifying sandflat topography in winter, and altering the development of intertidal communities, particularly those associated with salt marsh vegetation.

5.1.1.5 Light

Despite the relatively high current velocities and shallow depths characteristic of the lagoons, light transparency of the water column is quite high. Extinction coefficients calculated

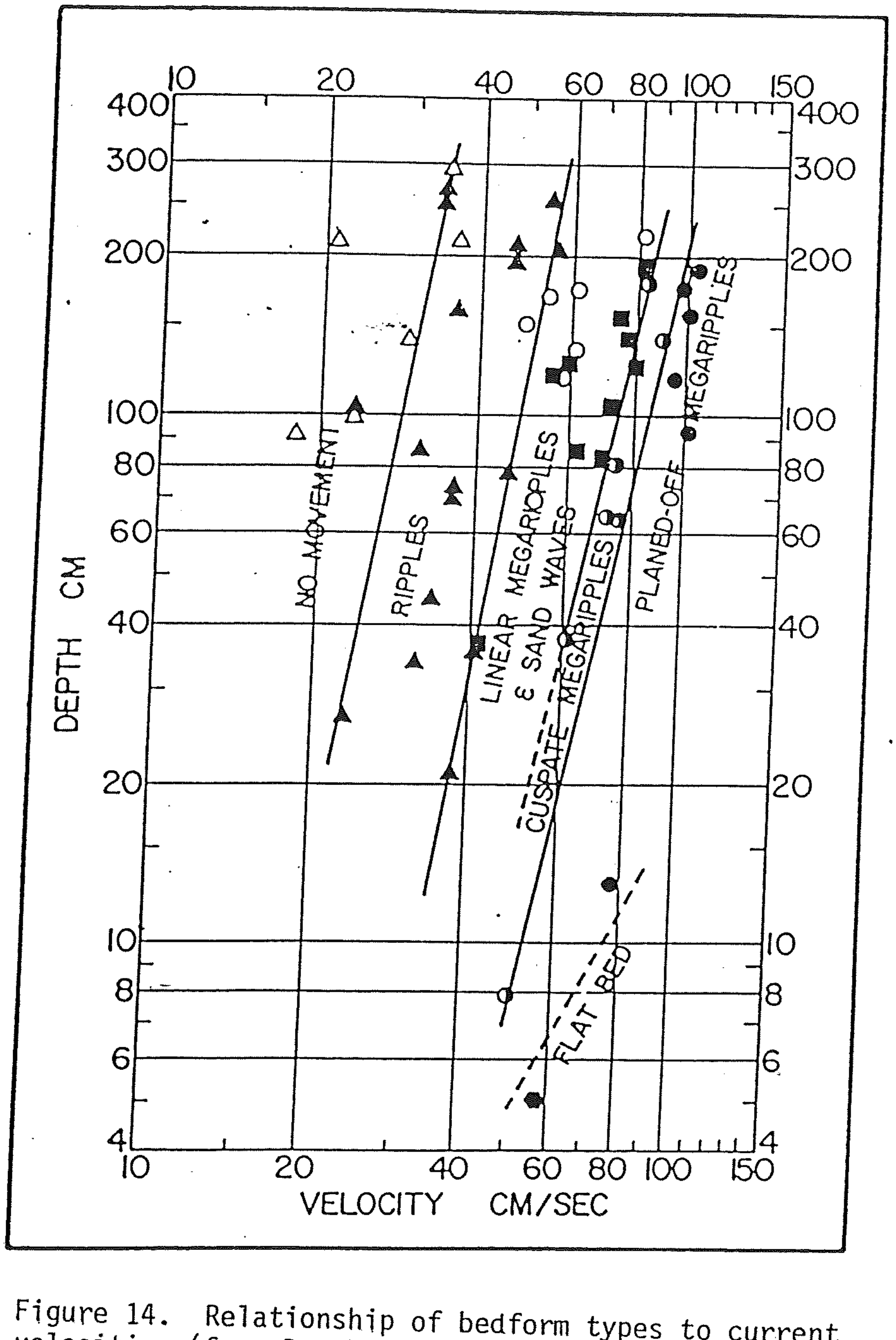

Figure 14. Relationship of bedform types to current velocities (from Boothroyd, 1985)

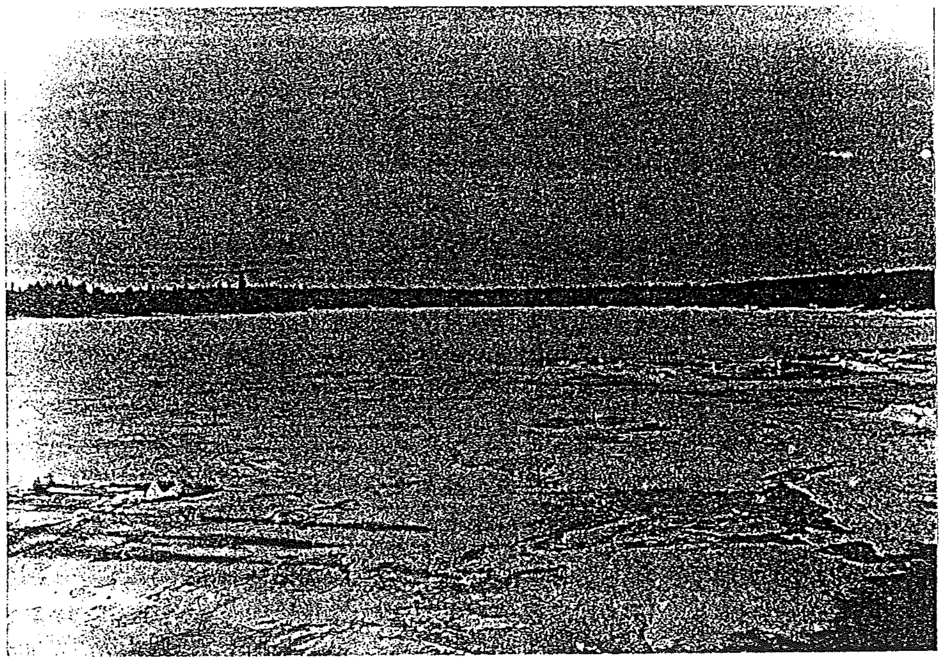

Figure 15a. Winter ice conditions: Basin Lake looking west

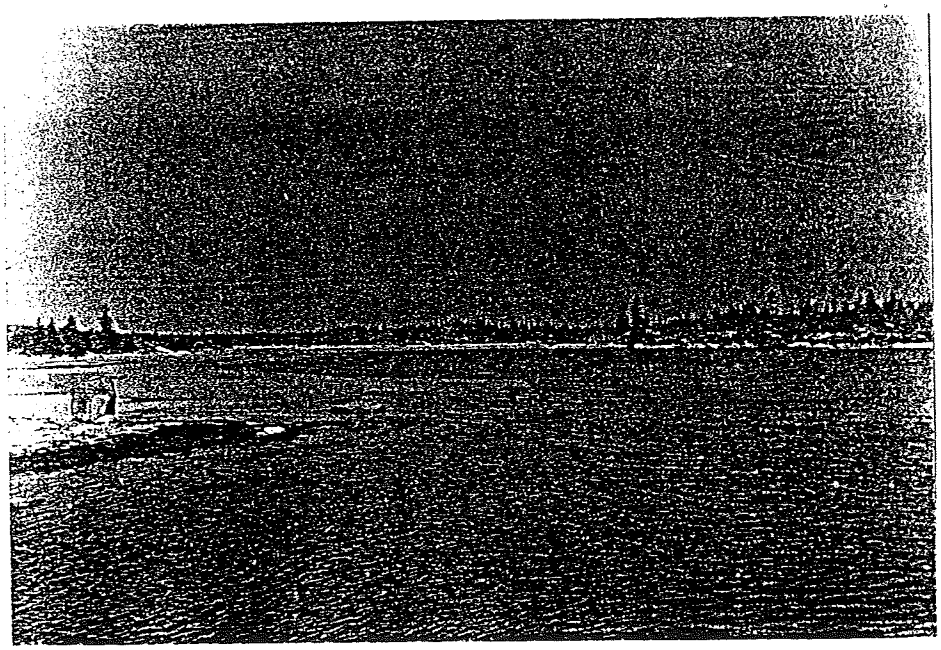

Figure 15b. Winter ice conditions: Channel between Little Port Joli Basin and Basin Lake looking North

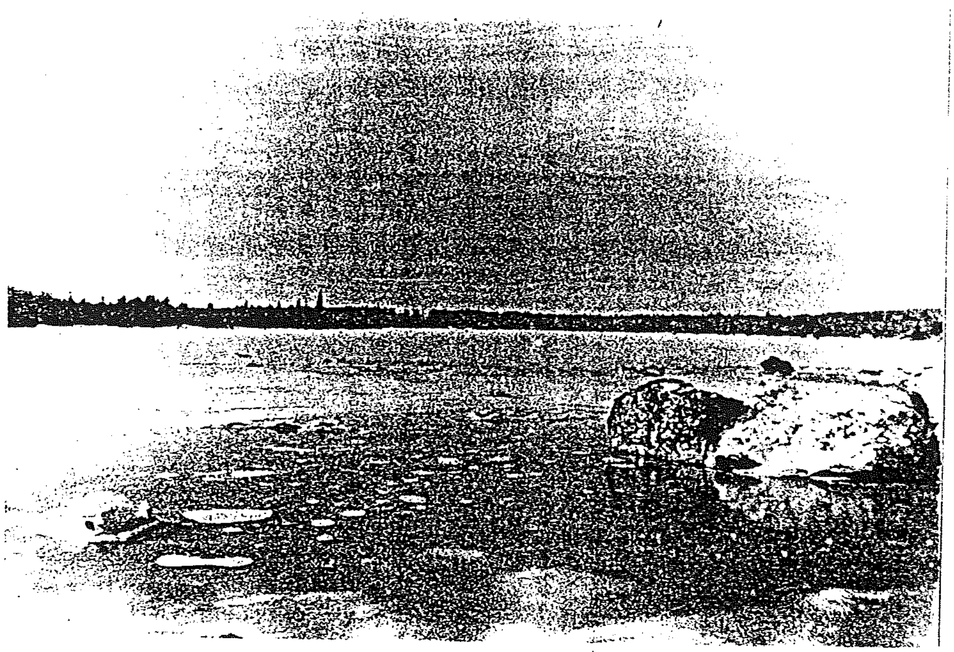

Figure 15c. Winter ice conditions: Little Port Joli Basin, west end

from percent light transmission measurements taken during the tidal cycle studies were always low, ranging from 0.34 to 0.82 and Secchi disc observations at other stations (Table 6) were usually greater than the total depth. These results indicate that in most areas of the lagoons sufficient light penetrates to the bottom to support photosynthesis by benthic primary producers.

The major factors that tend to attenuate light include suspended particulate matter (SPM), colored dissolved organic compounds and phytoplankton chlorophyll. SPM concentrations were always low (< 15 mg/l in most cases) and reflect the paucity of fine sediments available for resuspension in areas near the outer reaches of the lagoons. Fine sediments, present in some of the deeper areas of the channels and in the upper reaches of the lagoons, appear to be stabilized by either benthic microorganisms growing on the surface or eelgrass stands, both of which are known for their ability to immobilize sediments and inhibit resuspension.

Dissolved organic materials, particularly humic acids originating from coniferous drainage basins, such as those of the Adjunct, can be important in attenuating light. Observations of water color indicate that these materials do not accumulate to any great extent in the lagoons, although they undoubtedly enter the lagoon systems via streams and brooks. The high tidal flushing quickly dilutes this input.

Chlorophyll concentrations (Table 6) are also low (< 4 ug/l) and contribute little to light attenuation.

5.1.2 Chemical Characteristics

5.1.2.1 Salinity

Variations in salinity within different areas of each basin were measured on a flood tide during the fall site visit. In general, surface waters become more saline in the seaward direction. The lowest salinities were recorded in surface waters of Basin Lake which ranged between 24.7 to 25.3 $^{o}/oo$. Highest salinities were observed near the entrance to each basin and were on the order of 28 $^{o}/oo$ in Little Port Joli Basin and 30 $^{o}/oo$ in St. Catherines Basin. The difference between basins is probably more a reflection of measurements being made at slightly different stages of the tidal cycle rather than to differences resulting from the relative contribution of freshwater inputs to each basin.

Vertical stratification in salinity was observed at only two stations, both located within the upper reaches of Basin Lake, where differences of slightly less than 5 $^{o}/oo$ between surface and bottom waters were observed. This stratification probably results partly from the presence of dense stands of *Zostera*, which tend to baffle water movements, preventing mixing of bottom

Table 6. Light extinction coefficients, Secchi disc and chlorophyll measurements at selected locations in the marine basins.

Date	Location	Extinction Coefficient	Secchi Depth (m)	Chlorophyll (ug/l)
Oct. 18/86	Basin Lake (Sta 1)	–	2.3	<1.0
Oct. 18/86	Basin Lake (Sta 3)	–	>Bottom	1.2
Oct. 18/86	Port Joli Basin (Sta 6)	–	"	<1.0
Oct. 18/86	Port Joli Basin (Sta 7)	–	"	<1.0
Oct. 19/86	St. Catherines Basin (Sta 1)	–	"	–
Oct. 19/86	St. Catherines Basin (Sta 2)	–	"	<1.0
Oct. 19/86	St. Catherines Basin (Sta 3)	–	"	<1.0
Oct. 19/86	St. Catherines Basin (Sta 4)	–	"	4.1
Oct. 19/86	St. Catherines Basin (Sta 5)	–	"	–
Oct. 19/86	St. Catherines Basin (Sta 6)	–	"	2.3
Oct. 19/86	St. Catherines Basin (Sta 7)	–	"	–
Oct. 19/86	St. Catherines Basin (Sta 8)	–	"	–
June 8/87	Port Joli Basin Bridge	0.82	–	2.1
June 9/87	Port Joli Basin Channel	0.45	–	1.1
June 10/87	Port Joli Basin Bridge	0.75	–	<1.0
June 12/87	St. Catherines Basin Channel	0.43	–	<1.0
June 15/87	St. Catherines Basin Channel	0.34	–	<1.0

and surface waters, and partly from reduced turbulence resulting from the lower current velocities characteristic of the upper reaches of the lagoons. In addition, muddy bottoms, which are characteristic of *Zostera* beds, tend to retain waters of higher salinity as the tide recedes. The lack of significant salinity stratification in the upper reaches of St. Catherines Basin, where dense stands of *Zostera* also occur, is probably due to the shallower depths compared to Basin Lake, and the more open nature of this area with regard to water circulation.

5.1.2.2 Nutrients and pH

Measurements of silica, nitrogen and phosphorus, the major limiting micronutrients required for growth of phytosynthic organisms, were always low (Tables 7-9) and characteristic of levels occurring in coastal oceanic waters. There was little consistent variation between the different areas sampled.

Values of pH ranged from 6.90 to 7.85, being generally lowest in waters of lower salinity and highest in waters of high salinity, which reflects the relatively poor buffering capacity of freshwater inputs and the high buffering capacity of seawater.

5.1.2.3 Dissolved Oxygen

Dissolved oxygen concentrations both in surface and bottom waters were high at all stations sampled. Percent oxygen saturation values were also high and in some cases exceeded 100%. Such instances of supersaturation might result either from trapping of air bubbles within breaking waves, which require some time to diffuse to equilibrium, or from oxygen production by submersed but irradiated sea grasses.

5.1.3 Input/Output Relationships

In an attempt to determine the nature of input/output relationships between the marine lagoons and the offshore oceanic system, several stations located near the inlets to each basin (Figure 16) were occupied and measurements of various parameters taken at intervals over the tidal cycle. The results are presented in Tables 10 to 14 and Figure 16a-e.

The most obvious exchanges occurring are those related to salinity and temperature. In most cases flood waters are of higher salinity and lower temperature, indicative of the input of cold oceanic water, and ebb waters are of lower salinity and higher temperature, indicative of the outflow of freshwater entering the lagoons from the drainage basin and warming of shallower waters. This trend was observed at all stations except two, both of which were located near the entrance to St. Catherines Basin (Tables 13, 14). In these instances waters measured during the flood tide were composed of cold, <u>lower</u> salinity waters, whereas ebb waters consisted of warm, <u>higher</u>

Table 7. Values of Chemical and Physical Parameters in Little Port Joli Basin

Date	Station	Tidal State	Depth (m)	Salinity (°/oo)	Temp (°C)	SPM (mg/l)	pH	O_2 (mg/l)	Silica (mg/l)	Nitrogen (mg/l)	Phosphorous (mg/l)
Oct. 18/86	6	Ebb	0	26.6	9.2	10.0	7.35	9.2	0	13.5	1.0
"	"	"	0.5	26.5	9.1						
"	"	"	1.0	26.5	9.2						
"	"	"	1.5	26.3	9.1						
"	"	"	2.0	26.4	9.2						
"	"	"	2.5	26.2	9.1						
"	"	"	2.75	26.8	9.1						
Oct. 18/86	7	Ebb	0	28.2	9.0	4.14	7.25	10.5	0	10.1	0.9
Oct. 18/86	5	Flood	0	–	9.5	2.80	7.25		–	–	–

Table 8. Values of Chemical and Physical Parameters in Basin Lake

Date	Station	Tidal State	Depth (m)	Salinity (°/oo)	Temp (°C)	SPM (mg/l)	pH	O_2 (mg/l)	Silica (mg/l)	Nitrogen (mg/l)	Phosphorous (mg/l)
Oct. 18/86	3	Flood	0	25.3	8.4	3.08	7.10	8.2	0	14.1	1.0
"	"	"	0.25	26.1	8.5						
"	"	"	0.50	30.1	9.5						
"	"	"	0.75	30.0	9.3						
"	"	"	1.00	29.9	9.5			8.4			
Oct. 18/86	1	Flood	0	24.7	8.9	21.58	7.05	8.6	0.02	11.0	1.3
"	"	"	0.5	27.3	9.6						
"	"	"	1.0	28.1	9.2						
"	"	"	1.5	29.3	9.8	8.00	7.15	8.2	0.05	18.0	1.0
"	"	"	2.0	30.0	9.7						
"	"	"	2.5	29.6	9.8						
"	"	"	2.75	29.6	9.7	14.97	7.25	8.0	0.01	18.2	0.3
Oct. 18/86	4	Flood	0	29.8	9.5	11.20	7.25	8.6	0.08	7.0	0.6
"	"	"	0.75	30.4	9.7						
"	"	"	1.5	27.3	9.4	16.8	7.25	8.6	0.04	8.5	0.6

Table 9. Values of Chemical and Physical Parameters in St. Catherines Basin

Date	Station	Tidal State	Depth (m)	Salinity (°/oo)	Temp (°C)	SPM (mg/l)	pH	O_2 (mg/l)	Silica (mg/l)	Nitrogen (mg/l)	Phosphorous (mg/l)
Oct. 19/86	1	Ebb	0	29.4	10.2	1.39	7.25	9.8	0.06	9.5	3.6
"		"	1.25	29.4	10.3	-	7.30				
Oct. 19/86	2	Flood	0	28.5	7.9	2.38	6.90	8.2	0.05	18.3	2.5
"		"	0.35	30.3	8.8						
"		"	0.70	30.0	9.5			8.4			
Oct. 19/86	3	Flood	0	30.9	9.4	2.39	7.65		0.09	9.2	1.0
"		"	0.9	30.9	9.4						
Oct. 19/86	4	Flood	0	27.8	7.6		7.65	9.4	0.07	14.2	1.8
"		"	0.8	27.8	7.5						
Oct. 19/86	5	Flood	0	29.1	7.8	2.94	7.75	-	1.00	12.1	1.0
"		"	0.8	28.7	7.9						
Oct. 19/86	6	Flood	0	26.4	7.5	3.88	7.65	8.2	0.08	11.2	1.9
"		"	1.0	26.8	7.6						
"		"	2.0	27.1	8.0			8.8			
Oct. 19/86	7	Flood	0	30.9	9.2	-	7.85		0.03	14.5	0.8
"		"	1.0	30.8	9.2						
"		"	2.0	30.8	9.1						
Oct. 19/86	8	Flood	0	-	-	7.56	7.55	9.2	1.00	11.1	1.5

Table 10. Ebb tidal cycle data at Little Port Joli Bridge, June 8, 1987

Time	CV	Z	SAL	Temp	SPM	Chlor	DO	% Sat	N	Si	TP	OP
11:15	1.46											
11:30	1.48											
11:45	1.57											
12:00	1.56	75	30.35	12.8	11.0	1.8	9.0	88.2	14	0.1	0.6	0.2
12:15	1.49	80										
12:30	1.49											
12:45	1.51	80										
13:00	1.48	77	30.15	13.9	15.1	2.1	9.6	96.2	16	0.3	0.6	0.3
13:15	1.49											
13:30	1.49	75										
13:45	1.52											
14:00	1.46	73	30.30	15.4	17.9	2.7	12.1	133.4	18	0.3	0.6	0.2
14:15	1.45											
14:30	1.37	75										
14:45	1.14											
15:00	0.68	85	29.1	16.3	12.4	1.8	10.0	104.6	16	0.1	0.3	0.1
15:15	0.03	85										
15:30	0.04											
15:45	0.79	85										
16:00	1.09	90	28.3	16.1	12.3	2.1	9.4	98.3	14	0	0.2	0.1
16:15	1.27	100										
16:30	1.36	100										
16:45	1.36	100										
17:00	1.45	110	29.5	15.3	13.4	1.8	9.8	100.6	18	0.1	0.3	0.2

*Abbreviations are as follows:

CV, current velocity (m/sec); Z, depth (cm); SAL, salinity ($^{o}/oo$); SPM, suspended particulate matter; Chlor, chlorophyll a (mg/m^3); DO, dissolved oxygen (mg/l); % Sat, percent oxygen saturation; N, nitrogen (mg/l); Si, silicon (mg/l); TP, total phosphorous (mg/l); OP, orthophosphate (mg/l).

Table 11. Ebb tidal cycle data at entrance to Little Port Joli Basin, June 9, 1987*

Time	CV	Z	SAL	Temp	SPM	Chlor	DO	% Sat	N	Si	TP	OP
12:45	0.75											
13:00	0.66	130	30.4	13.0	14.1	0.5	13.0	95.9	2.0	1.0	0.3	0.1
13:15	0.70											
13:30	0.64											
13:45												
14:00	0.39	130	30.0	14.7								
14:15	0.34											
14:30	0.15											
14:45	0.01											
15:00	0.00	155	29.3	15.9	11.7	0.7	15.9	96.2	2.0	0	0.3	0.1
15:30	0.00											
15:45	0.00											
16:00	0.02	160	30.7	14.6	12.0	0.0	14.6	100.4	2.0	0	0.2	0.1
16:15	0.02											
16:30	0.01											
16:45	0.01											
17:00	0.15	165	33.6	11.6	11.4	0.0	11.6	94.0	2.0	0	0.3	0.1

*Abbreviations are as follows:

CV, current velocity (m/sec); Z, depth (cm); SAL, salinity ($^{o}/oo$); SPM, suspended particulate matter; Chlor, chlorophyll a (mg/m^3); DO, dissolved oxygen (mg/l); % Sat, percent oxygen saturation; N, nitrogen (mg/l); Si, silicon (mg/l); TP, total phosphorous (mg/l); OP, orthophosphate (mg/l).

Table 12. Flood tidal cycle data at Little Port Joli Bridge, June 10, 1987*

Time	CV	Z	SAL	Temp	SPM	Chlor	DO	% Sat	N	Si	TP	OP
6:45	1.27											
7:00	1.34	95	30.9	13.3	12.7	1.8	13.3	84.3	1.0	0	0.5	.05
7:15	1.75											
7:30	1.85											
7:45	1.81											
8:00	1.95	125	31.1	7.4								
8:15	2.04											
8:30	1.88				15.8	0.5	7.1	82.5	2.0	1.0	0.2	.01
8:45	1.39											
9:00	1.24	150	30.9	6.8								
9:15	1.31											
9:30	1.01											
9:45	0.63											
10:00	0.29	145	31.6	7.7								
10:15	0.00											
10:30	0.05											
10:45												
11:00	1.01	125	31.6	8.6								
11:15												
11:30	0.67											
11:45												
12:00												

*Abbreviations are as follows:

CV, current velocity (m/sec); Z, depth (cm); SAL, salinity ($^{o}/oo$); SPM, suspended particulate matter; Chlor, chlorophyll a (mg/m^3); DO, dissolved oxygen (mg/l); % Sat, percent oxygen saturation; N, nitrogen (mg/l); Si, silicon (mg/l); TP, total phosphorous (mg/l); OP, orthophosphate (mg/l).

Table 13. Ebb tidal cycle data at entrance to St. Catherines Basin - June 12, 1987*

Time	CV	Z	SAL	Temp	SPM	Chlor	DO	% Sat	N	Si	TP	OP
11:30	0.10	170	28.1	6.9								
11:45	0.35											
12:00	0.26				13.0	0			4	0.4	0.6	0.1
12:15	0.22											
12:30	0.13	145	28.9	8.2								
12:45	0.15											
13:00	0.03				16.5	0			0	1.3	0.2	0.1
13:15	0.01											
13:30	0.02	135	30.6	9.0	16.5	0			2	0.5	0.4	0.2
13:45	0.09											
14:00	0.00				43.3							
15:00	0.0	130	30.9	9.4	36.4	0			3	0.4	0.3	0.1
16:00	0.01	120		9.7	13.5	1.1			2	3.2	0.3	

*Abbreviations are as follows:

CV, current velocity (m/sec); Z, depth (cm); SAL, salinity ($^{o}/oo$); SPM, suspended particulate matter; Chlor, chlorophyll a (mg/m^3); DO, dissolved oxygen (mg/l); % Sat, percent oxygen saturation; N, nitrogen (mg/l); Si, silicon (mg/l); TP, total phosphorous (mg/l); OP, orthophosphate (mg/l).

Table 14. Flood tidal cycle data at entrance to St. Catherines Basin - June 15, 1987*

Time	CV	Z	SAL	Temp	SPM	Chlor	DO	% Sat	N	Si	TP	OP
8:45	0.01											
9:00	0.01	110	29.5	10.5	12.2	0			5	0.4	0.3	0.2
9:15	0.34											
9:30	0.44											
9:45	0.87											
10:00	0.24	120	25.5	7.0	13.5	0	9.4	79.9	6.2	0.3	0.3	0.2
10:15	0.37											
10:30	0.37											
10:45	0.73											
11:00	0.97	130	24.0	5.1	12.5	0	10.2	82.5	7.0	0.2	0.2	0.2
11:15	1.03											
11:30	1.02											
11:45	1.00											
12:00	0.75	140	25.2	5.2	13.2	0	10.4	84.1	5.0	0.2	0.2	0.1
12:15	0.92											
12:30	0.74											
12:45	0.69											
13:00	0.58	135	25.1	6.2	10.7	1.8	10.2	84.5	5.0	0.2	0.2	
13:15	0.35											

*Abbreviations are as follows:

CV, current velocity (m/sec); Z, depth (cm); SAL, salinity ($^{o}/oo$); SPM, suspended particulate matter; Chlor, chlorophyll a (mg/m^3); DO, dissolved oxygen (mg/l); % Sat, percent oxygen saturation; N, nitrogen (mg/l); Si, silicon (mg/l); TP, total phosphorous (mg/l); OP, orthophosphate (mg/l).

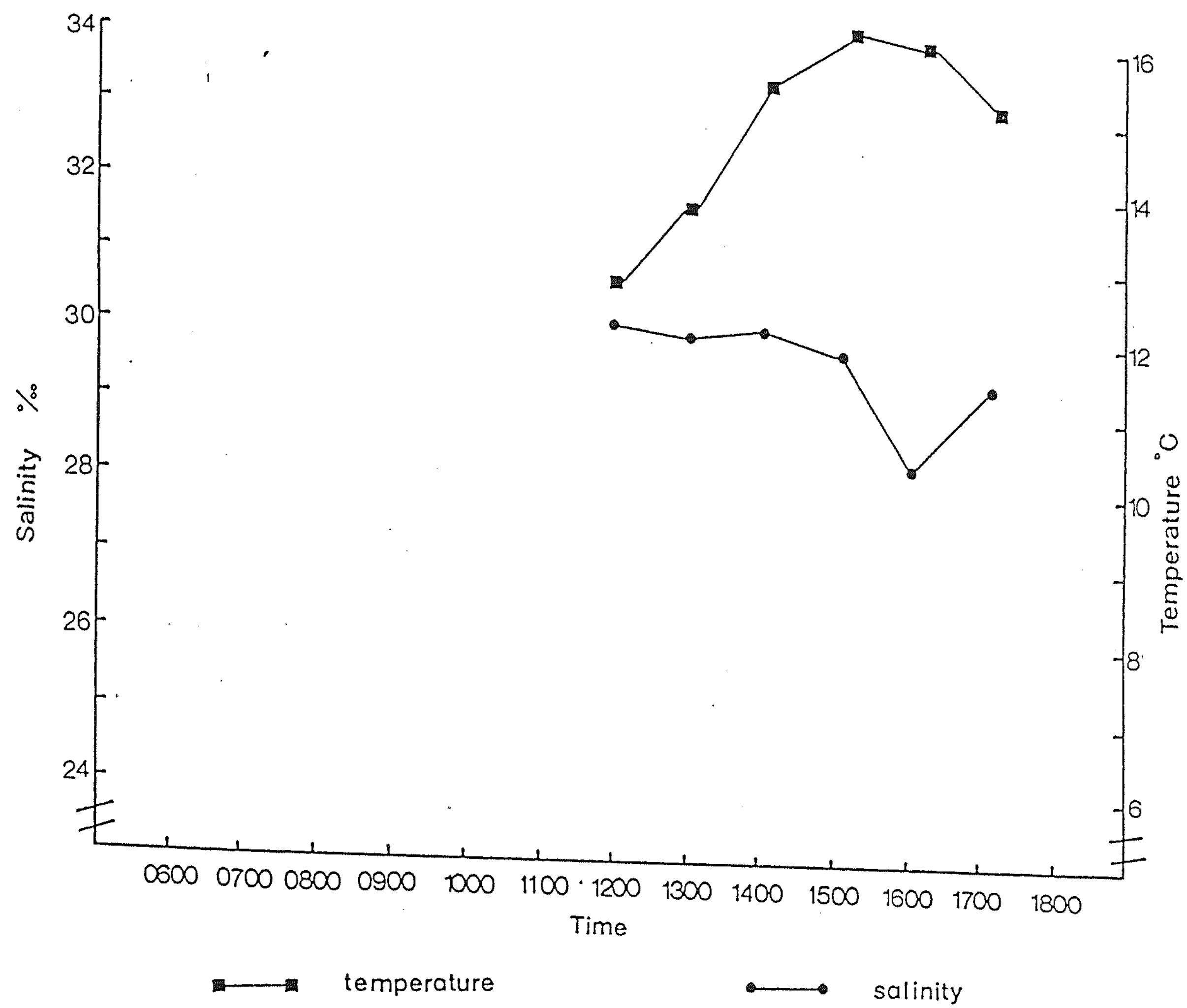

Figure 16a. Variations in salinity and temperature over a tidal cycle at entrance to Little Port Joli Basin, June 9, 1987

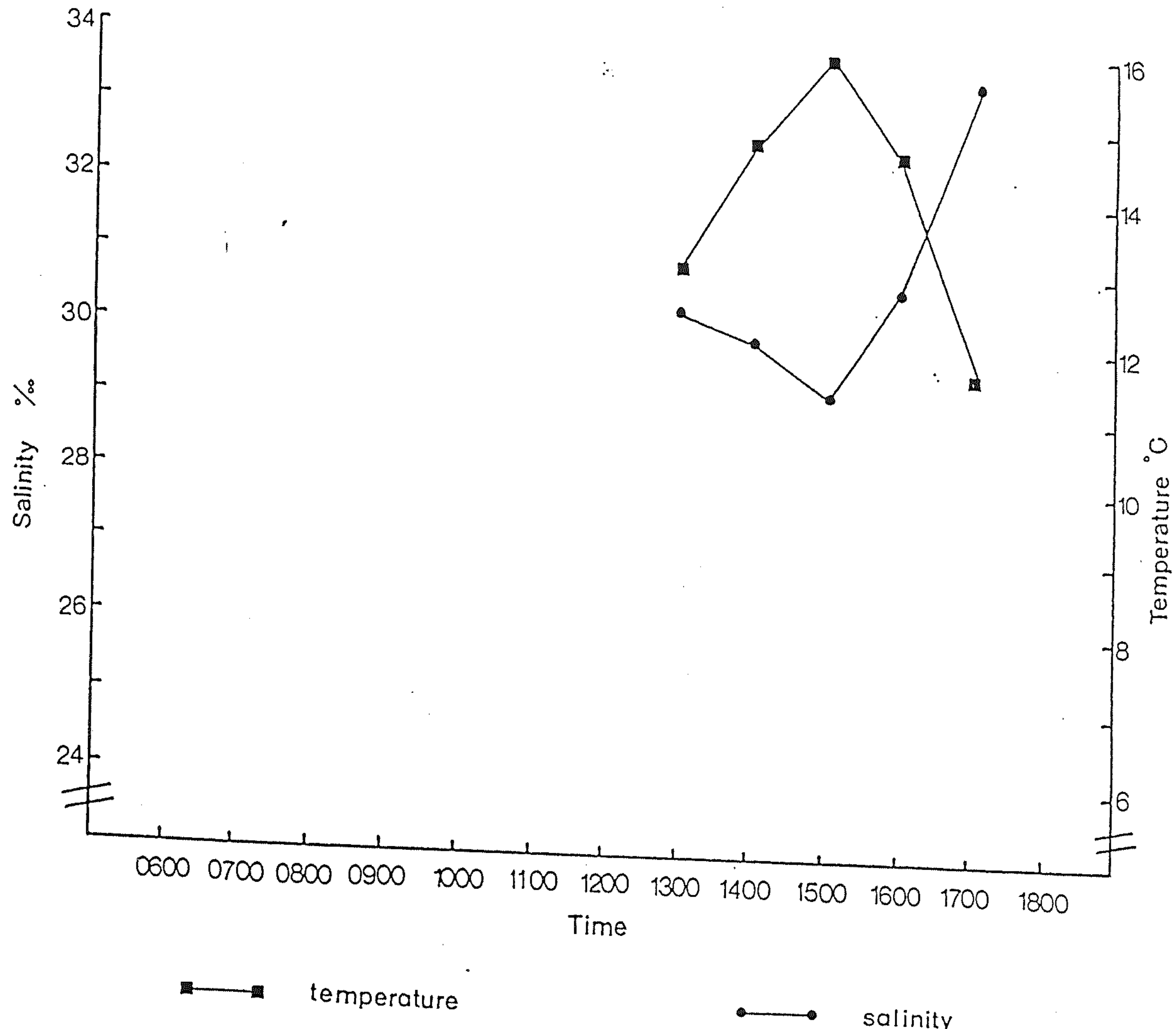

Figure 16b. Variations in salinity and temperature over a tidal cycle at entrance to Little Port Joli Basin, June 9, 1987

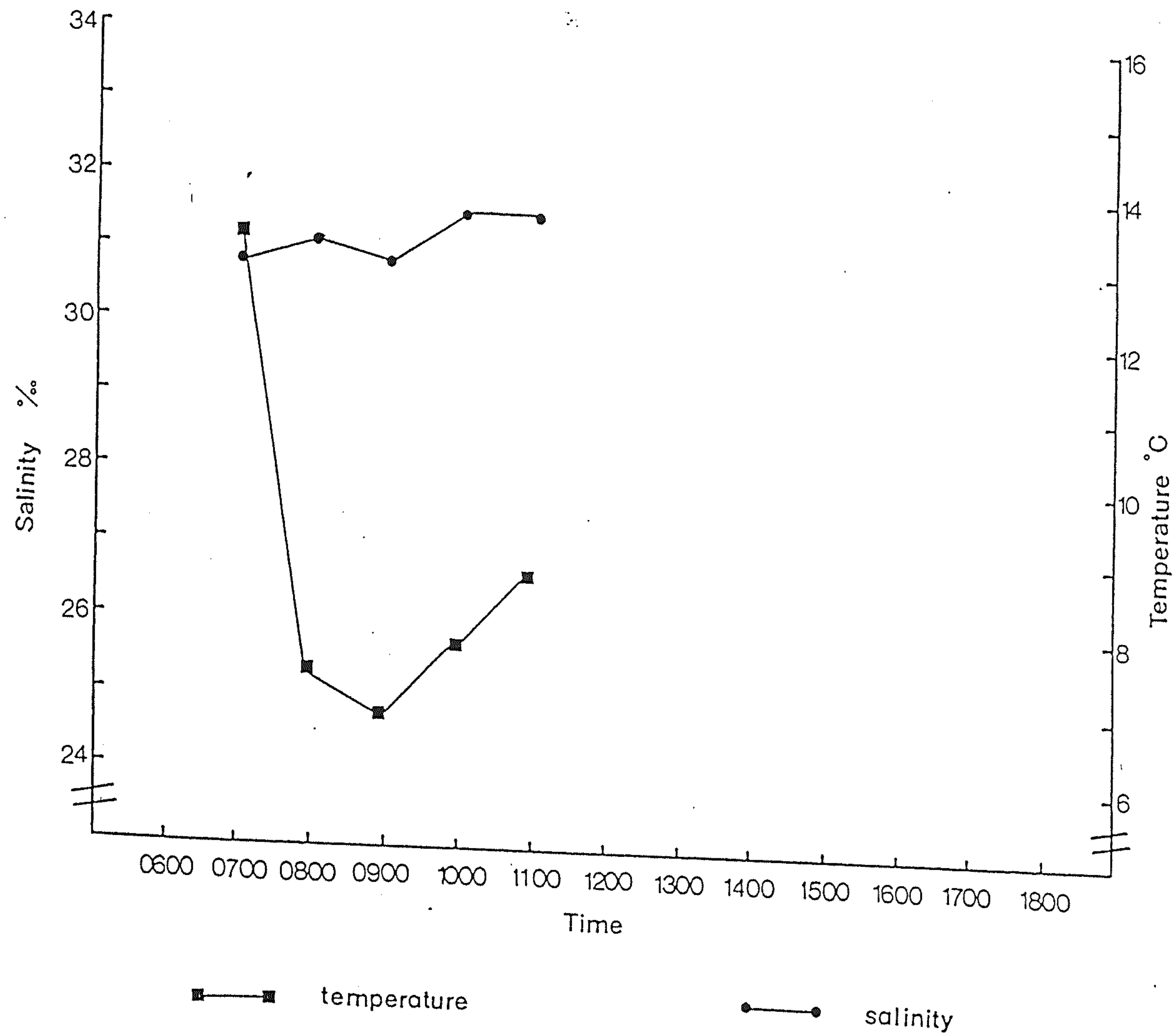

Figure 16c. Variations in salinity and temperature over a tidal cycle at Little Port Joli Bridge, June 10,1987

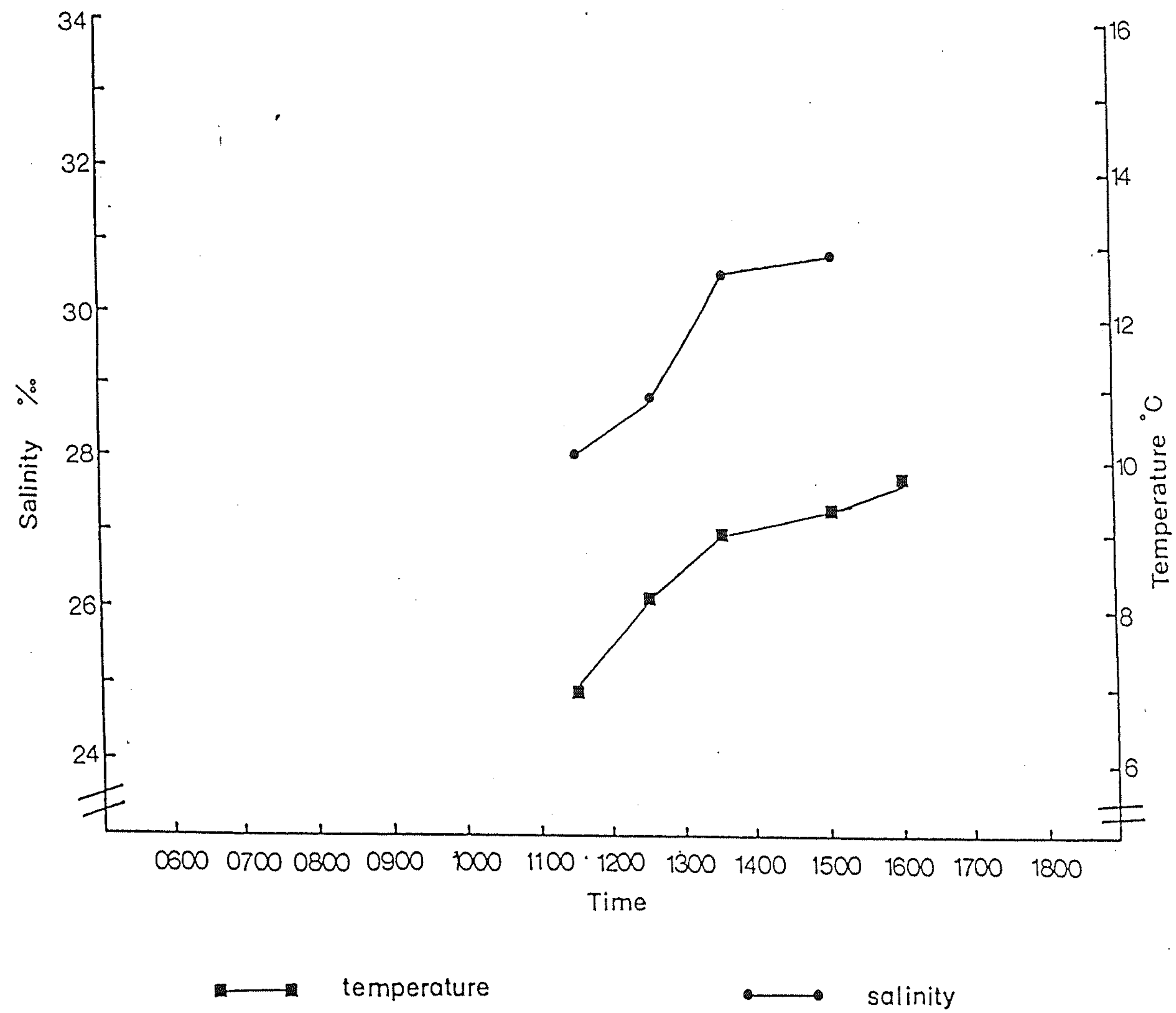

Figure 16d. Variations in salinity and temperature over a cycle at entrance to St. Catherines Basin, June 12, 1987

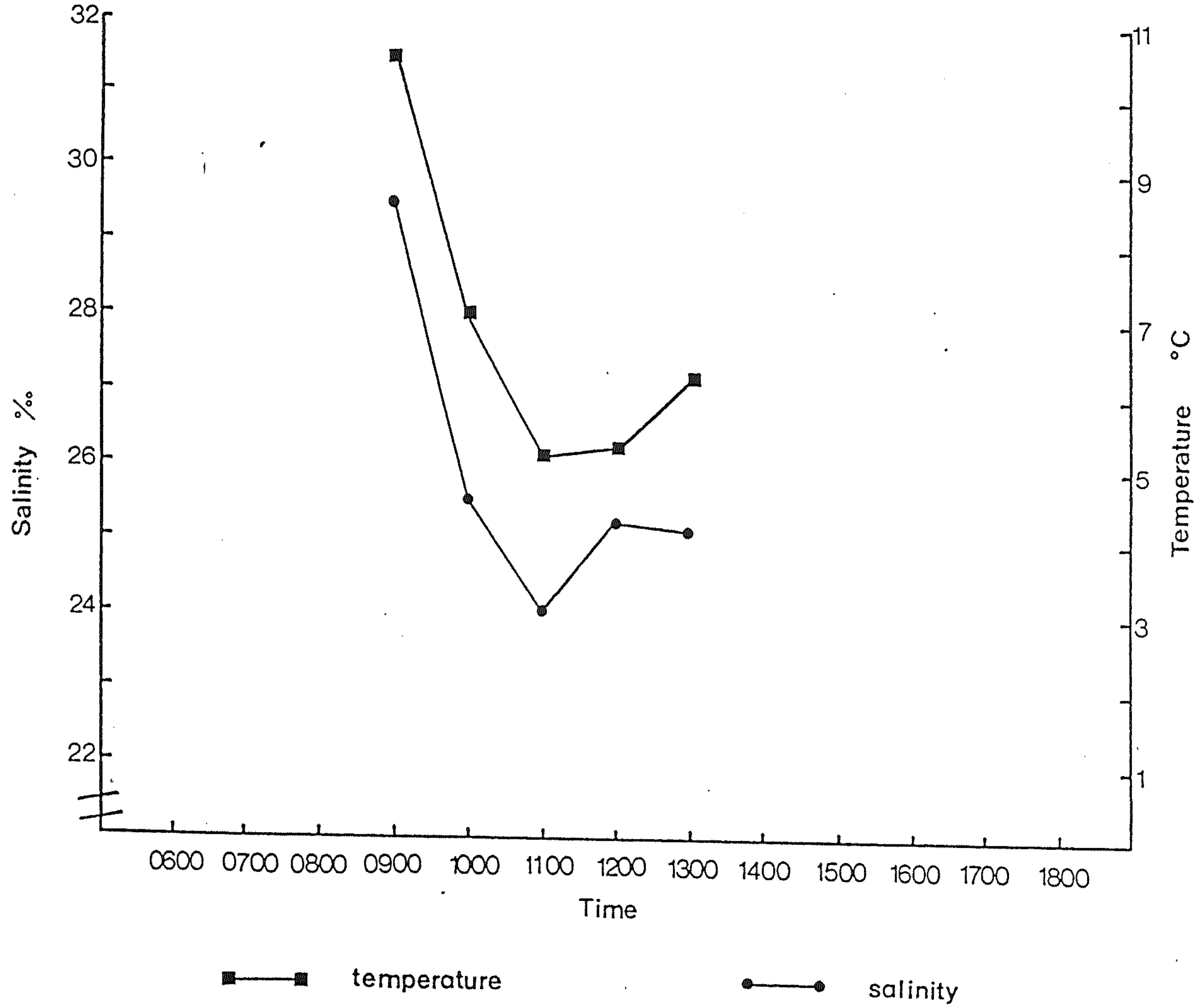

Figure 16e. Variations in salinity and temperature over a tidal cycle at entrance to St. Catherines Basin, June 14, 1987

salinity waters. We are unable to provide an unequivocal explanation for these observations. It is doubtful that the input of low salinity water from the ocean system is associated with nearby inputs from rivers, since there are no large rivers in the immediate area. An output of high salinity water might suggest significant evaporation occurring within the basin but this also seems unlikely since weather conditions at this time were generally cool and humid. One possibility, related to the location of our sampling stations, is that a complex circulation pattern exists in which flood waters tend to move into the basin on one side of the channel while ebb waters are still moving out on the opposite side. This phenomenon is more commonly associated with some larger estuarine systems than that at St. Catherines Basin. Lateral stratification of this kind has been recorded for the Cornwallis River, N.S. (Daborn and Pennachetti, 1979), where it is caused by the meandering form of the lower river estuary. The tortuous course of the channels at the entrance to St. Catherines Basin could produce a similar effect.

With regard to the other factors surprisingly little difference was found between materials entering and leaving the basins. Suspended particulate matter (SPM) levels varied little over the tidal cycle although in some instances there was an increase at low tide, probably reflecting resuspension of bottom sediments already within the basins, or the downstream movement of the turbidity maximum. Chlorophyll and nutrient concentrations were low in both ebb and flood waters.

5.1.4 Biological Characteristics: Habitat and Community Types

5.1.4.1 Introduction

Details with regard to observations made, and results of analyses of species present and their relative abundances at each sampling site, are presented in Appendix A. The following is an overview of the habitat and community types that were identified in the marine lagoons of the Adjunct. Table 3 presents information on the area occupied by each habitat and two maps (Figures 27 and 28) provided as an insert at the back of this report illustrate the distribution of habitats within each lagoon. Figure 17a-j presents photographs illustrating some of these habitats. The similarities between Little Port Joli and St. Catherines Basin, in terms of both habitat types and species composition, far outweigh the differences, and they are discussed together in the description that follows. Important differences between these systems, where they do occur, are noted.

5.1.4.2 Pelagic System

The pelagic system consists of the water body contained in the basin. The three major community types common to all pelagic systems include the plankton, nekton and neuston.

Figure 17a. Intertidal sand flat

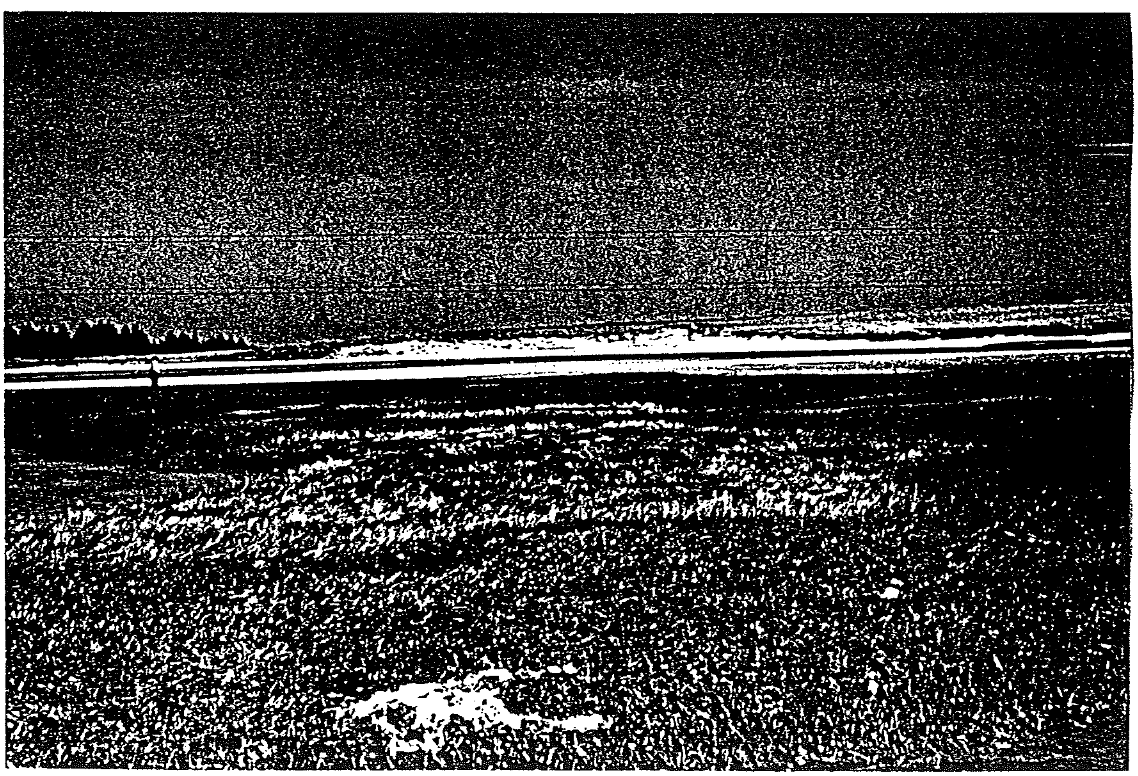

Figure 17b. Intertidal salt marsh

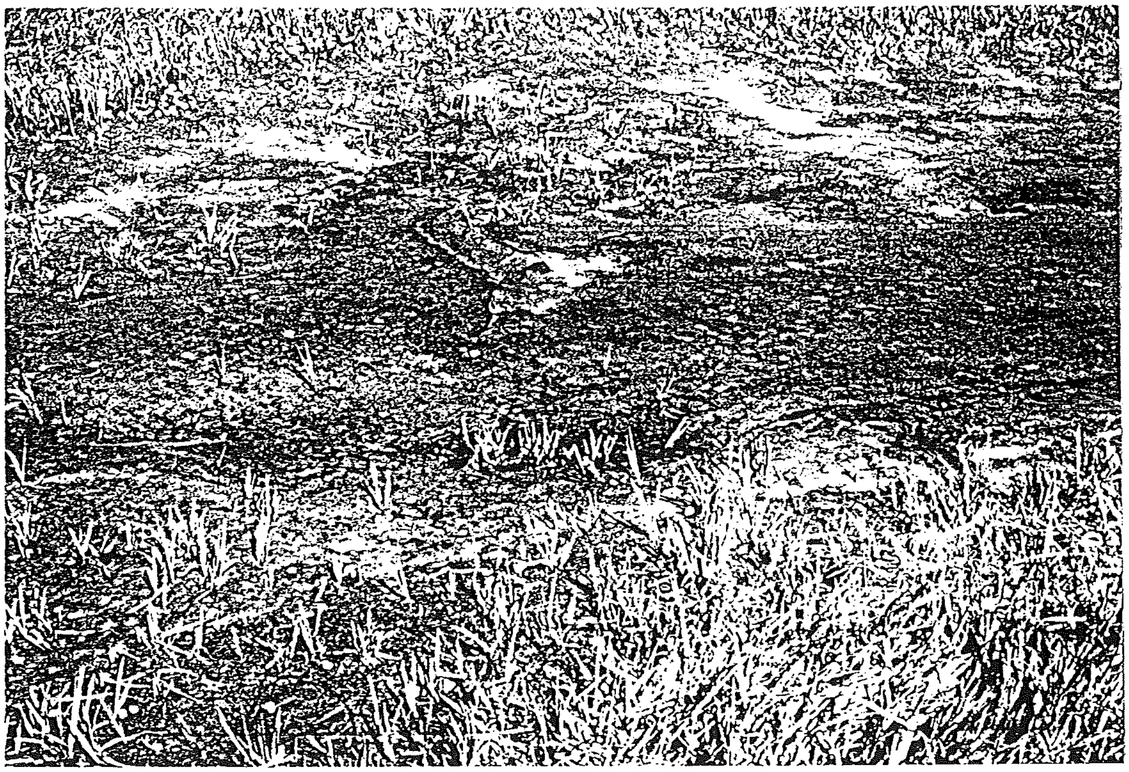

Figure 17c. Bacterial-algal mat community

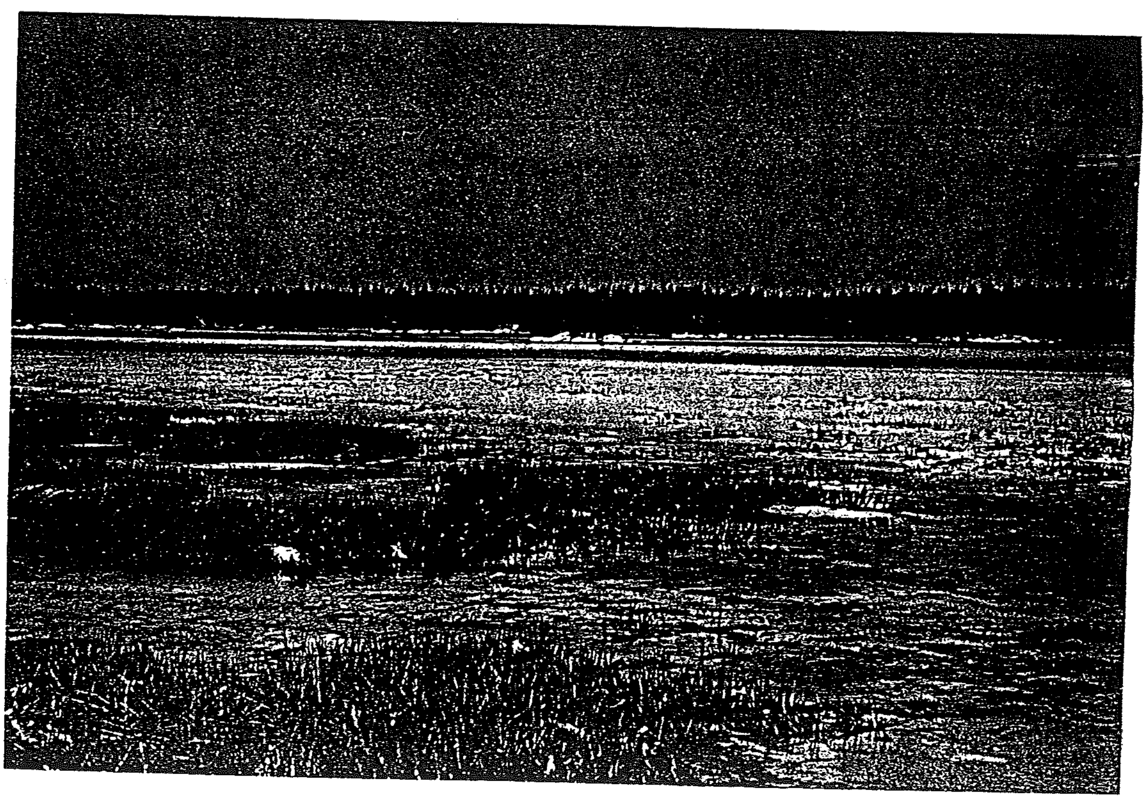

Figure 17d. Tidal panne

Figure 17e. Intertidal salt marsh pool and surrounding Spartina marsh

Figure 17f. Intertidal sand flat and tidal channels

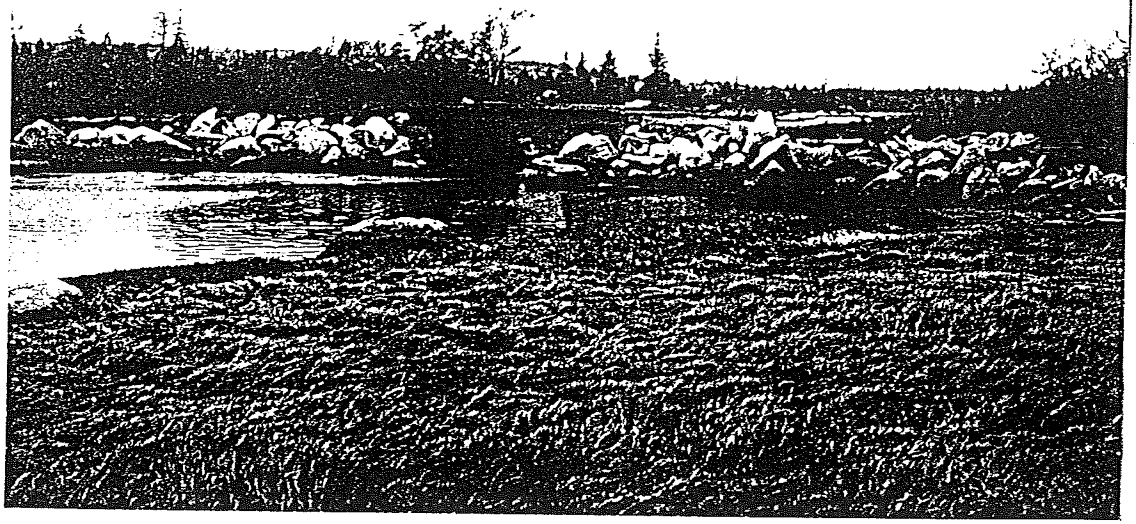

Figure 17g. Mixed habitats at Little Port Joli Bridge (Anchor Stn. A)

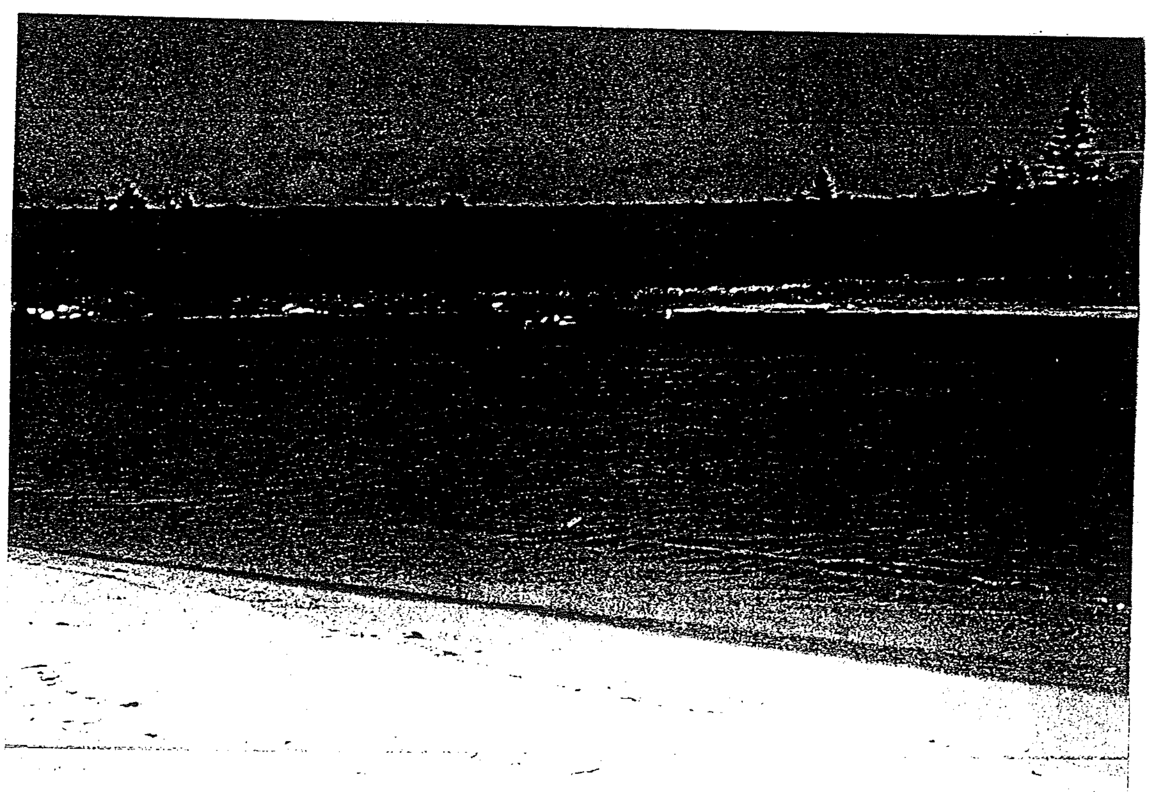

Figure 17h. Tidal inlet at Little Port Joli Basin (Anchor Stn. B)

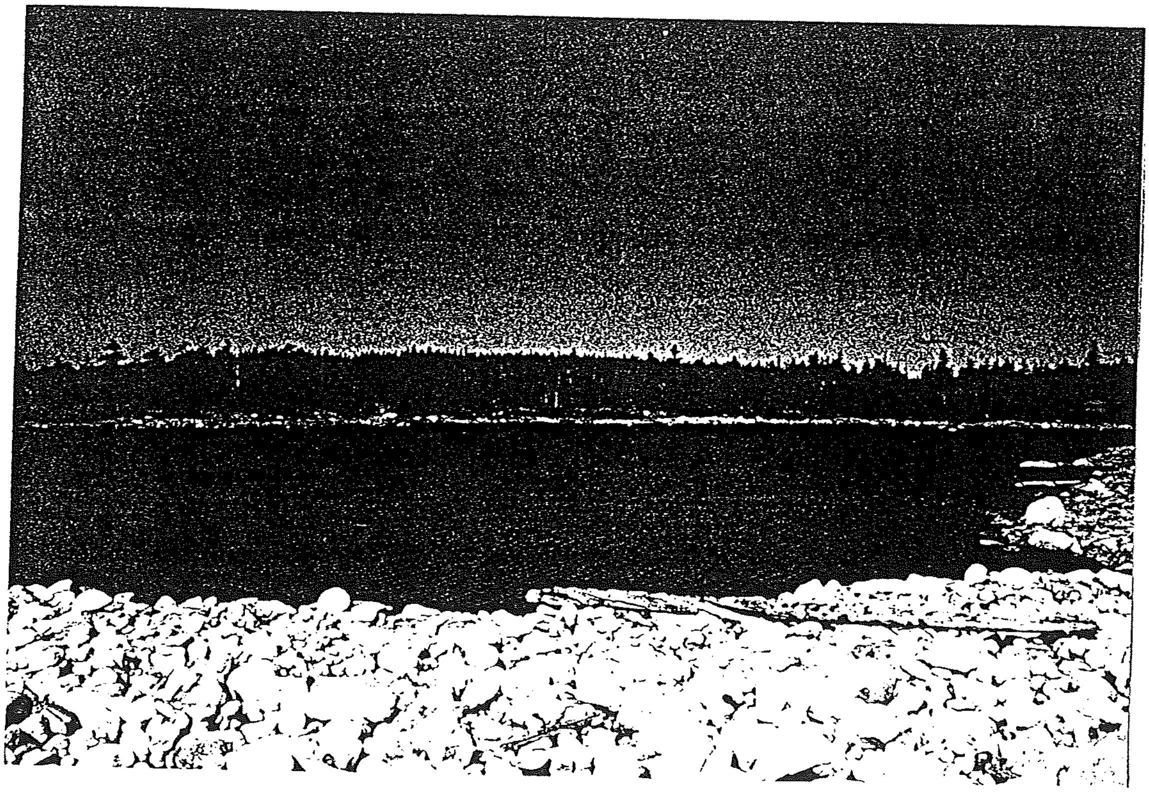

Figure 17i. Port Joli Headpond

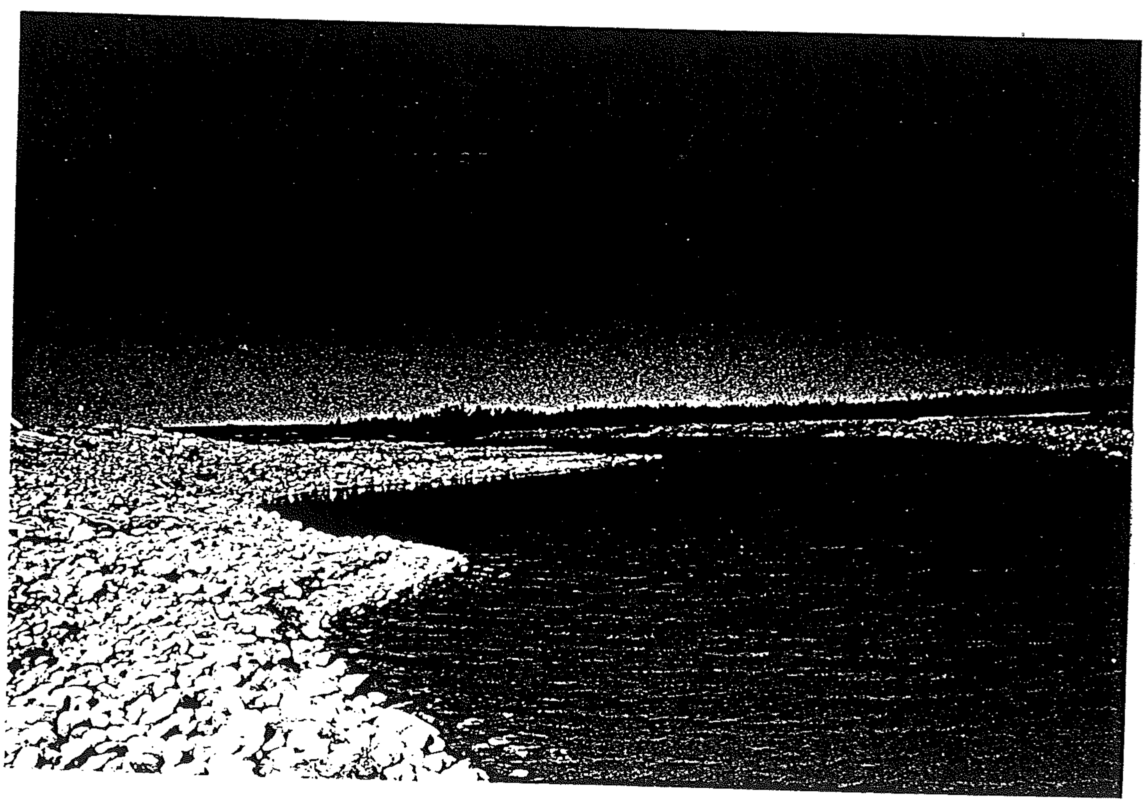

Figure 17j. Boyd's Cove Headpond

Planktonic organisms are those having limited powers of locomotion, and for the most part are carried about and distributed according to water circulation patterns. Planktonic communities are commonly divided into **phytoplankton** (microscopic plants) and **zooplankton** (microscopic animals). The latter is often divided into **holoplankton**, organisms that spend their entire life cycle as plankton, and **meroplankton**, organisms that spend only part of their life cycle as plankton. A major component of the latter are larval stages of benthic animals, examples being many bivalves (e.g., clams, mussels and oysters) and many polychaete annelids. Nektonic organisms are those having the ability to move independently of water currents and this category includes most of the large swimming crustaceans such as shrimp and euphausids, and the fishes. The neuston includes those organisms that live at the interface between water and air (e.g., jellyfish). In some cases the neuston can be a significant component of marine systems.

The planktonic habitat of the marine lagoons is primarily oceanic in nature, being composed of water of high salinity and low temperature. Although there are freshwater inputs into the lagoons, their contribution is small relative to the tidal exchange volume and there is little development of typical estuarine or brackish-water habitats. The salinity gradient from the seaward entrance to the upper reaches of the lagoon is small, being on the order of 5 ^{o}/OO.

Table 15 summarizes information on the taxa collected in phytoplankton samples. Species composition varied little between basins. Most species are typically oceanic. Diatoms were most abundant, with *Chaetoceros* sp., *Skeletonema costatum*, *Thallassiosira* sp., *Rhizosolenia delicatula* and *Asterionella japonica* being most common. Some benthic diatoms were also present, particularly in samples taken near intertidal sand bodies, primarily of the genus *Gyrosigma*, indicating the resuspension of benthic algae occurs in these systems. Dinoflagellates were present, mainly *Peridinium* sp., *Dinophysis accuminata* and *Ceratium minutum*, but always in low numbers. There is some seasonal variation in species composition. *Rhizosolenia delicatula*, *Biddulphia aurita*, *Ditylum brightwelli*, *scenedesmus sp.*, *Peridinium sp.* and *Dinophysis accuminata* were found early in the fall collections and *Navicula* spp., *Licmophora spp.* and *Ceratium minutum* were present only in the spring collections. This seasonal variation is a reflection of the normal species succession that occurs in the nearby coastal oceanic waters caused by the development of thermal stratification during the summer period.

Species composition of zooplankton collections also varied little between basins and contained species that are typically oceanic. Table 16 presents a list of taxa taken in zooplankton tows. Copepods were most abundant, particularly *Acartia longiremis*, *Temora longicornis*, *Pseudocalanus minutus* and *Calanus finmarchicus*. In areas near eel grass beds the mysids *Mysis stenolepis* and *Praunus flexuosus* were abundant. Meroplankton consisted of larvae of barnacles, bivalves, gastropods,

Table 15. List of Major Phytoplankton Taxa in Phytoplankton Samples from Little Port Joli and St. Catherines Basin

October, 1986

Chaetoceros sp.
Skeletonema costatum
Thallassiosira sp.
Rhizosolenia delicatula
Biddulphia aurita
Ditylum brightwellii
Asterionella japonica
Gyrosigma spp.
Ceratium longipes
Scenedesmus sp.
Melosira sulcata
Coscinodiscus spp.
Peridinium sp.
Dinophysis accuminata

June, 1987

Chaetoceros sp.
Skeletonema costatum
Fragilaria sp.
Asterionella japonica
Gyrosigma spp.
Navicula spp.
Thallassiosira sp.
Licmophora spp.
Ceratium minutum
Melosira sulcata

Table 16. List of Taxa Taken in Zooplankton Tows from Little Port Joli and St. Catherines Basin

Phylum Protozoa	foraminifera
Phylum Cnidaria	
Class Hydrozoa	*Obelia sp.*
	Rathkea octopunctata
	Sarsia princeps
	Hybocodon prolifer
Phylum Ctenophora	*Pleurobrachia pileus*
Phylum Chaetognatha	*Sagitta elegans*
Phylum Nematoda	
Phylum Arthropoda	
Class Crustacea	
Order Copepoda	*Centropages hamatus*
	Acartia hudsonica
	Eurytemora herdmani
	Acartia longiremis
	Temora longicornis
	Pseudocalanus minutus
	Calanus finmarchicus
	Oithona sp.
	10+ harpacticoid spp.
Order Amphipoda	*Gammarus oceanicus*
	Jassa fulcata
Order Mysidacea	*Mysis stenolepis*
	Praunus flexuosus
Order Cladocera	*Evadne sp.*
	Bosmina sp.
Order Decapoda	caridean larvae
	crab zoea
Subclass Ostracoda	
Subclass Cirripedia	larvae
Phylum Annelida	
Class Polychaeta	larvae
Phylum Echinodermata	larvae
Phylum Mollusa	
Class Bivalvia	larvae
Class Gastropoda	eggs/larvae
Phylum Chordata	
Class Ascidiacea	larvae
Class Larvacea	*Fritillaria sp.*

polychaetes and ascidians. Some seasonal variation was evident. Fall samples contained fewer meroplanktonic forms than spring samples as a result of the greater reproductive activity occurring in spring. Copepod species composition showed less seasonal variation other than the presence of *Centropages hamatus* and *Acartia hudsonica* in fall and an abundance of *Oithona sp.* during spring.

The nekton community consists of a number of fish species (Table 17) some of which are more typical of estuarine than oceanic conditions, such as four and nine-spined sticklebacks, blackspotted sticklebacks, northern pipe fish and killifish. The more oceanic species consisted of sand lance, herring, pollack, hake and sculpins. In addition to fishes, shrimps (*Crangon septomspinosa*) were also common nekton components.

Although no attempt was made to extensively sample the neuston community it was observed that ctenophores (*Pleurobrachia pileus*) were abundant during the spring in the upper reaches of the lagoons where they appear to become entrained and concentrated.

5.1.4.3 Benthic Systems

The benthic systems of the marine lagoons, unlike the pelagic, contain a great diversity of habitat and community types. These include a number of intertidal habitats located between the high and low water marks, and a number of subtidal habitats below the low water mark. Although the diversity of habitats is greatest in the intertidal zone, community development and species abundance are greatest in the subtidal zone.

The animal community types associated with benthic habitats are usually divided into two components, the **epifauna** and **infauna**. The epifauna include all animals living upon the sediment surface or upon rocks, stones and vegetation. The infauna include all animals living buried or crawling within a substrate and are confined usually to sandy or muddy substrates.

5.1.4.3.1 Intertidal Benthic Habitats

The intertidal benthic habitats identified in the marine lagoons consist of saltmarshes, fringing rocks, tidal ponds, and a diverse assemblage of mud flats and sand bodies. Most of the intertidal area is occupied by mud flats and sand bodies followed by salt marshes. Fringing rocks and tidal pools occupy a relatively small proportion of the total intertidal area.

<u>Salt Marshes</u>

Salt marsh habitats, composed primarily of *Spartina alterniflora* and *S. patens*, occur along most of the shoreline

Table 17. List of Fish Taken in Seines From Little Port Joli and St. Catherines Basins

Ammodytes americanus	(American Sand Lance)
Anguilla rostrata	(American Eel)
Apeltes quadracus	(Fourspine Stickleback)
Clupea harengus	(Herring)
Fundulus heteroclitus	(Mummichog)
Gasterosteus aculeatus	(Threespine Stickleback)
Gasterosteus wheatlandi	(Blackspotted Stickleback)
Myoxocephalus aeneus	(Little Sculpin)
Pollachius virens	(Pollock)
Pungitius pungitius	(Ninespine Stickleback)
Pseudopleuronectes americanus	(Winter Flounder)
Syngnathus fuscus	(Northern Pipefish)
Urophycis regius	(Hake)

Table 18. List of Invertebrate Taxa Taken in Seine, Shrimp Net, Dip Net, and by Hand Collections from Little Port Joli and St. Catherines Basin.

Phylum Cnidaria	
Class Anthozoa	*Metridium senile*
Class Scyphozoa	*Aurelia aurita*
Phylum Ctenophora	*Pleurobrachia pileus*
Phylum Bryozoa	*Electra pilosa*
Phylum Annelida	
Class Polychaeta	*Ophelia limacina* *Arenicola marina* *Nereis virens* *Nereis succinea* *Nepthys caeca*
Phylum Arthropoda	
Class Crustacea	
Order Isopoda	*Idotea balthica* *Idotea phosphorea* *Jaera marina* *Chiridotea caeca*
Order Amphipoda	*Gammarus oceanicus* *Gammarus lawrencianus* *Gammarellus angulosus* *Jassa fulcata* *Pontogeneia inermis*
Order Mysidacea	*Mysis stenolepis* *Praunus flexuosus* *Neomysis americana*
Order Decapoda	*Carcinus maenas* *Cancer irroratus* *Crangon septemspinosa*
Subclass Branchiura	*Argulus sp.*
Subclass Cirripedia	*Balanus sp.*
Phylum Mollusca	
Class Bivalvia	*Modiolus modiolus* *Mytilus edulis* *Mya arenaria* *Anomia aculeata*
Class Gastropoda	*Littorina littorea* *Lacuna vincta* *Acmaea testudinalis*
Order Nudibranchia	*Doto coronata*
Phylum Echinodermata	
Class Stelleroidea	*Asterias vulgaris*
Class Echinoidea	*Strongylocentrotus droebachiensis*

surrounding the basins. With few exceptions, the salt marsh occupies a narrow band, seldom exceeding 10 m in width. The exceptions are in areas behind the beach-dune complexes where intertidal gradients are more gentle, allowing a wider area for colonization by salt marsh plants, and in areas where streams and creeks enter the lagoons, particularly those originating at St. Catherines River lake and Meadow Lake. In areas where *Spartina* grades into *Zostera* beds, *Ruppia maritima* often occurs in the transition zone. Salt marshes also occur on some of the tidal flats having higher elevations, the flat near the entrance to Little Port Joli Basin being the best example. None of the salt marsh habitats is well developed. Those along the shore lack the tidal channels characteristic of well developed marsh systems and they appear to be unable to keep pace with rising sea levels due to the paucity of materials available for sedimentation. Salt marshes located on the tidal flats are subject to considerable erosion as evidenced by the relatively deep channels along their margins. The bottom and edges of these channels are often composed of soft organic muds and peat that appear to be remnants of earlier marsh systems.

The animal communities within the salt marshes are composed primarily of gastropods (mainly *Littorina* sp. and *Hydrobia* sp.) which feed on the epiphytic algae growing on the stems of the marsh plants and benthic diatoms growing on the sediment surface.

Tidal Pools

A number of tidal pools are present in the lagoons. All are located within salt marsh habitats and are more correctly referred to as tidal pannes. Tidal pannes are typical of young salt marsh systems and are caused by an unequal distribution of sediments which results in incomplete drainage of water and death of the standing vegetation. The tidal marsh system located at the mouth of Little Port Joli Basin contains the most extensively developed tidal panne.

Although the sediments in the pannes are strongly anaerobic, these systems are biologically rich, containing a great variety of both plants and animals. Algal communities in the shallower areas consist of filamentous green algae. *Rhizoclonium sp.* is most abundant, but *Chaetomorpha linum*, *Cladophora* sp. and *Enteromorpha* sp. are also present. In areas where filamentous algae are absent, the surface sediments are covered by dense growths of benthic diatoms, which give the surface a golden-brown hue, or sulfur bacteria, which impart a deep purple color to the sediments.

The epifauna includes mainly gastropods (*Littorina* sp. and *Hydrobia minuta*) and the infauna some mussels (*Mytilus edulis*), a few clams *Mya arenaria*) and isopods (*Jaera marina*). Beach seines revealed an abundance of sticklebacks, and killifish. Although polychaete holes were abundant, we failed to obtain specimens of living polychaetes in our samples.

Fringing Rock Habitats

This habitat is confined to large rocks and boulders that occur either along the shoreline or protruding above the low water level and occurs in many places scattered throughout Little Port Joli and St. Catherines Basins. Like the tidal pannes, the area occupied by intertidal fringing rock habitats is not great, but they are biologically rich and interesting. This habitat is colonized primarily by algal macrophytes which exhibit the zonation patterns characteristic of intertidal rocky shores. However, because of being compressed into a small zone as a result of the steep gradient, this zonation is not immediately obvious. The zone nearest the high tide mark is dominated by *Ascophyllum nodosum*, the mid-intertidal by *Fucus evanescens* and the low tide level by *Fucus vesiculosus*. In some cases *Enteromorpha* sp. forms a growth of long trailing filaments. Further zonation below the low tide level is discussed in the section on subtidal habitats.

Animals within this habitat include some barnacles (*Balanus balanoides*) and mussels (*Mytilus edulis*), and often large numbers of *Littorina sp.* which probably feed mainly on the epiphytic microscopic algae commonly found growing on the surface of these macrophytes. Other organisms found living within and on the macrophytes include amphipods (*Gammarus oceanicus*) and isopods (*Idotea balthica*).

Intertidal Sand Bodies and Mud Flats

The non-vegetated intertidal zone is composed of tidal mud and sand flats which occur primarily near the entrance to each basin. In these areas deltas have built up from sedimentary materials originating in the offshore oceanic system, and from wind-blown materials from the sand dunes. A diversity of habitats is present, resulting from the progradation of sedimentary materials during the ebb and flood tidal cycle. Sediment size becomes coarser in the seaward direction, whereas the upper intertidal areas, which are relatively low sloping features, are composed of fine sands and muds, and the lower intertidal areas of medium to coarse sands.

The physical conditions in this environment, particularly temperature, periods of submersion and emersion, and current velocities, are extremely variable and this range of conditions is reflected in the wide variation of community types within a relatively small area. In addition, the intricate patterns of current directions and velocities result in considerable local differences in sediment types and the spatial distribution of community types becomes difficult to separate into clear patterns. Although the diversity of habitat types and their associated communities is high, species diversity within communities is low, most collections revealing only two to four species.

Despite the heterogeneity of this environment some generalizations are evident. Community development is greatest within the upper intertidal flats of Little Port Joli Basin. This area appears to accumulate organic materials, primarily seaweeds and saltmarsh detritus, along the base of the sand dunes. Although sediments were anaerobic approximately 2 cm, and sometimes less, below the surface, there was an abundance of polychaetes (mainly *Nereis* sp. and *Ophelia limacina*), clams (*Mya arenaria*) and burrowing isopods (*Chiridotea coeca*). In some areas green algal mats were abundant. Associated with these were polychaetes, clams and gastropods (both *Littorina* sp. and *Hydrobia* sp.). Much of the sediment surface in this area, as well as further seaward, is covered with benthic diatoms. In some areas dense microbial mats are present where they form thin (2-3 mm), leathery olive green sheets at the sand surface. Sand grains are structural components of these mats. Although no attempt was made to identify the species of organisms making up these mats, they are generally composed of filamentous blue-green algae and bacteria.

As one progresses further down the intertidal zone, community development quickly decreases and consists primarily of a *Mya* and *Nereis* community with few other species present. In some areas *Nereis virens* occurs in combination with *Polydora ligni*, another tube-dwelling polychaete. In still other areas the dominant polychaete is the bamboo worm (*Nicomache sp.*).

Near the low tide mark where sediments are coarsest very few organisms were found, although as the tide rose many burrowing isopods could be seen moving about the surface. The instability of sediments in this region is so great that sessile and tube building organisms have little opportunity to establish themselves before being eroded away or covered with sediments. An example of this is shown in the Figure 18 which shows polychaete tubes being exposed by sediment resuspension.

Although the same community types are present in St. Catherines Basin, their development is much less. This environment appears to be even less stable and consists primarily of coarse sands. The intertidal area also appears to collect less organic detritus along the shoreline, which is probably important in stabilization of the upper intertidal zone.

5.1.4.3.2 Subtidal Benthic Habitats

Introduction

The distribution of subtidal benthic habitats, like that of intertidal benthic habitats, is determined primarily by the distribution of substrate types. Three major habitat types are present in the lagoons. The smallest in area is the submersed cobbles, rocks and boulders which are colonized primarily by algal macrophyte communities. A larger area is composed of a sand-mud substrate on which benthic diatoms grow, and this

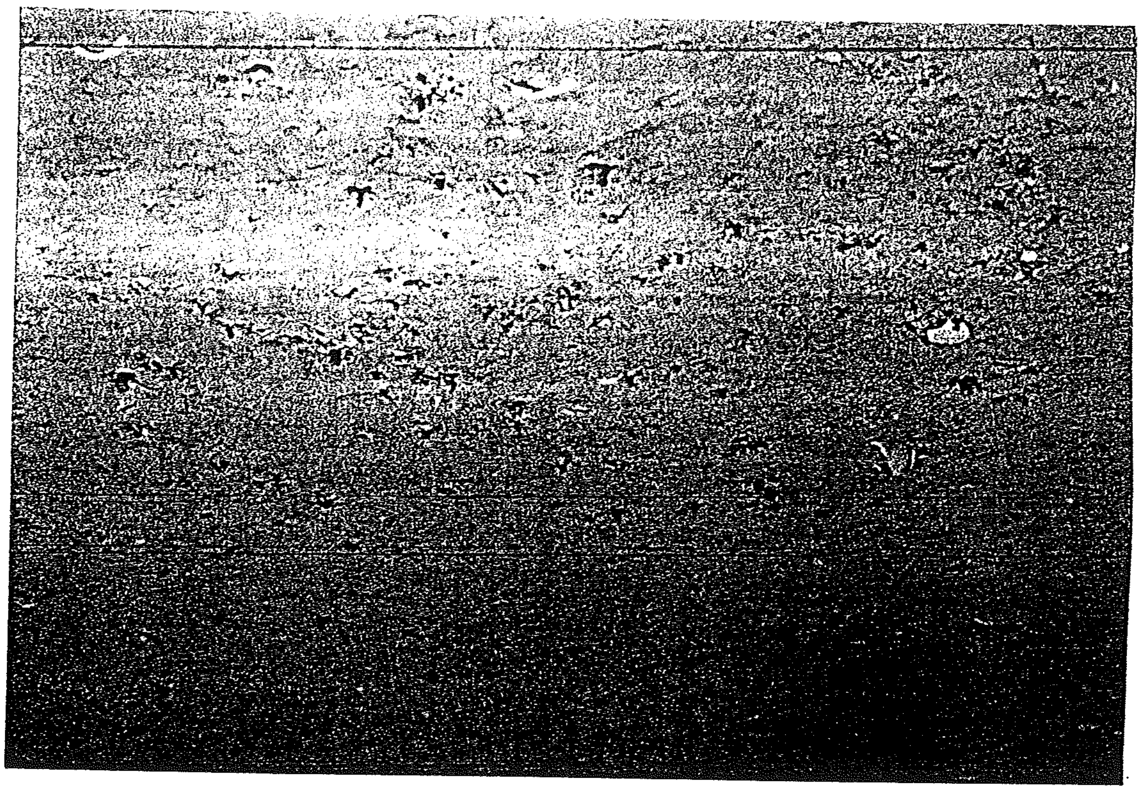

Figure 18. Photograph showing exposure of tube dwelling polychaetes

habitat often contains large populations of gastropods, mainly *Littorina* sp. The largest area, composed of fine sands and muds and located almost exclusively in the upper reaches of the lagoons, supports dense stands of eel grass (*Zostera*) which exhibit the greatest community development of all habitats.

Algal-macrophyte Communities

Subtidal algal macrophyte communities, although quite diverse in number of species, are limited in abundance due to the lack of stable substrates. They occur only in rocky areas along the shore zone and on cobbles, rocks and boulders located within tidal channels. It is only in these environments that they find suitable substrates for attachment by holdfasts and the high current velocities that provide the water exchange needed for nutrient replenishment. Despite this limited distribution, approximately 25 different species were collected with all groups--brown, red and green--being well represented (Table 19).

Although vertical zonation of algae below the low water levels was not well developed due to the shallow depths of the basins, there is considerable horizontal variation from the entrance to the upper reaches of the lagoons. Near the inlets, on small rocks and cobbles occurring in the channels, species diversity is greatest, especially for many of the smaller forms of red algae, although biomass is not particularly high. Diversity is also high on rocky areas along the shore zone of the inlets, but here brown algae are much more prominent. The shore zone further up the tidal channels contains mainly rockweeds (*Fucus* spp.). On boulders within the channels *Fucus* spp. occurs together with kelps (*Laminaria saccharina*) and lesser amounts of both red and green algae. On some boulders diversity is quite high and although the total area of this habitat is small, it represents one of the better areas for observing algae. Towards the upper reaches of the basins, green algae become more prominent. In some areas within eel grass beds unialgal stands of sea lettuce (*Ulva lactuca*) and other green algae often occur.

In some cases seaweeds occurred unattached and free floating at the bottom of the tidal channels. They often appeared to be healthy and still growing and may be able to exist for long periods of time in this habitat. In some coastal waters, large quantities of live floating seaweeds represent a distinct microhabitat in the pelagic zone that offers both refuge and food for a variety of fish and pelagic crustaceans (Parsons, 1986).

Animal abundance within the algal community is not great. In some areas mussels grow among the algae and some of the rockweeds and kelps often have *Littorina* grazing on their surfaces. Starfish (*Asterias*) also often occur within the algal masses, particularly if mussels are present. There were surprisingly few sea urchins observed grazing on the kelps, probably as a result of the high current velocities which makes it difficult for them to remain attached while feeding. Collections made from within algal mats revealed amphipods

Table 19. Algal Macrophyte Taxa Collected in Little Port Joli and St. Catherines Basin

Brown Alga	Habitat
Fucus vesiculosus	attached to rocks, subtidal and intertidal
Fucus evanescens	attached to rocks, subtidal and intertidal
Fucus spirillus	attached to rocks, subtidal and intertidal
Ascophyllum nodosum	attached to rocks, subtidal and intertidal
Laminaria saccharina	attached to rocks, subtidal
Desmarestia aculeata	drifting in channel, attached to rocks, subtidal
Desmarestia viridis	drifting in channel, subtidal
Petalonia fascia	attached to rocks in swift currents, subtidal
Eudesme virescens	attached to rocks in swift currents, subtidal
Chordaria flagelliformes	attached to rocks in swift currents, subtidal
Chorda sp.	attached to rocks in swift currents, subtidal
Red Alga	
Chondrus crispus	attached to rocks, mainly subtidal
Polysiphonia sp.	attached to rocks and other seaweeds, subtidal
Ceramium sp.	attached to rocks and other seaweeds, subtidal
Rhodomela coutervoides	attached to rocks in swift currents, subtidal
Dumontia incrassata	attached to rocks in swift currents, subtidal
Ptilota serrata	attached to rocks in swift currents, subtidal
Porphyra miniata	drifting in channel, subtidal
Palmaria miniata	drifting in channel, subtidal
Green Alga	
Chaetomorpha linum	quiet waters, subtidal
Enteromorpha sp.	quiet waters, subtidal and intertidal
Chaetomorpha sp.	quiet waters, subtidal and intertidal
Rhizoclonium sp.	quiet waters, subtidal and intertidal
Monostroma sp.	quiet waters, subtidal and intertidal
Ulva lactuca	attached to rocks, subtidal

(*Gammarus oceanicus* and *Jassa falcata*), isopods (*Idotea balthica*) and a number of small unidentified bivalves.

Sand-Mud Subtidal Habitat

These habitats occur primarily in areas where current velocities are high and include most of the bottom of tidal channels. Near the entrance to the basins, where currents are strongest, these areas appear to be relatively barren of both epifauna and infauna, although it was difficult to sample properly for the latter because of the strong currents. In the middle of the basins, where current speeds are less, the substrate becomes colonized by benthic diatoms which tend to stabilize and prevent resuspension of the sediments. In some of these areas the surface becomes quite hard. Here gastropods (mainly *Littorina*) are particularly abundant as are clam and polychete holes. Although empty moon snail (*Lunatia heros*) shells were often present in these areas, no live specimens were found and it is not determined if this organism occurs in the lagoons or whether the shells were washed in from outside. Some starfish and an occasional crab (*Cancer* sp.) were also observed.

Where finer sediments occur, especially in the upper reaches around *Zostera* beds, lugworms (*Arenicola marina*) often occur in great numbers where they probably play a significant role in bioturbation processes. Sediments here are often anaerobic which prevents the development of a more extensive infauna.

Subtidal Eel Grass Beds

Eel grass (*Zostera marina*) beds occupy a large proportion of the subtidal system. They occur primarily in the upper reaches of the lagoon where current velocities are slowest and fine sedimentary materials accumulate. The sediments within eel grass beds are strongly anoxic. These sediment characteristics are produced to a large extent by *Zostera* through its effect on reducing water currents, which induces deposition of fine sedimentary materials, and production of organic matter that accumulates and decays in the sediments. Most of the eel grass beds in the lagoons are monospecific, containing few other macrophytes, but in some areas, particularly within Basin Lake, large areas (10-20 m in diameter) of *Ulva lactuca* and *Rhizoclonium* occur. Most other plants are microscopic, living epiphytically on the leaves of *Zostera* plants.

Although the diversity of animals present in the eel grass beds is high, few animals live as infauna within the sediments because of the anoxic conditions. An exception is the lugworm, *Arenicola marina*, a large burrowing polychaete that can live within this reduced environment due to its ability to pump large volumes of water for aeration. Even these organisms, however, are limited primarily to the periphery of *Zostera* beds where sediments are sandier and their burrowing activities are not hindered by the dense root matrix immediately below *Zostera* plants.

Diversity and abundance of animals living within the eelgrass leaves is great. Seine collection revealed numerous mysids (*Mycis stenolepis*, *Praunus flexuosus*, *Neomysis americanus*), sand shrimp (*Crangon septemspinosa*), crabs (*Carcinus maenas*, *Cancer irroratus*), isopods (*Idotea balthica*, *I. phosphorea*, *Chiridotea caeca*), and amphipods (*Pontogencia inermis*, and *Gammarus oceanicus*). Fishes included all species of sticklebacks, pipefish and eels. Many of these organisms, particularly the smaller isopods and amphipods probably live within the **Aufwuchs** (epiflora and epifauna) community growing on the *Zostera* leaves. Also abundant on *Zostera* leaves were snails (*Littorina* sp. and *Hydrobia* sp.).

On almost all occasions when Basin Lake was being surveyed, otters were present, probably feeding on the abundant crabs within the *Zostera* beds. It was here that the neuston, composed of jellyfish (*Aurelia aurita*) and ctenophores (*Pleurobrachia pileus*) were most abundant.

5.1.4.3.3 Terrestrial/Marine Interactions

Aside from the obvious input of organic matter originating from leafloss and death of salt marsh grasses, there do not appear to be any strong functional linkages between the terrestrial and marine systems. Freshwater inputs are generally small relative to ocean inputs and it is doubtful that allochothonous input from the drainage area surrounding the lagoons is important in terms of either nutrients or organic matter. The relative clarity of water in the lagoons, compared with that of water in streams entering the lagoons, indicates that brown waters entering are diluted rapidly and provides additional evidence of the small contribution of inputs to the basins. Although there is some exchange between terrestrial and marine systems as a result of the feeding activities of mammals (e.g., racoons and otters) and aquatic waterfowl, this exchange is probably small and of little significance to the overall functioning of the marine systems.

5.1.4.4 Brackish-water Headponds

5.1.4.4.1 Physical Characteristics

<u>Physiography</u>

The four brackish-water headponds located within the Adjunct all lie adjacent to the ocean shoreline. Each is separated from the ocean by a steep shingle beach. It is difficult to evaluate, based on available information, the origin of these ponds. They appear to be simple depressions, perhaps formed by glacial scouring processes, in what is now a heath-bog environment. The ponds are for the most part relatively shallow

(< 1 m) and most have small streams or creeks as inputs, the Port Mouton headpond being an exception. Water input to this system probably consists primarily of groundwater seepage and it appears to undergo large variations in volume and may at some times completely dry up (B. Helleman, personal communication). There are no obvious outflows from any of these ponds, but brownwater stains sometimes observed on the seaward side of the shingle beaches suggests that water leaves these systems through these semi-permeable barriers. At all headponds it appears that the shingle beaches are gradually moving landward and slowly filling in the headponds. This is most evident at the Boyd's Cove ponds where large cobble completely covers the bottom and can be observed lining the shoreline on the most landward edges of the ponds. Figures 19 to 21 present bathymetric maps of each pond and Table 20 presents information on morphometric paramaters.

Sediment Types

The sediments of the Port Mouton headpond are composed primarily of soft organic muds that are anaerobic. Their color is dark brown, indicative of mild reducing conditions. At Port Joli the headpond sediments are composed of soft organic muds along the inland shoreline and sandy muds near the seaward shoreline. The bottoms of the Boyd's Cove headponds contain a layer of coarse cobble underlain by light brown sediments similar to the "dy" substrates typical of dystrophic lakes. In all headponds, most of the bottom is covered by a dense stand of macrophytes.

Light

Although light measurements necessary for calculation of extinction coefficients were not made at the headponds, Secchi disc depths were recorded. All headponds are characterized by heavily colored brown water but, because of their shallow depths, have euphotic zone depths greater than the bottom as evidenced by the growth of benthic macrophytes. Secchi disc depth at all headponds were similar and ranged between 0.7-0.8 m.

Winter Ice Conditions

During the February, 1987 site visit, the Headponds at Boyd's Cove and Port Joli were visited. In both, ice cover was 100% with thickness ranging from 1 to 10 cm near the immediate shoreline.

5.1.4.4.2 Chemical Characteristics

Salinity

All of the headponds are obviously brackish, but not of exceptionally high salinity, in most cases being < 5 $^{o}/oo$. The

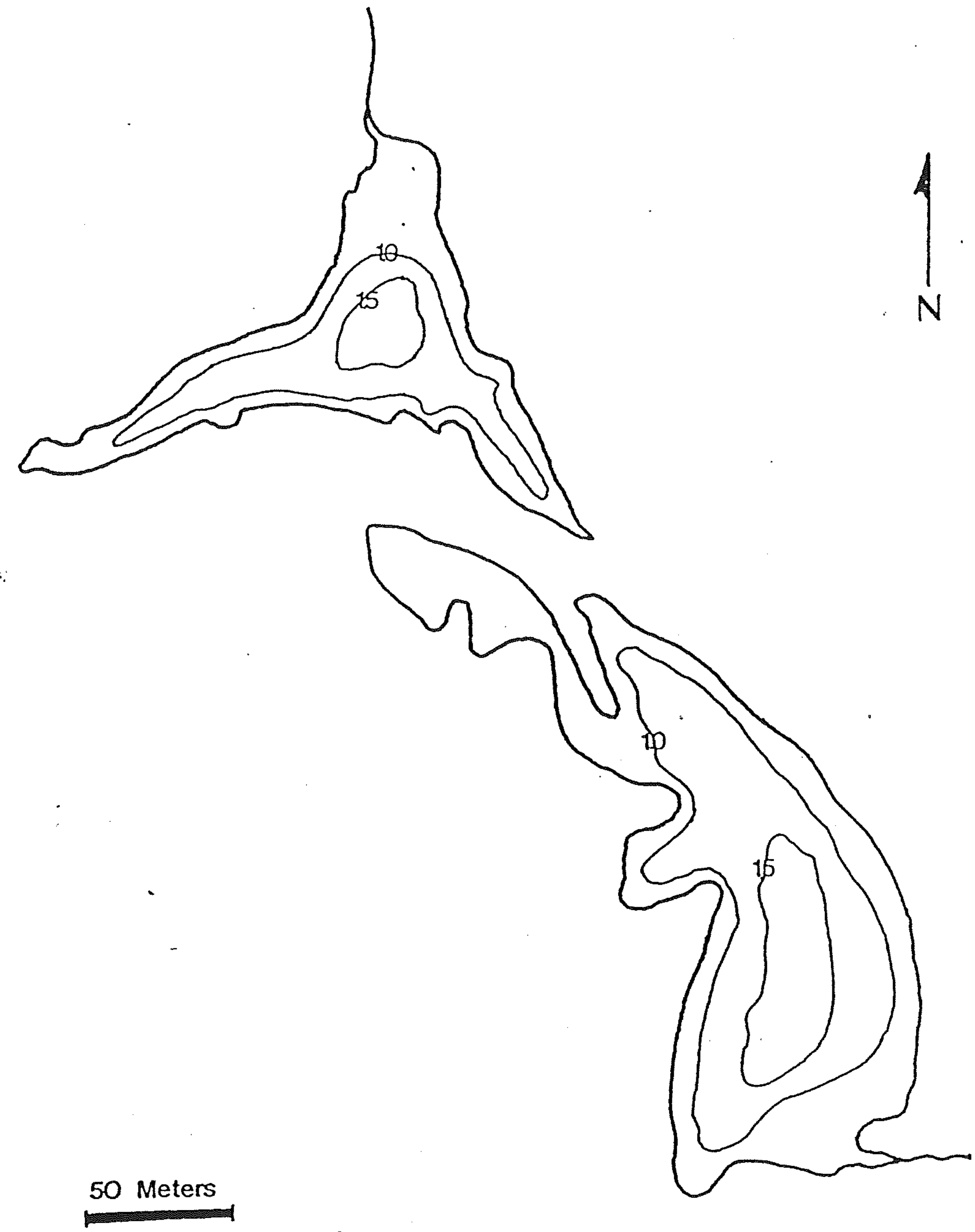

Figure 19. Morphology of Boyd's Cove Headponds

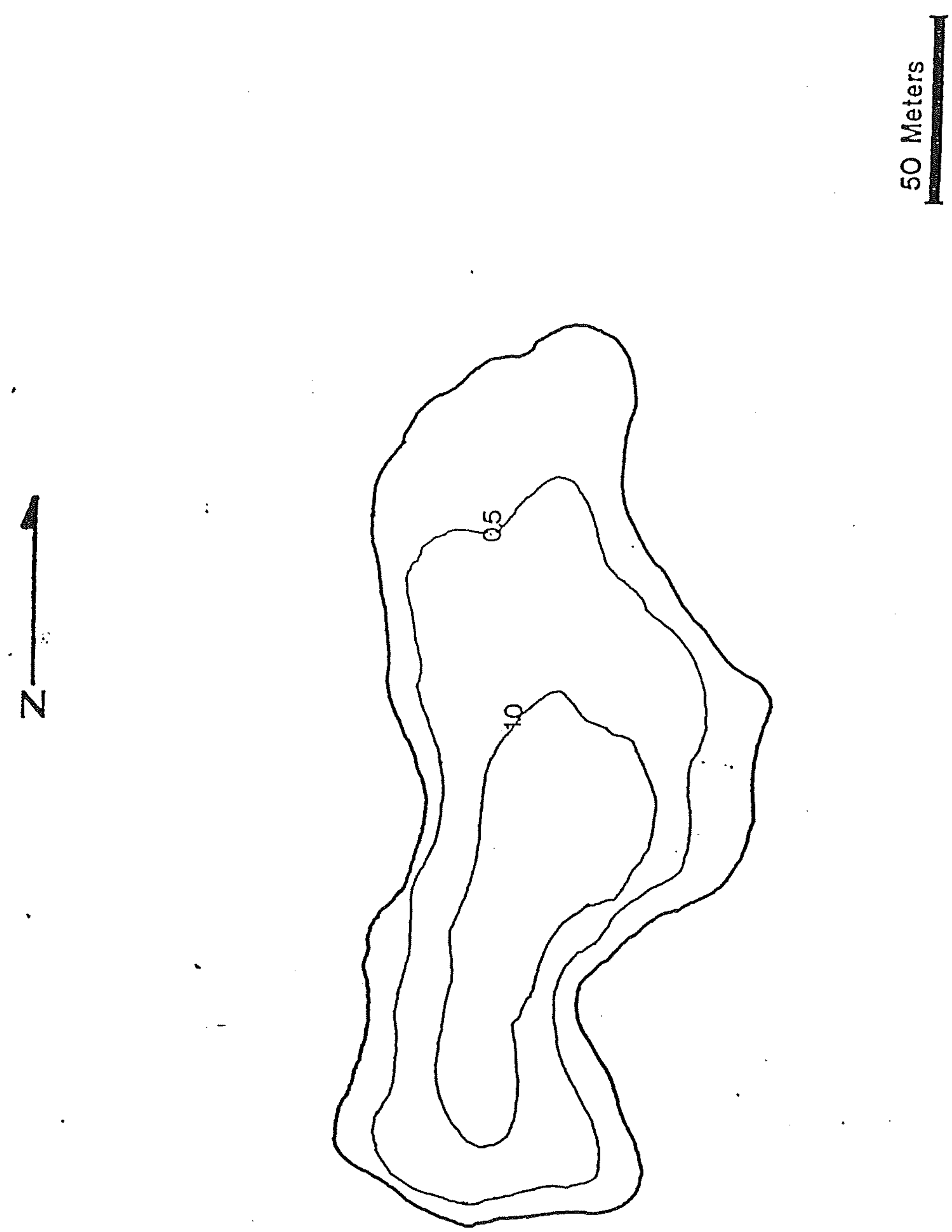

Figure 20. Morphology of Port Joli Headpond

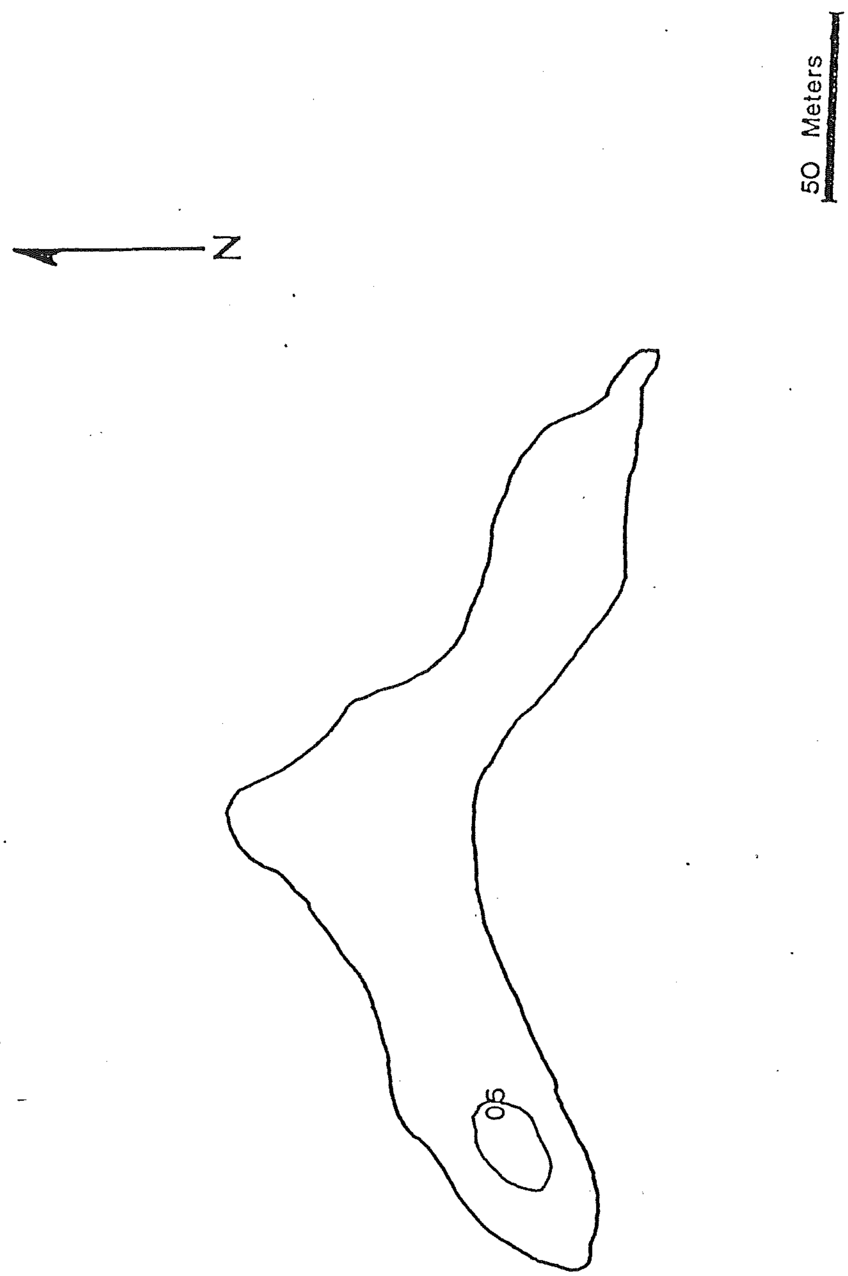

Figure 21. Morphology of Port Mouton Headpond

Table 20. Morphometric parameters of Headponds located within the Seaside Adjunct*

	Port Mouton	Port Joli	Boyd's Cove North	Boyd's Cove South
Shoreline Length (m)	614	605	665	982
Shoreline Development	1.4	1.9	2.4	4.3
Maximum Length (m)	235	180	180	173
Maximum Breadth (m)	100	63	100	53
Mean Breadth (m)	68	47	34	24
Maximum Depth (m)	0.5	1.0	1.5	1.5
Mean Depth (m)	0.3	0.8	1.2	1.0
Relative Depth	0.35	0.96	1.7	2.0
Surface Area (m^2)	16,094	8,438	6,110	6,139
Volume (m^3)	4,828	6,750	7,332	4,139
Development of Volume	0.6	0.8	0.8	0.7

*It should be noted that many of these parameters are approximate since considerable changes occur in both surface area and volume of the headponds during dry and wet periods.

highest salinities were observed in the Port Mouton Headpond and the lowest at the Boyd's Cove headponds (Table 21). The levels of salinity suggest that the major contribution of salts to the headponds is by sea spray originating in the surf zone of the ocean shoreline. Because it was not always possible to bring a boat to the headponds, we were usually unable to determine if these ponds are vertically stratified with respect to salinity. In the one instance where this was possible, during the October, 1986 site visit, the Port Mouton headpond showed no indication of vertical stratification in either temperature or salinity.

Nutrients and pH

Silica, phosphorous and nitrigen concentrations were generally low and typical of values commonly observed in brown water systems where nutrient complexing by humic acids tends to make nutrients unavailable. pH values were also low, ranging between 3.95-4.90, reflecting the acid-bog characteristics of the drainage basins surrounding these systems.

Dissolved Oxygen

In all cases, dissolved oxygen values were high with saturation values near 90%. Although the bottom muds are mildly anaerobic, it is doubtful that these anaerobic conditions ever extend into the water column as there was little evidence of conditions suitable for the development of stratification or of the presence of hydrogen sulfide in large amounts.

5.1.4.4.3 Biological Characteristics

Biologically, the headponds represent a relatively harsh environment for life. This harshness is imposed primarily by salinity levels which are too low for most marine organisms and too high for most freshwater organisms. In addition, it is likely that salinities vary considerably according to periods of dry and wet weather which imposes an additional strain on organisms having little ability to control their osmoregulatory capacity. An additional strain on organisms living within these systems is the low pH resulting from the acid brown-waters entering these ponds. Since low pH is known to affect osmoregulatory processes, especially in fish, the combination of acid conditions together with a high salt content makes this environment a particularly difficult one to inhabit. As a result, species diversity of both benthic and pelagic communities within the headponds is low.

Macrophyte abundance in the headpond is great but diversity is low, most species present being those common to brackish-water habitats. The bottom of the Port Mouton headpond is almost completely covered by a monospecific stand of bur-weed (*Sparganium* sp.). The bottoms of the Port Joli and Boyd's Cove headponds are covered primarily by *Enteromorpha*, but other

Table 21. Physical and Chemical data for Headponds in the Seaside Adjunct

Date	Location	Depth (m)	Sal. (°/oo)	Temp (°C)	Chlor (mg/l)	Secchi (m)	pH	O_2 (mg/l)	O_2 (% sat)	Si (mg/l)	Nit (mg/l)	Phos (mg/l)
10/19/86	Port Mouton	Surface	1.05	6.5	3.1	> Bot	4.95	12.4	92	0.05	15.0	3.26
		0.5	1.05	6.7	-		5.50	-				
6/11/87	Port Mouton	Surface	4.6	19.8	5.0	> Bot	4.95	8.7	90	0.05	0	0.30
6/13/87	Port Joli	Surface	3.9	-	4.3	0.6	4.25	8.6	-	0.10	6.0	1.10
6/13/87	Boyd's Cove (North)	Surface	0.5	-	3.5	0.7	3.95	8.7	-	0.01	12.0	1.60
6/13/87	Boyd's Cove (South)	Surface	0.5	-	-	0.7	4.65	8.4	-	0.02	15.0	1.30

macrophytes are also present, mainly along the shorelines. At Port Joli headpond, (*Drepanocladus fluitans*) is present near the shoreline in shallow water (< 0.5 m) along with ditchgrass (*Ruppia maritima*) and spike rush (*Eleocharis* sp.). The Boyd's Cove ponds have the greatest diversity of macrophytes with pondweed (*Potamogeton perfoliatus*), mares tail (*Hippurus vulgaris*) and bur-weed (*Sparganium* sp.) being the most common species present.

Phytoplankton collections revealed low abundance and few species, most of which were desmids of the type characteristic of brown-water systems, being most abundant. Planktonic diatoms were virtually absent, reflecting the low availability of silica.

Zooplankton, dip net and seine collections at the headponds contained animal species more characteristic of freshwater than marine systems. Zooplankton samples were dominated by cladocerans, rotifers, ostracods and aquatic insect larvae although some typically estuarine or brackish-water species, such as *Eurytemora affinis* and *Bosmina* sp. were also present. Larval stages of various copepods, both nauplii and copepodites, were abundant, indicating that these organisms probably go through their life cycle within the headponds. The major fish species present, none of which were very abundant, included three, four and nine-spined sticklebacks.

5.1.4.4.4 Functional Aspects

Because of the harsh nature of these environments, due primarily to the presence of sea salts in combination with a low pH and brown-waters, the headponds are relatively uninteresting from a functional point of view. Levels of production, for both plants and animals, are undoubtedly low. The main autochthonous inputs of organic matter are photosynthesis by phytoplankton and benthic macrophytes. Although the biomass of benthic macrophytes is high, the species present have characteristically low production rates. Phytoplankton biomass is low, due primarily to the low availability of nutrients and darkly stained water making conditions poor for photosynthesis, and its contribution to organic inputs is probably very small. The major allochthonous organic inputs entering through streams are most likely dissolved organic materials composed primarily of tannins and humic acids, both of which degrade very slowly. The dominant decomposers typical of systems of this sort are fungi and bacterial species that, although adapted to acid-bog conditions, have low metabolic rates. As a result, these systems are probably accumulating organic materials and will gradually become filled to succeed into heath-bog systems.

6. DISCUSSION

6.1 General Features of the Seaside Adjunct

The Seaside Adjunct contains a wide variety of marine and estuarine habitats within a limited area that has not been excessively modified by human activity. Many of the habitats, however, are in physically stressed environments, and therefore have poorly developed biological communities. The physical stresses include the low pH and high water colour of inner lakes caused by humic acids and tannins from the terrestrial environment, the unstable and mobile sands of intertidal flats and dunes, and the strong tidal currents that in places scour out deposited materials from tidal channels. All of these physical variables, however, are subject to change over time. The progressive rise in local sea level - now accelerating because of global greenhouse effects - slowly but persistently increases the role of oceanic waves and currents. Intermittent events, such as storms, undoubtedly play a disproportionate role in changing the nature and location of channels, causing breaches in the sea wall of the dunes, or relocating outflows from the basins. More predictable daily, seasonal and annual variations in tidal movements, wind strength and direction, and precipitation, however, also keep intertidal and subtidal deposits in a state of constant change and instability.

The degree of stability varies from habitat to habitat within the marine/estuarine complex of the Park. The innermost regions of the system, remote from oceanic influence, experience relatively benign conditions. Here, sediments are stabilized by slowly growing *Zostera* beds in subtidal situations, and occasionally by *Spartina*-dominated marshes in intertidal ones. Progressively less stable habitats are encountered as one approaches the truly marine environment, because of high currents and wave action, and the mobility of the predominant sandy substrate. In the absence of a rapidly-growing vegetation that can firmly bind the substrate under such conditions, biological communities of any diversity are unable to develop. Dominant animal species tend to be opportunistic or vagile : either colonizing during short periods of relative tranquility, or foraging over wide areas, including unstable habitats when access is possible.

Biological communities that do develop in such robust environmental conditions tend to be of low diversity, and are inclined to be fragile, subject to periodic elimination by natural processes or human activities. Consequently, such communities demand special consideration.

A feature of the Seaside Adjunct is that many diverse habitats, with their characteristic biotic associations, exist in close proximity to one another. The boundaries between habitats are often tightly compressed in space, affording an opportunity for direct comparison of the determinantal effects of physical processes on the biological community. Perhaps the most interesting setting, from the point of view of both abundance and diversity of habitat and species, is the area near the bridge at the junction between Basin Lake and Little Port Joli Basin. Strong tidal currents created by the narrow constriction between these two basins, combined with the abundance of rock surfaces for attachment, provide an exceptional environment for suspension feeders and algal macrophytes. Nearby subtidal mudflats, heavily colonized by benthic algae, provide an excellent habitat for deposit feeders. Common and abundant animals attached to or crawling over rocks and boulders include mussels, barnacles, sea anemones, gastropods, sea urchins, starfish and crabs. Subtidal mudflats harbour numerous gastropods and polychaetes. Fishes, particularly sticklebacks and pipefish, can also be commonly seen moving through the channel, foraging in the lush growth on the rocks, or on suspended material in the rapidly-moving water. Intertidally, a narrow band of saltmarsh occurs on one side of the bridge, and large boulders on the other, offering a sharp contrast in habitats and adding to the diversity of the immediate area. Organic materials, particularly detritus from the *Zostera* beds and attached algal macrophytes, accumulate on the shoreline, providing easily accessible habitat for wrack-inhabiting forms such as amphipods and brine flies.

The variety of habitats and communities represents one of the most appealing aspects of the lagoon system of the Seaside Adjunct. The contrasts evident between the extremely harsh environment of the intertidal sand flats, where large fluctuations in current velocity, temperature, and ice effects yield a poorly-developed biological community, and the relatively high productivity and diversity of *Zostera* beds, are readily observable. In terms of energy flow to the system, the *Zostera* community is undoubtedly of most importance.

6.2 Evaluation of the Marine Resources

6.2.1 Interpretive Value

Hunter and Associates (1987) summarized a number of interpretive opportunities that exist within the Adjunct, some of which involve the marine resources :

1. The marine encroachment of former terrestrial habitats. There is considerable evidence of this within the marine lagoons, where drowned but standing trees are common.

2. The pronounced ecological variation that occurs across the transition from the nearshore marine, through estuarine habitats, to the freshwater lakes (primarily St. Catherines Lake and Meadow Lake) immediately inland.

As indicated above, in the whole area of the Adjunct one encounters a wide variety of habitats and community types, often closely adjacent to one another. These habitats are illustrative of major landform types of both coastal regions (e.g., sand and cobble beaches, headlands, dunes, tidal sand and mud flats) and estuaries (e.g., saltmarshes and eelgrass communities, brackish and dystrophic habitats, etc.). The existence of such features, and the readily-observable processes that cause them, are of considerable heuristic value.

6.2.1.1 Sedimentation Processes

The dominant physical processes that influence patterns of sedimentation, from the scouring effects of strong tidal currents to the dramatic but intermittent effects of storms, are readily observable in the lagoons and intertidal areas. Sand waves and ripples, eroding and depositing areas are well represented. But sedimentation is not solely a physical phenomenon. Many of the organisms living within the lagoons are important either in stabilizing or destabilizing these sediments. *Zostera* is undoubtedly the most influential stabilising organism in the Seaside Adjunct : its stems and leaves reduce turbulence, inducing deposition of material carried by flooding waters, while its roots and rhizomes bind the sediments together, reducing erosion. This plant characteristically occupies the most persistent and stable of the subtidal habitats of the lagoons, which in fact the plant has helped to create. Saltmarsh plants function in a similar way in the intertidal zone. Algal-bacterial mats and slicks of benthic diatoms secrete complex polysaccharides that cement sand grains together, and tubicolous polychaetes use sand particles to create their parchment or stick-like tubes that equally reduce the susceptiblity of the sand flats to erosion.

Organisms that tend to destabilize sediments include those that feed at the sediment surface. Notable among these is the lugworm *Arenicola*, which ingests and then egests large quantities of sand that it strips of diatoms, bacteria and other organic food. Its large fecal coils can be readily seen in the intertidal zone as the tide recedes, but these rapidly disappear over the next flood tide, testifying to the susceptibility of these 'processed' particles to be moved by tidal currents. Burrowing organisms, such as the isopods, and deposit-feeding clams are other important destabilizing agents of intertidal sediments.

These physical-biological interactions are important, and readily demonstrable in the Seaside Adjunct lagoon system.

6.2.1.2 Nutrient Recycling

Most of the primary producers within the lagoons are benthic organisms for which obtaining nutrients is not usually a problem, particularly where extensive tidal flushing occurs. In some instances, however, nitrogen may become limiting where root zones are inadequately aerated, and anaerobic conditions prevail. This is particularly true of *Spartina* growing in poorly drained soils. Both *Spartina* and *Zostera* are thought to act as "nutrient pumps" bringing reduced, soluble phosphorus from sediments to the surface, and in the case of *Zostera* which is submerged, into the water column. *Zostera* is also known to fix elemental nitrogen, and there is some evidence that *Spartina* roots contain nitrogen-fixing bacteria (Patriquin and Knowles, 1972).

Benthic algae and macrophytic algae probably obtain most of their nutrients from the water column. Although nutrient concentrations in the water are low as a result of the very small terrestrial nutrient input in the area of the Adjunct, the rate of supply is high because of the tremendous tidal flushing.

Nutrient regeneration in these systems is probably primarily due to the activities of detritivores in association with bacteria growing on detritus particles, since most of the primary production of the system is channeled into the detritus portion of the food web.

6.2.1.3 Food Web Relationships

No attempt was made to determine experimentally the food web relationships within the biological communities present within the Seaside Adjunct. These relationships, however, may be readily inferred from studies elsewhere. Figures 22 to 26 illustrate the probable trophic relationships of the major communities identified within the system. These are derived in part from other studies relating to large expanses of a given community type, within which many organisms may spend their complete life cycle. In contrast, the different communities of the Adjunct lie in close proximity, so that there is extensive interchange between adjacent communities, in both species that may forage in more than one community, and in terms of organic exchange. This is evident in the mixtures of detritus derived from eel grass, algal macrophytes and saltmarsh plants that may be seen cast up in the drift line on beaches.

Saltmarsh, eelgrass and the major algal macrophytes are similar in that very little of the organic material produced is consumed directly by herbivores. Most of the production enters the food web in the form of detritus. Consequently, strict herbivores are relatively uncommon among the fauna of these systems. Exceptions may be the grazing of *Zostera* by Canada geese and of kelp by sea urchins. Since the lagoons are subject to onshore winds and dominated by flooding tidal currents that tend to move flotsam landward, most detritus probably remains within the basins, becoming stranded at high water levels along the shoreline. Material that is not mineralised before it is buried by sedimentation processes eventually may be converted to peat. *Spartina* is particularly resistent to decay and degradation because of the large proportion of the stem that is refractory organic material. In contrast, *Zostera* and the major seaweeds are degraded relatively rapidly. Much of this material is probably broken down by amphipods and other inhabitants of the shore drift zone, becoming more susceptible to resuspension or resolution, and thus entering the pelagic food web. Once within the pelagic zone it may be utilised there by particulate feeders, filtered

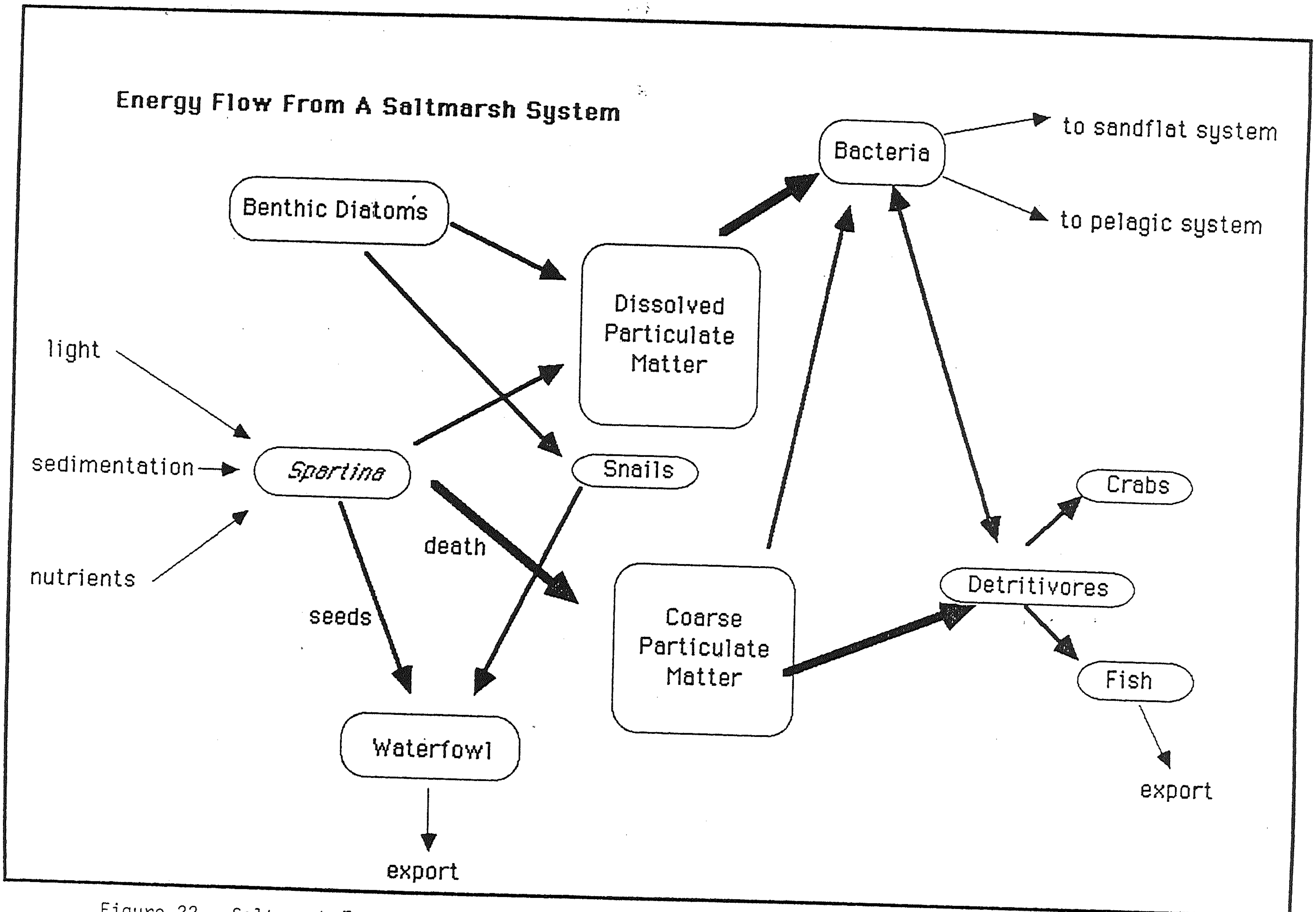

Figure 22. Saltmarsh Food Web

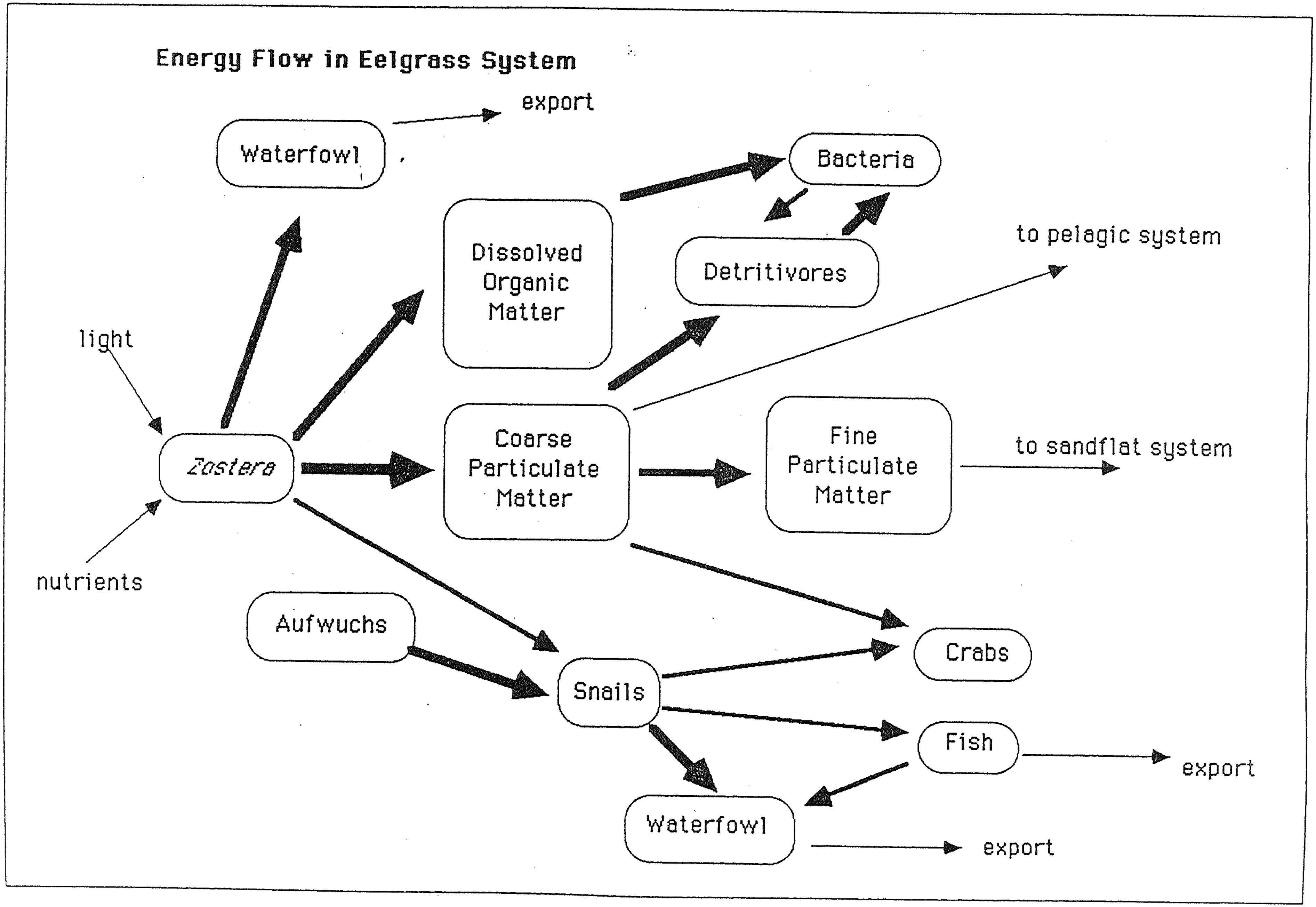

Figure 23. Eelgrass Food Web

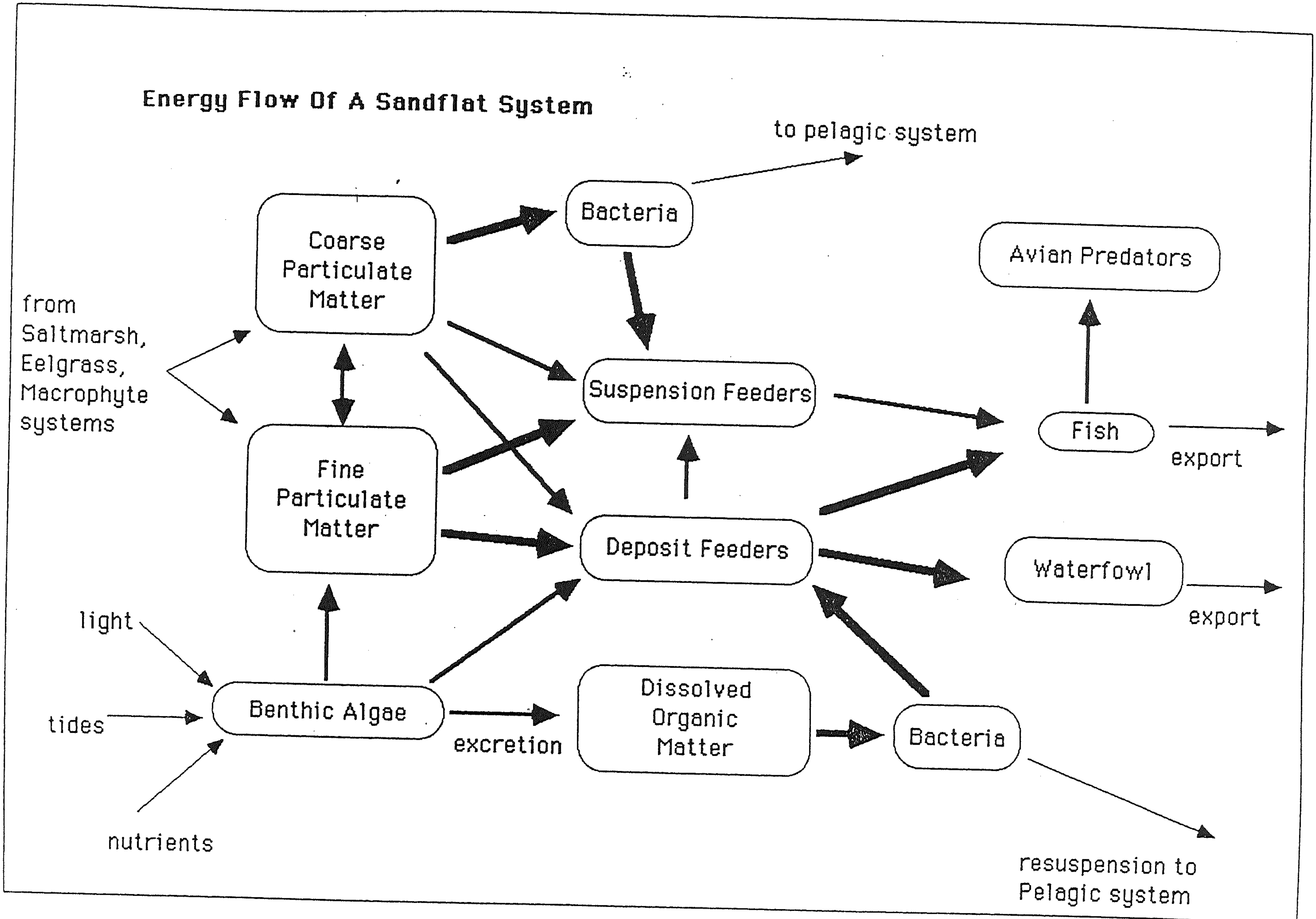

Figure 24. Intertidal Flat Food Web

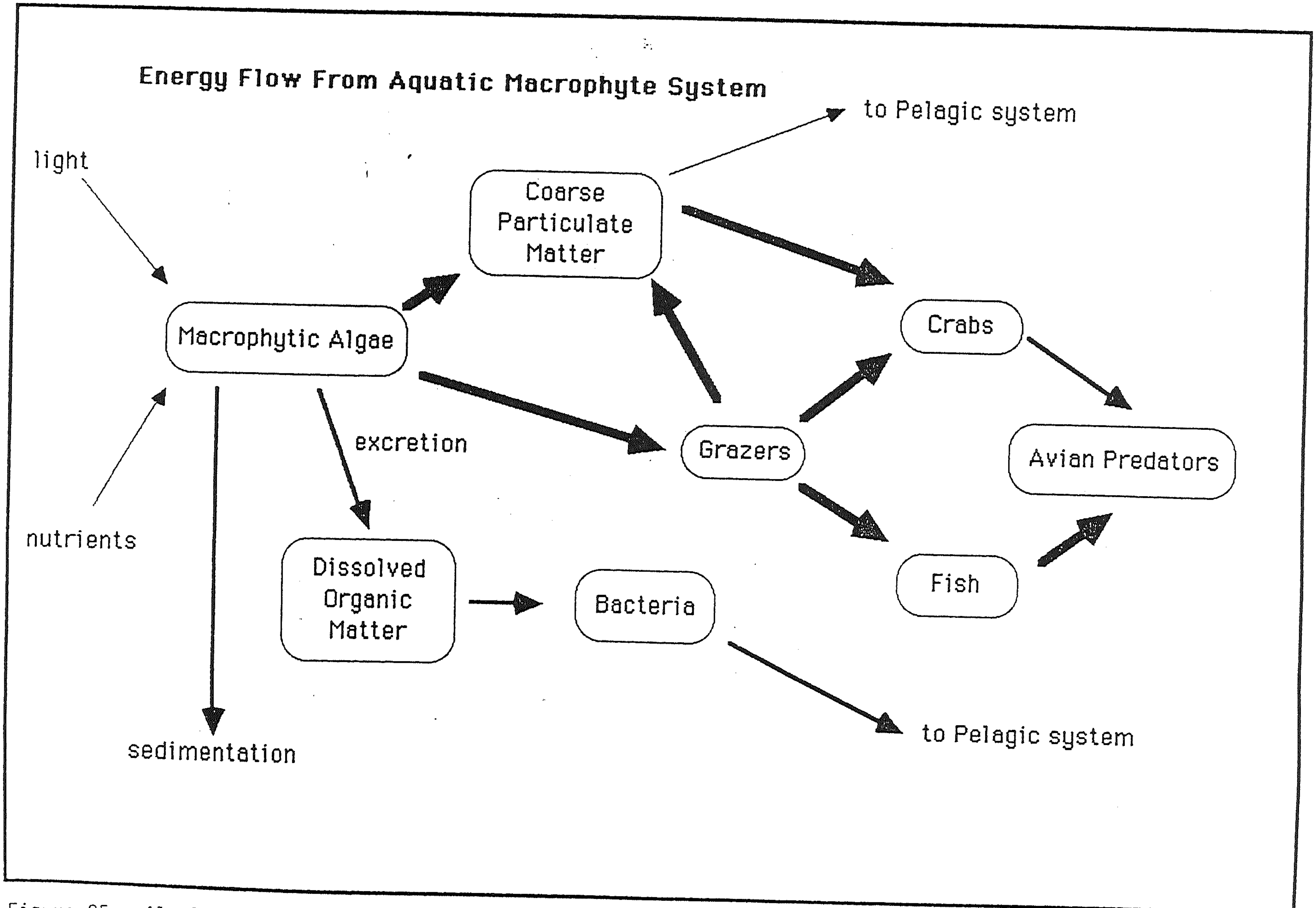

Figure 25. Algal Macrophyte Food Web

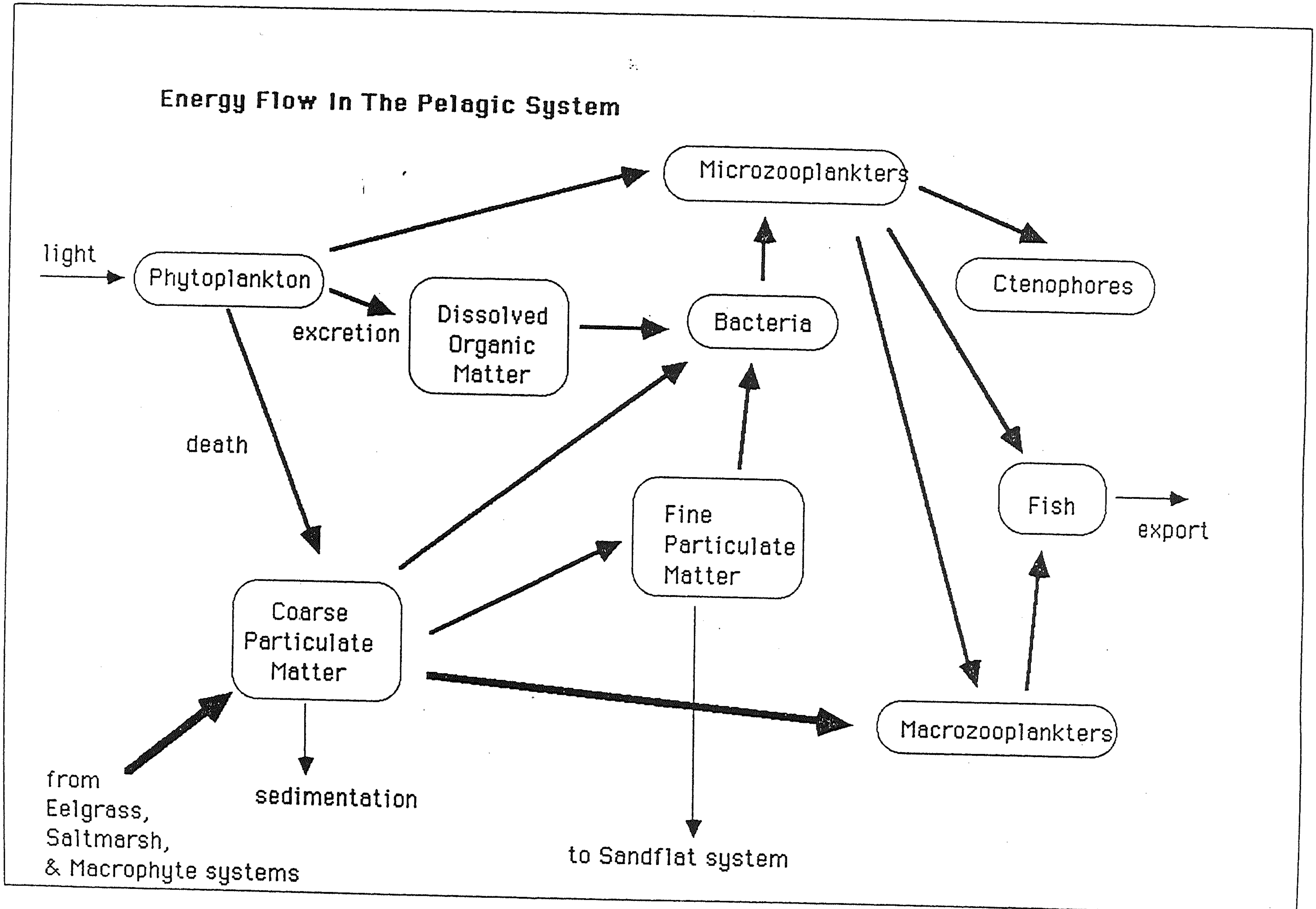

Figure 26. Pelagic Food Web

out by benthic suspension feeders, or redeposited for use by deposit feeders. In many cases, this process involves microbial colonization and growth on the detritus, and it is the bacteria and fungi themselves that form the primary food source for "detritivores". Some animals, however, including mysids and other shrimp, have been shown to harbour cellulolytic gut bacteria that allow the digestion of coarse detritus.

A considerable portion of these detrital materials is also converted into dissolved organic matter and thus becomes available for uptake by bacteria. The bacteria themselves subsequently are consumed by animals having the ability either to filter them from the water column, or harvest them from sediment deposits.

Within the *Zostera* community, a considerable number of organisms exist primarily on the **Aufwuchs** community. This epiphytic association of microscopic diatoms, green and blue-green algae, and microscopic animals is seen as a brownish-green furry growth over the surface of submersed macrophytes, and has been shown to be at least as productive as the *Zostera* plant itself. The often abundant Littorina seen on *Zostera* leaves is undoubtedly utilising this food source.

Many of the more mobile organisms living within the *Zostera* beds, such as mysids or crangonid shrimp, are important in moving materials between the eelgrass system and other systems (Rassmussen, 1973). These are extensively preyed upon by migratory fish and larger invertebrate predators such as crabs. In general, pelagic carnivores such as the fish, and the ctenophores and jellyfish common in Basin Lake, depend largely upon zooplankton. Benthic carnivores include the crabs and predatory polychaetes that eat other polychaetes, and the microscopic infauna of protozoans and nematodes that live interstitially between deposited sediment particles. In general, predatory organisms are relatively uncommon.

It does not seem likely that input of allochthonous organic matter represents an important energy source for the marine lagoon communities. Freshwater inputs are small in relation to tidal exchange, and we saw no significant amounts of organic drift material entering the basins from the offshore environment.

6.2.1.4 Ecological Significance

Although the area and systems of the Seaside Adjunct have an intrinsic educational value, they are probably not unique among south shore ecosystems in most respects. There is little indication that the lagoons play significant roles as nursery areas of commercially important fish. Our observations do not indicate that the saltmarsh and eelgrass systems of the Adjunct export organic carbon to an extent that would be of importance to coastal ecosystems, although this has been demonstrated in relation to a number of estuarine marshlands elsewhere. No species encountered during this study are unique to this area, or even notably more abundant, presumably because productivity is limited and the harsh environmental conditions are experienced in other neighbouring areas. Nonetheless, utilization of the lagoons and beaches of the system by waterfowl and other birds of great interest suggest that the ecological significance of the Seaside Adjunct may be higher than just indicated.

The sandy beaches harbour several nesting pairs of Piping plovers, a species that is on the Endangered Species List. Since access to these beaches is difficult at the present time, they may play a significant role in preserving the Nova Scotian population of this rare bird.

Canada geese and Black ducks use the saltmarshes of the Adjunct, as with other areas, during their spring and fall migrations. Black ducks also nest in the region, although evidence to date suggests relatively few broods are hatched within the confines of the Adjunct itself. Saltmarshes are utilized by Black ducks during summer and fall as both moulting and staging areas, the adults and young feeding on *Littorina*, *Hydrobia* and seeds of *Spartina alterniflora*. Canada geese arrive in large numbers during fall to feed on the abundant *Zostera* beds.

6.2.1.5 Harvestable Resources

Historically the Adjunct was a popular area for hunting, particularly of waterfowl and deer, but since the acquisition of the property by Environment Canada Parks, hunting has been disallowed. Softshell clam digging is the only harvest activity now allowed in the Adjunct and this is limited to non-commercial harvesting.

6.2.1.6 Recreational Values

The recreational potential of the Adjunct is well-known and considerable. The marine habitats are examples of relatively pristine marine environments, showing rather little influence from man's activities. This 'untouched' quality arises in part from the relative isolation of the marine systems. Access is and has always been rather difficult, although the natural attractiveness of the region would otherwise have been expected to induce a great deal of human utilization.

The beaches of the Adjunct are wild and spectacular, and include the largest such beach (St. Catherines River beach) along the south shore of Nova Scotia. Non-consumptive and non-deleterious activities that the beach complexes favour include walking, beach-combing, and wildlife watching. The great diversity of habitats is reflected in a diverse waterfowl association, including Canada geese, eider, scoter, Harlequin ducks, Piping plover, herons, and Arctic and Common terns. Ospreys nest in the vicinity and are to be seen hunting over the shallows. Otters and seals are also readily observable by the unintrusive watcher on the shore or in a small boat. Below the waterline, but still visible because of the clarity of the water, is a great variety of marine macrophytes.

The Adjunct provides a unique combination of features for the informed aesthete : the monotony of a physically stressed environment of sun, wind and sand, together with striking examples of marine diversity.

6.3 Limitations to Use

In contrast to these recreational opportunities, are some severe constraints upon the potential for development. As indicated in previous sections, the habitats of the Adjunct are characteristically fragile, and could easily be damaged by inappropriate activities. The sand dune - beach complexes are easily destroyed by excessive public use, yet the integrity of the outer dune systems are essential to maintenance of the character and features of all the marine habitats within the Adjunct. Consequently, only low impact recreational activities should be permitted in these areas.

In other ways, recreational activities are limited by safety considerations. Strong tidal currents preclude safe SCUBA diving and even boating in most areas of the Park. The complex channel systems, and rapid changes in their observable features as the tide changes, make unguided boating or walking occasionally hazardous. Furthermore, the local weather conditions change rapidly, with fog banks that roll in from offshore obscuring landform features within only minutes. Under these circumstances, even experienced boaters find themselves disoriented, unable to determine a true and safe course through the winding channels.

6.4 Conservation Issues

Because of their fragility, and their esential role in protecting enclosed basins, the sand dune systems of the Adjunct must be carefully protected. Without the seaward barrier of the dunes, the dynamic tidal sandflats within the Adjunct would be exposed to direct ocean influences, and would consequently suffer both from rising sea levels and intermittent storms that have great destructive force. The lagoons and wide expanse of sand flats would quickly disappear.

Saltmarshes also represent vulnerable habitat that could not tolerate much human interference. Although the contributory role of the saltmarshes in providing organic matter to support animal populations in the intertidal and subtidal zones could not be evaluated during this short study, it has been shown elsewhere that such a role is important. Consequently, the integrity of these narrow fringing marshes needs to be preserved as far as possible.

Of special significance is the few pairs of Piping plovers that nest on beaches within the complex. This species is extremely limited in distribution in Nova Scotia, and human activities on other beaches threatens to reduce the number of birds even more. For this reason also, maintenance of the beach complex must be of highest priority.

6.5 Management Issues

In addition to the requirements for conservation and preservation of critical habitats, management plans must include the currently exploited clam population within the adjunct. Overexploitation of soft-shelled clams is occurring elsewhere, and, with the growth of public interest in marine foods such as clams and mussels, the potential exists for unacceptable impact upon the population of the Adjunct. A sound management plan must be based upon periodic investigation of age structure and density in each of the exploited beds. Such plans should incorporate regular monitoring activities.

6.6 Monitoring Requirements

Continued re-evaluation of the marine resources of the Adjunct, particularly those being exploited, requires periodic monitoring of intrinsically important parameters. These should include, as indicated above, age structure and density of clams, and the current programme of monitoring Piping plover nesting pairs.

Water quality aspects, however, must also be systematically monitored at several sites within the Adjunct. Currently, the marine and estuarine waters of the Park are relatively clean, but the continued growth of Port Joli and Port Mouton represent changes that must be carefully watched. The proximity of these two centres to the inlets of the Adjunct suggest a significant likelihood that pollution, both industrial and residential, could compromise the water quality of the Park. Bacteriological assays should be carried out at frequent and regular intervals, because of the established existence of pollution in the region of Port Mouton, particularly (Menon, 1985; Vanotterloo *et al.*, 1974).

A potential problem exists with regard to paralytic **shellfish poisoning** of the soft-shell clams in the Adjunct. PSP contamination has been recorded in nearby inlets and harbours, and although no positive record yet exists for the Adjunct (Belliveau, 1987), a monitoring programme involving bioassay of clams taken from the flats during summer should be instituted. The possibility that public users of the Adjunct might collect clams for private consumption during their stay in the Park makes this recommendation most important.

6.7 Future Research

Although numerous suggestions can be made with regard to further studies on the marine systems of the Adjunct, two items stand out because of their obvious importance to interpretation and recreational use of the marine lagoons. Perhaps the most important, because of its strong influence on physiography and hence the marine habitats and communities, concerns information on sedimentary characteristics and processes occurring within and outside the lagoons. It is obvious that the integrity of the lagoon is dependent on the protection afforded by the adjacent headlands and beach-dune complexes, and that the sedimentation processes occurring within the lagoon are very dynamic. Evaluation and documentation of changes that have occurred in the past, as well as monitoring present and future changes, would provide a basis for interpretation of the natural evolution of these systems. This information is necessary to distinguish changes occurring as a result of natural evolutionary processes from those brought about by increased recreational activities. An evaluation of past changes should be possible through an analysis of historical aerial photography, and monitoring of present and future changes could be accomplished by field measurements at selected sites together with aerial surveys over short time intervals.

Another item that should be studied further concerns the tidal nature of the lagoons. As indicated earlier, the morphology of the lagoons is complex and there is considerable difference between the tide times and heights occurring within the lagoons and that predicted by tide tables for Port Mouton. Since a good deal of the recreational potential of the Adjunct involves either exploring the marine systems or harvesting soft-shell clams, it is important that visitors have reliable information on tide states in order to plan the times of their visits. This information could be easily obtained by installing a series of tidal gauges at appropriate locations in the basins and comparing the data obtained with tidal predictions for Port Mouton.

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8. GLOSSARY OF TERMS

allochthonous - arising in another biotope

aufwuchs - organisms attached or clinging to stems and leaves of rooted plants or other surfaces projecting above the bottom

autochthonous - arising in the biotope under consideration

benthos - organisms attached or resting on the bottom or living in the bottom sediments

detritus - non-living organic material

development of volume - a morphometric parameter of a water body calculated as the ratio of mean to maximum depth

dystrophic - a trophic condition characterized by brown-water and high humus content (literally means badly nourished)

epifauna - organisms living on the surface of the bottom, either attached or moving freely

epiphytes - plants that are not rooted in the bottom but rather use other sustrates without penetrating into them

euphotic zone - that part of a water body that contains sufficient solar radiation to allow net growth of plants (generally assumed to be that portion of the water column containing an amount of solar radiation equal to or greater than 1% of surface light intensity)

extinction coefficient - a calculated value which reflects the rate at which solar energy is attenuated as it passes through a body of water. The vertical extinction coefficient is calculated as follows:

$$\text{ext. coeff} = \frac{\ln Io - \ln Iz}{z}$$

where $\ln Io$ and $\ln Iz$ is the natural logarithm of percent light transmission at the surface and depth z respectively and z is depth in meters.

holoplankton - planktonic organisms that spend their active life cycle in the plankton community

infauna - organisms that dig into the bottom substrate or construct tubes or burrows

littoral - the shoreward region of a body of water

macrophytes - large plants; marine macrophytes include higher plants such as *Ruppia* and *Zostera* as well as algae such as *Fucus* and *Laminaria*

meroplankton - organisms that spend only part of their life cycle (usually the larval stage) in the plankton community

nekton - organisms of the pelagic community that are capable of moving about independently of water movements

neuston - organisms that live at the air-water interface

pelagic - the region of free water in aquatic systems

plankton - the community of the free water consisting of organisms that have limited ability to move independent of water movements

phytoplankton - the plant portion of the plankton

relative depth - a morphometric parameter of a water body that describes the maximum depth as a percentage of the mean depth. It is calculated as follows:

$$\text{relative depth} = \frac{50\ Zm\ \sqrt{\pi}}{\sqrt{Ao}}$$

where Zm = maximum depth
Ao = surface area

shoreline development - a morphometric parameter of a water body calculated as the ratio of the length of the shoreline to the length of the circumference of a circle of equal area to that of the water body:

$$\text{shoreline development} = \frac{L}{2\sqrt{\pi\ Ao}}$$

where L = shoreline length
Ao = surface area

zooplankton - the animal portion of the plankton

9. APPENDICES

Appendix A.

Results of Analyses of Specimen Collections

Appendix A.1 List of samples/organisms collected along St. Catherines River Basin Transect

Sample No.: T1
Location: St. Catherines River Basin, Transect Station 1
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
    Chiridotea coeca (12)

Sample No.: T1-b
Location: St. Catherines River Basin, Transect Station 1
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
    Polychaete (unidentified) (1)

Sample No.: T1-c
Location: St. Catherines River Basin, Transect Station 1
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
    No specimens collected

Sample No.: T2
Location: St. Catherines River Basin, Transect Station 2
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
    Beach fleas (Family Talitridae) (1)
    Ophelia limacina (19)

Sample No.: T3
Location: St. Catherines River Basin, Transect Station 3
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
    Chiridotea coeca (7)
    Nereis sp. (2)
    Etone flava (1)
    Polychaetes (unidentified) (3)

Sample No.: T4
Location: St. Catherines River Basin, Transect Station 4
Date: June 12, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
    Chiridotea coeca (1)
    Insect larvae (unidentified) (1)

Sample No. T5
Location: St. Catherines River Basin, Transect Station 5
Date: June 12, 1987
Type of sample: Beach Seine
Specimens collected:

- Chiridotea coeca (14)
- Carcinus maenus (1)
- Pleurobrachia pileus
- Gammarus lawrencianus
- Gammarus oceanicus
- Idotea balthica (20)
- Pungitius pungitius (2)
- Gasterosteus aculeatus
- Apeltes quadracus

Appendix A.2 List of samples/organisms collected along Little Port Joli Basin Transect

Sample No.: T1
Location: Little Port Joli Basin, Transect Station 1
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
No specimens collected

Sample No.: T1-b
Location: Little Port Joli Basin, Transect Station 1
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
Specimens collected:
Beach fleas (Family Talitridae) (abundant)

Sample No.: T2
Location: Little Port Joli Basin, Transect Station 2
Date: June 9, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
Chiridotea coeca (1)
Lacuna vincta (1)
Polydora ligni (abundant)
Nereis sp. (abundant)
Polychaete (unidentified capitellid)
Polychaete (unidentified) (1)

Sample No.: T2-b
Location: Little Port Joli Basin, Transect Station 2
Date: June 9, 1987
Type of sample: Hand Collection
Specimens collected:
Mya arenaria (common)

Sample No.: T3
Location: Little Port Joli Basin, Transect Station 3
Date: June 9, 1987
Type of sample: Hand Collection
Specimens collected:
Jaera marina
Littorina littorea
Mytilus edulis

Sample No.: T4
Location: Little Port Joli Basin, Transect Station 4
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
Specimens collected:
Jaera marina (1)
Chiridotea coeca (2)
Littorina littorea (common)
Mytilus edulis (common)
Gemma gemma

Lacuna vincta
Nereis virens (abundant)
Nereis succinea
Polydora ligni (abundant)
Polychaete (unidentified)

Sample No.: T6
Location: Little Port Joli Basin, Transect Station 6
Date: June 9, 1987
Type of sample: Benthic Core (2 10 cm X 10 cm samples combined)
Specimens collected:
Chiridotea coeca (2)
Gemma gemma (6)
Nereis virens (5)
Spio setosa (1)
Polychaete (unidentified) (1)

Sample No.: T7
Location: Little Port Joli Basin, Transect Station 7
Date: June 9, 1987
Type of sample: Shrimp Net Collection
Specimens collected:
Crangon septemspinosa (11)
Chiridotea coeca (23)
Littorina littorea
Gemma gemma (1)
Idotea balthica (1)
Gammarus lawrencianus (45)
Gammarus oceanicus (1)
Unidentified Sticklebacks (2)

Sample No.: T8
Location: Little Port Joli Basin, Transect Station 8
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
Specimens collected:
Chiridotea coeca (4)

Sample No.: T9
Location: Little Port Joli Basin, Transect Station 9
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
No specimens collected

Sample No.: T10
Location: Little Port Joli Basin, Transect Station 10
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
Specimens collected:
Chiridotea coeca (1)
Nereis virens /Nereis succinea (abundant)
Polydora ligni (abundant)
Hydrobia minuta
Mya arenaria (7)

Sample No.: T11
Location: Little Port Joli Basin, Transect Station 11
Date: June 9, 1987
Type of sample: Benthic Core (10 cm X 10 cm)
No specimens collected

Sample No.: T12
Location: Little Port Joli Basin, Transect Station 12
Date: June 9, 1987
Type of sample: Hand Collection
Specimens collected:
Gemma gemma
Hydrobia minuta
Unidentified salt water mite

Sample No.: T13
Location: Little Port Joli Basin, Transect Station 13
Date: June 9, 1987
Type of sample: Hand Collection
Specimens collected:
Mytilus edulis
Carcinus maenus
Littorina littorea
Fundulus heteroclitus

Sample No.: T14
Location: Little Port Joli Basin, Transect Station 14
Date: June 9, 1987
Type of sample: Shrimp Net Collection
Specimens collected:
Fundulus heteroclitus (2)
Gasterosteus aculeatus (1)
Apeltes quadracus (1)
Argulus sp. (1)

Sample No.: T15
Location: Little Port Joli Basin, Transect Station 15
Date: June 9, 1987
Type of sample: Hand Collection
Specimens collected:
Nereis sp.
Polydora ligni
Nicomache lumbricalis (common)
Polychaetes (unidentified)

Sample No.: T15-b
Location: Little Port Joli Basin, Transect Station 15
Date: June 9, 1987
Type of sample: Shrimp Net Collection
Specimens collected:
Crangon septemspinosa (2)
Carcinus maenus (5)
Cancer irroratus (1)

Appendix A.3 List of samples/organisms collected by seine, benthic, or hand collection methods at St. Catherines River Basin

Sample No.: A'
Location: St. Catherines River Basin, exposed sandflat
Date: June 11, 1987
Type of Sample: Benthic Box Core (2 10 cm by 10 cm samples combined)
Specimens Collected:
- Chiridotea coeca (abundant)

Sample No.: B'
Location: St. Catherines River Basin, main channel
Date: June 11, 1987
Type of Sample: Beach Seine
Specimens Collected:
- Crangon septemspinosa (8)
- Idotea balthica (2)
- Ammodytes americanus (94)
- Gasteroteus aculeatus (1)

Sample No.: C'
Location: St. Catherines River Basin, salt marsh pool
Date: June 11, 1987
Type of Sample: Beach Seine
Specimens Collected:
- Carcinus maenas (7)
- Fundulus heteroclitus (64)
- Pungitius pungitius (4)
- Myoxocephalus aeneus (1)
- Gasterosteus wheatlandi (19)
- Gasterosteus aculeatus (16)

Sample No.: D'
Location: St. Catherines River Basin, eelgrass beds
Date: June 11, 1987
Type of Sample: Hand Collection
Specimens Collected:
- Littorina littorea (abundant)

Sample No.: E'
Location: St. Catherines River Basin, seaweed beds
Date: June 11, 1987
Type of Sample: Hand Collection
Specimens Collected:
- Asterias vulgaris
- Strongylocentrotus droebachiensis
- Idotea balthica (abundant)
- Jaera marina
- Gammarus oceanicus (abundant)
- Gammarus lawrencianus
- Gammarellus angulosus
- Jassa fulcata
- Lacuna vincta

Appendix A.4 List of samples/organisms collected by seine, benthic, or hand collection methods at Little Port Joli Basin

Sample No.: A
Location: Basin Lake, mudflat
Date: June 9, 1987
Type of Sample: Benthic grab
Specimens Collected:
- Carcinus maenas (2)
- Littorina littorea (3)
- Acmaea testudinalis (1)
- Nereis virens/Nereis succinea (14)

Sample No.: C
Location: Basin Lake, eelgrass bed
Date: June 8, 1987
Type of Sample: Shrimp Net Collection
Specimens Collected:
- Carcinus maenas (2)
- Littorina littorea
- Crangon septemspinosa (abundant)
- Idotea balthica (26)
- Gammarus oceanicus (2)
- Mysis stenolepis (abundant)
- Praunus flexuosus (abundant)
- Aurelia aurita (1)
- Gasterosteus aculeatus (18)

Sample No.: D
Location: Little Port Joli Basin
Date: June 10, 1987
Type of Sample: Beach Seine
Specimens Collected:
- Pleurobrachia pileus (93)
- Mytilus edulis (1)
- Gasterosteus aculeatus (4)
- Gasterosteus wheatlandi (10)
- Urophycis regius (1)

Sample No.: D-2
Location: Little Port Joli Basin
Date: June 10, 1987
Type of Sample: Beach seine
Specimens Collected:
- Strongylocentrotus droebachiensis (1)
- Carcinus maenas (6)
- Crangon septemspinosa (abundant)
- Idotea balthica (5)
- Idotea phosphorea (1)
- Chiridotea coeca (5)
- Gammarus lawrencianus (6)
- Gammarus oceanicus (2)
- Neomysis americana (1)
- Praunus flexuosus (13)

Modiolus modiolus
Doto coronata
Electra pilosa
Gastropod (unidentified)
Amphipod (unidentified)

Littorina littorea (3)
Mytilus edulis (5)
Gasterosteus aculeatus (2)
Gasterosteus wheatlandi (1)
Urophycis regius (4)
Ammodytes americanus (117)
Pseudopleuronectes americanus (3)
Clupea harengus (43)
Syngnathus fuscus (1)
Myoxocephalus aeneus (2)
Pollachius virens (4)

Sample No.: E
Location: Little Port Joli Basin, salt marsh edge
Date: June 10, 1987
Type of Sample: Hand Collection
Specimens Collected:
Gammarus lawrencianus (abundant)
Ophelia limacina (6)
Jaera marina (1)
Anomia aculeata (1)

Sample No.: E-2
Location: Little Port Joli Basin, salt marsh pool
Date: June 10, 1987
Type of Sample: Beach Seine
Specimens Collected:
Carcinus maenas (11)
Crangon septemspinosa (abundant)
Scyphozoan (unidentified) (1)
Gasterosteus aculeatus (4)
Gasterosteus wheatlandi (1)
Fundulus heteroclitus (27)
Anguilla rostrata (3)
Pungitius pungitius (12)

Sample No.: E-3
Location: Little Port Joli Basin, mudflat
Date: June 10, 1987
Type of Sample: Benthic Box Core (several combined)
Specimens Collected:
Arenicola marina (7)
Nereis virens (14)
Nepthys caeca
Mya arenaria (2)
Carcinus maenas (1)
Gammarus lawrencianus

Sample No.: F
Location: Little Port Joli Basin, channel
Date: June 10, 1987
Type of Sample: Beach Seine
Specimens Collected:
Crangon septemspinosa
Pleurobrachia pileus

Gasterosteus aculeatus (1)
Gasterosteus wheatlandi (10)
Urophycis regius (12)
Pollachius virens (1)

Appendix A.5 List of samples/organisms collected in headponds

Sample No.: PM-1
Location: Port Mouton Headpond
Date: June 11, 1987
Type of Sample: Horizontal Zooplankton Tow
Specimens Collected:

- Copepod Nauplii (153)
- Copepodites (59)
- *Eurytemora affinis* (3)
- Harpacticoids (numerous unidentified species) (56)
- Gastropod eggs (10)
- Ostracods (64)
- Hemiptera (water boatmen) (2)

Sample No.: PM-2
Location: Port Mouton Headpond
Date: June 11, 1987
Type of Sample: Dipnet Collection
Specimens Collected:

- Hemiptera (water boatmen) (abundant)
- Harpacticoids (numerous unidentified species)
- Ostracods (3)
- Insect larvae (unidentified)

Sample No.: PM-3
Location: Port Mouton Headpond
Date: June 11, 1987
Type of Sample: Shrimp Net Collection
Specimens Collected:

- *Gasterosteus aculeatus* (13)
- *Apeltes quadracus* (12)

Sample No.: BC-1
Location: Boyd's Cove Headponds
Date: June 13, 1987
Type of Sample: Horizontal Zooplankton Tow
Specimens Collected:

- Harpacticoids (numerous unidentified species) (100)
- Ostracods (1)
- *Bosmina* sp. (9)
- Cladocerans (unidentified) (16)

Sample No.: BC-2
Location: Boyd's Cove Headponds
Date: June 13, 1987
Type of Sample: Beach Seine
Specimens Collected:

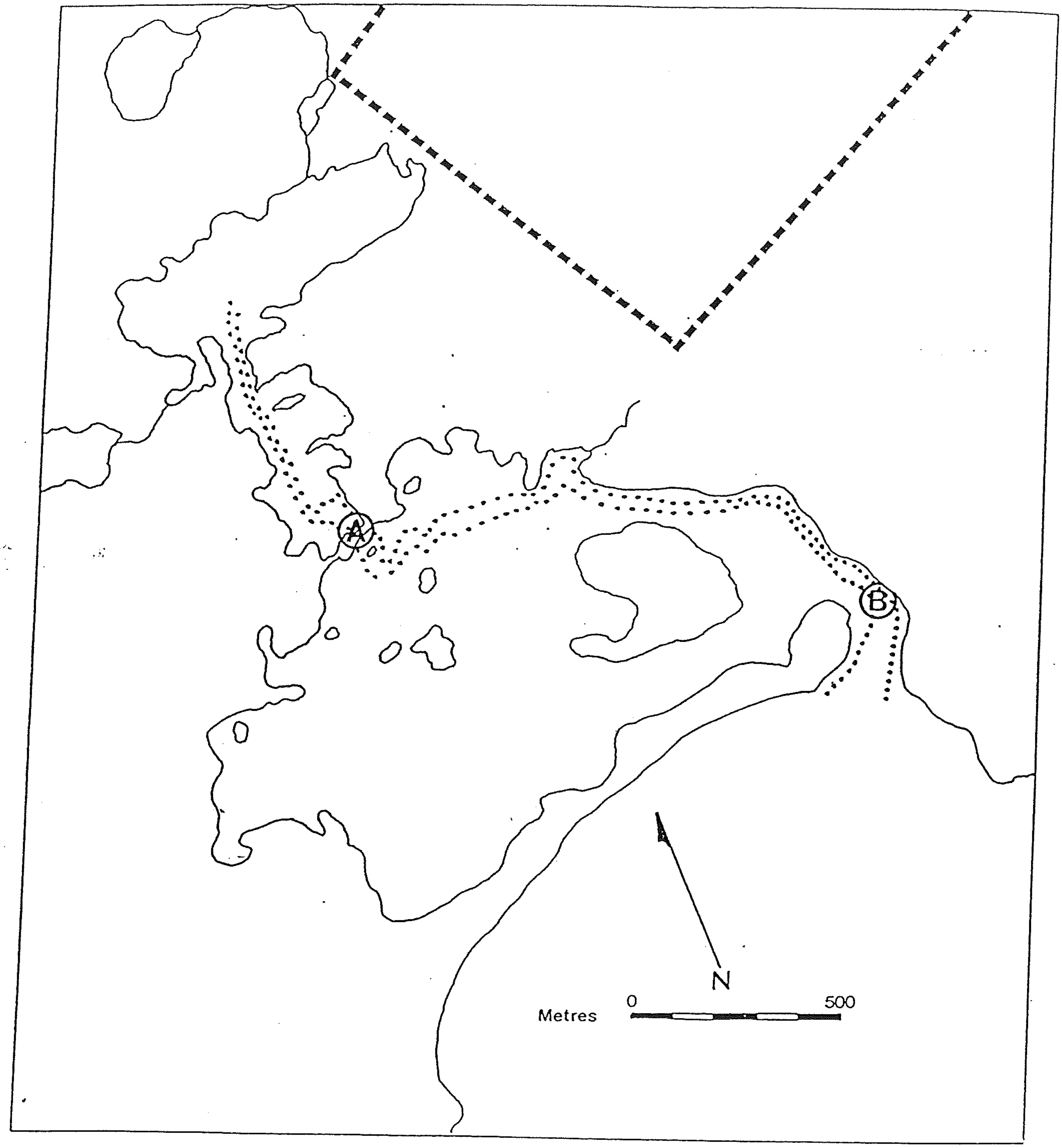
- *Pungitius pungitius* (5)
- Caddisfly larvae (8)
- Odonata naiad (1)

Sample No.: PJ-1
Location: Port Joli Headpond
Date: June 13, 1987
Type of Sample: Beach Seine
Specimens Collected:

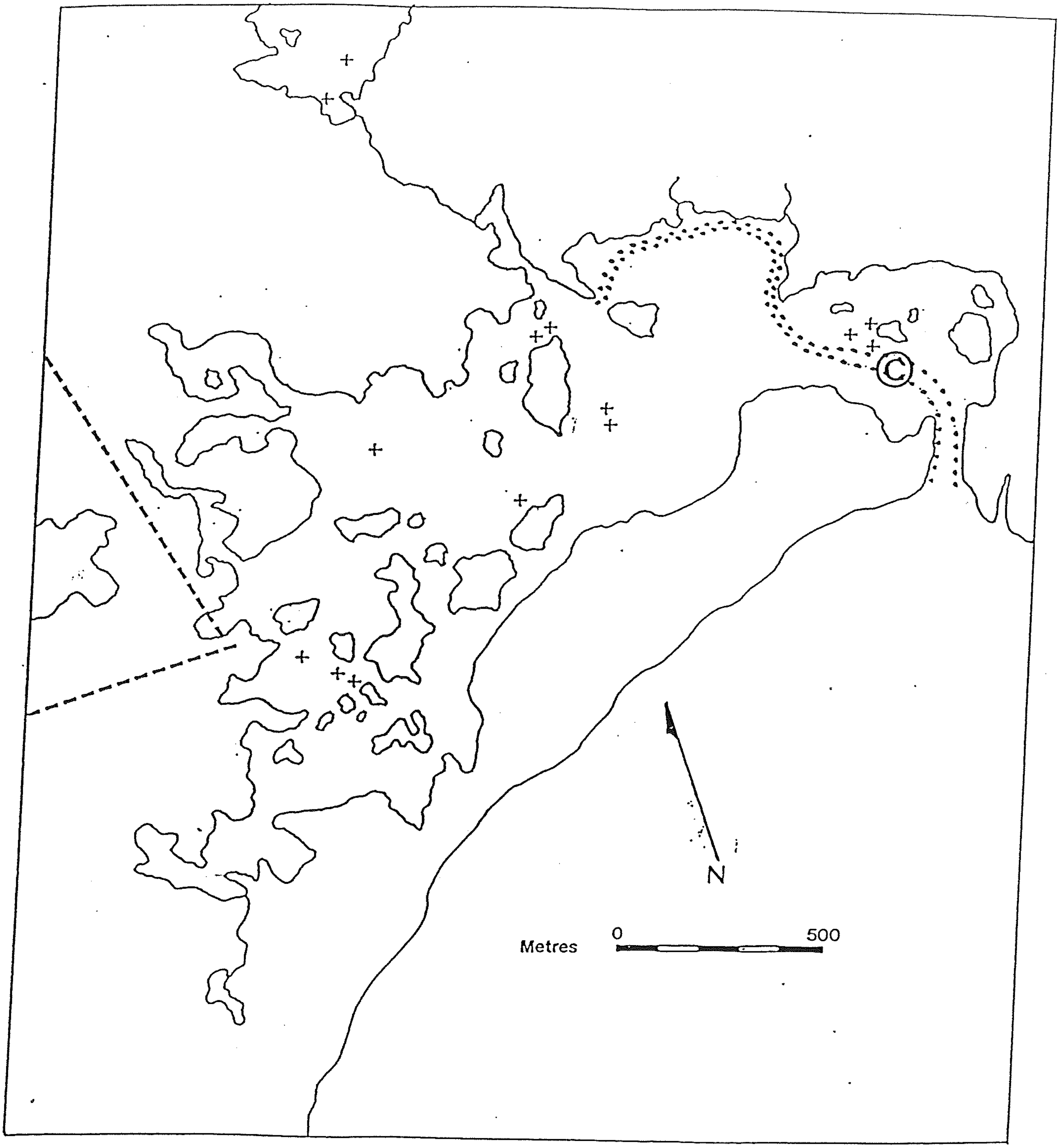
- Pungitius pungitius (21)
- Apeltes quadracus (8)
- Fundulus heteroclitus (38)
- Tadpoles (unidentified) (30)

Appendix B.

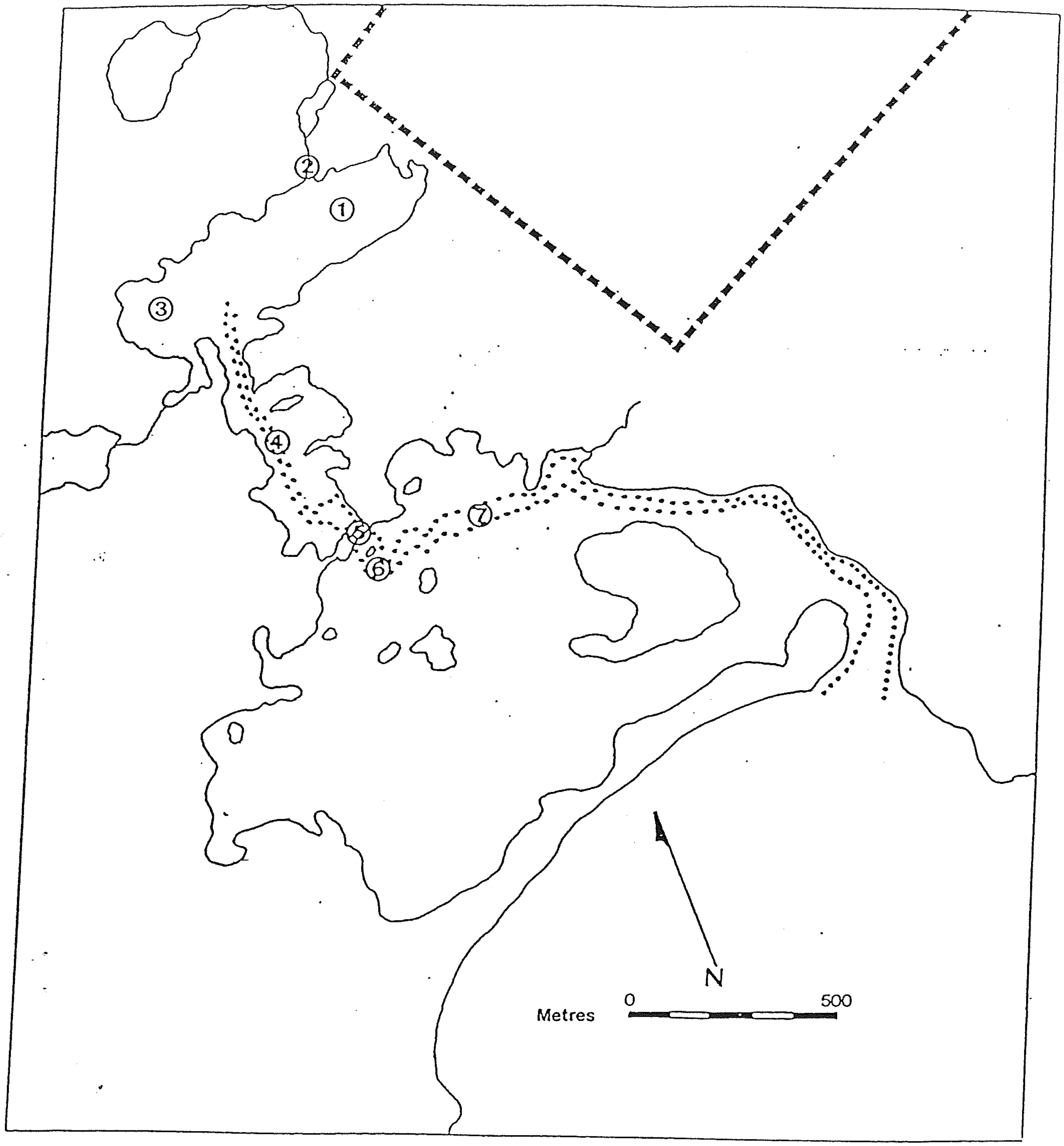
Location of Sample Stations, Anchor Stations and Transects for Little Port Joli and St. Catherines River Basins



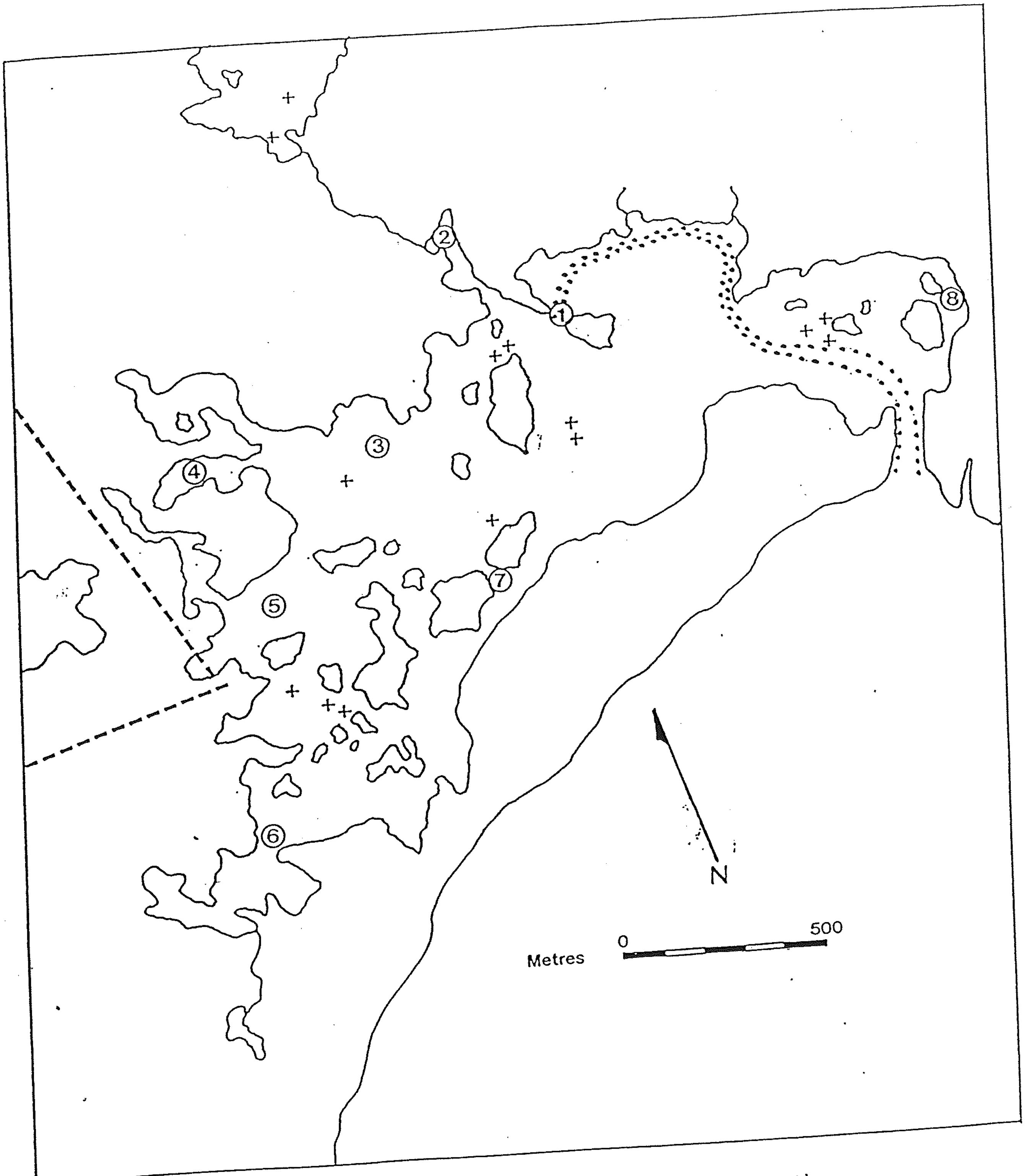
Anchor Station (A and B) locations at Little Port Joli Basin



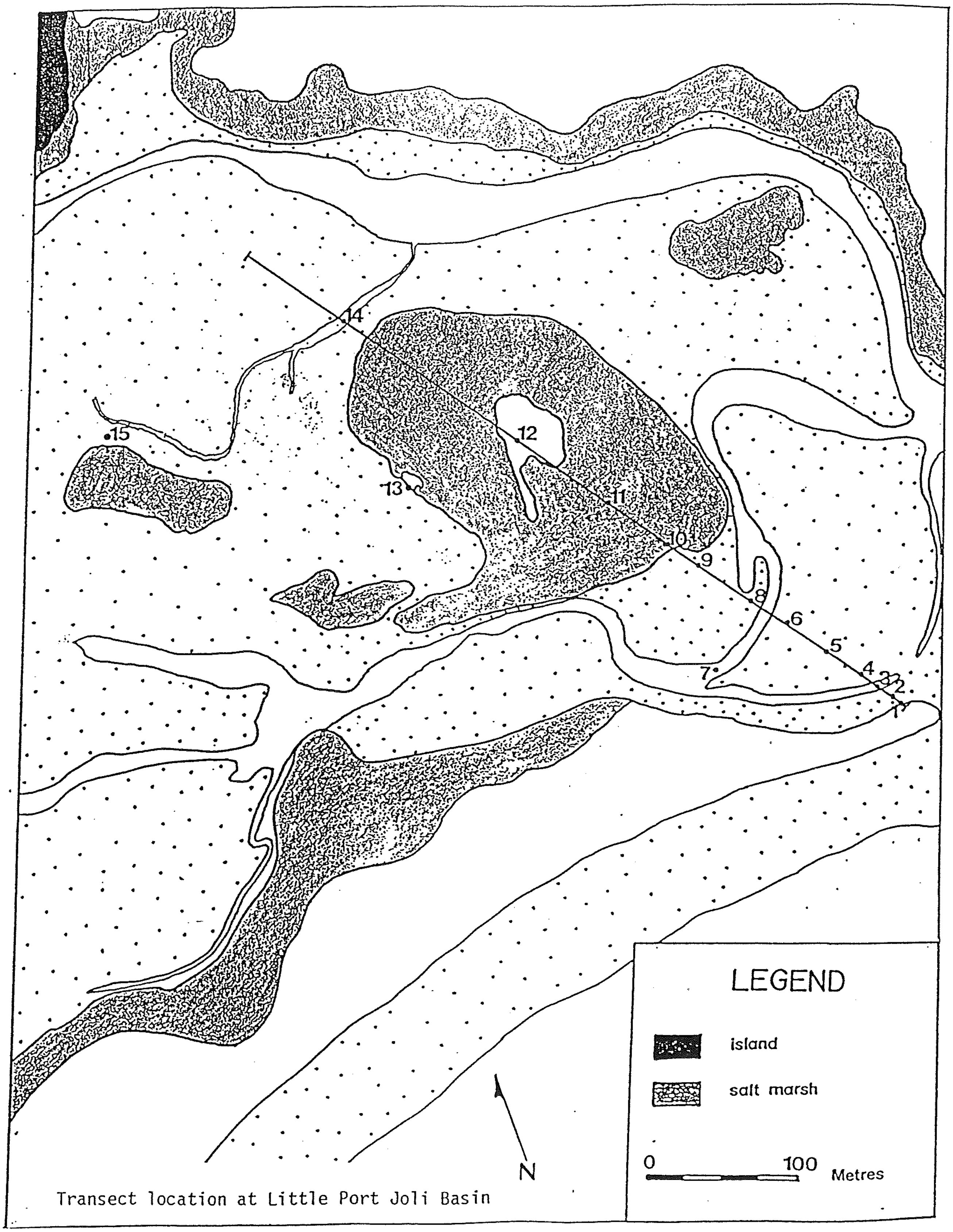
Anchor Station (C) location at St. Catherines River Basin



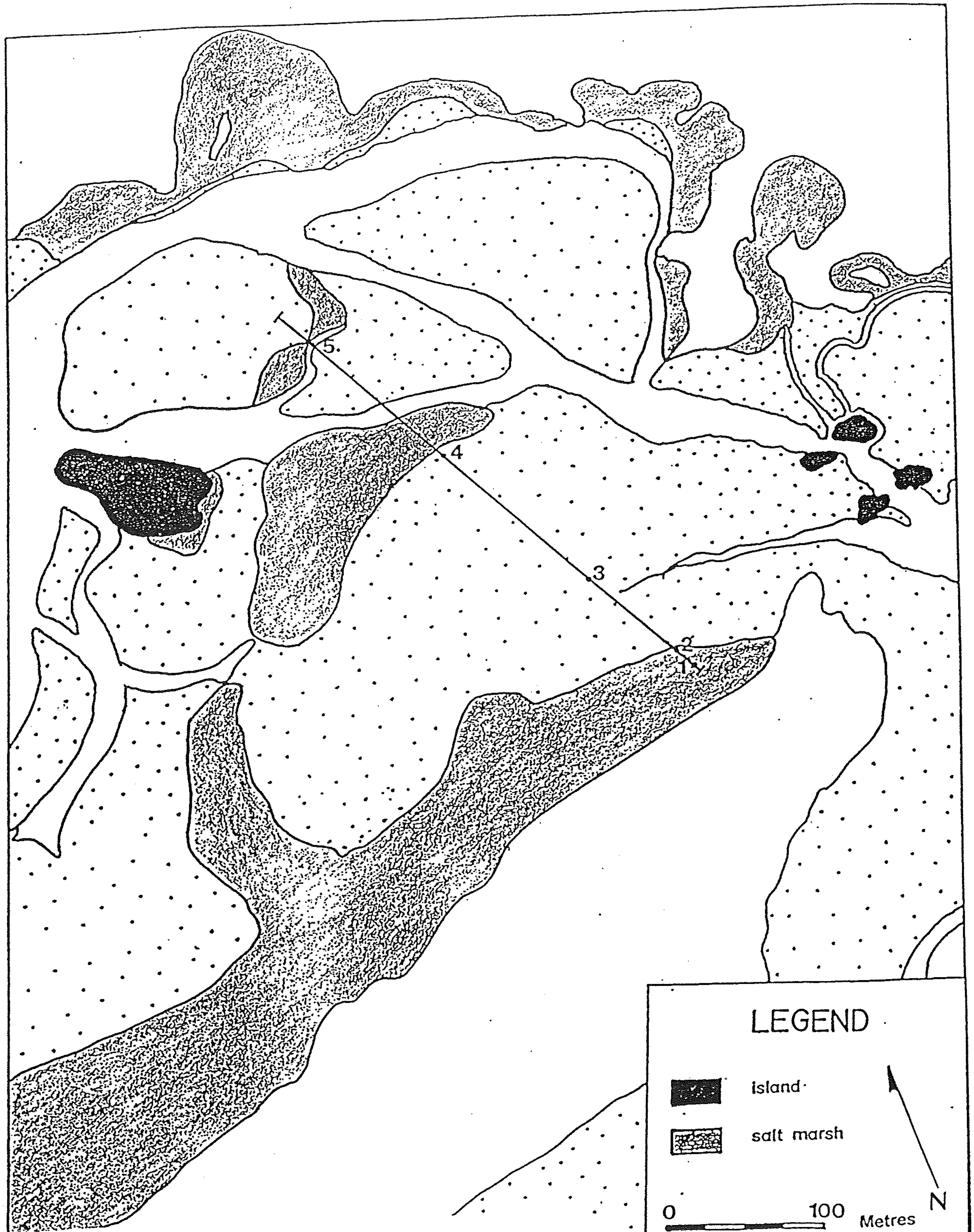
Sample locations at Little Port Joli Basin (October, 1986)



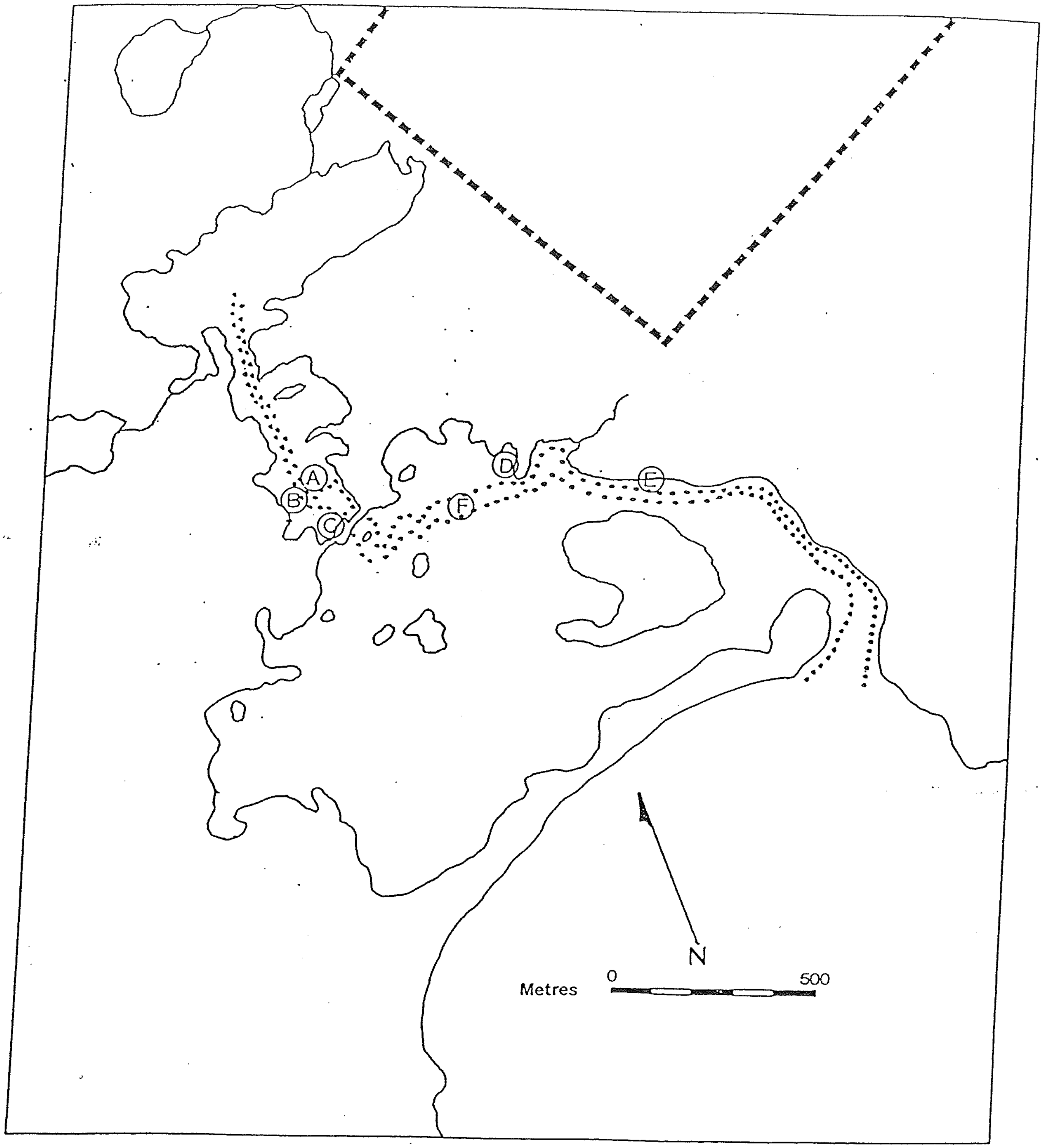
Sample locations at St. Catherines River Basin (October, 1986)



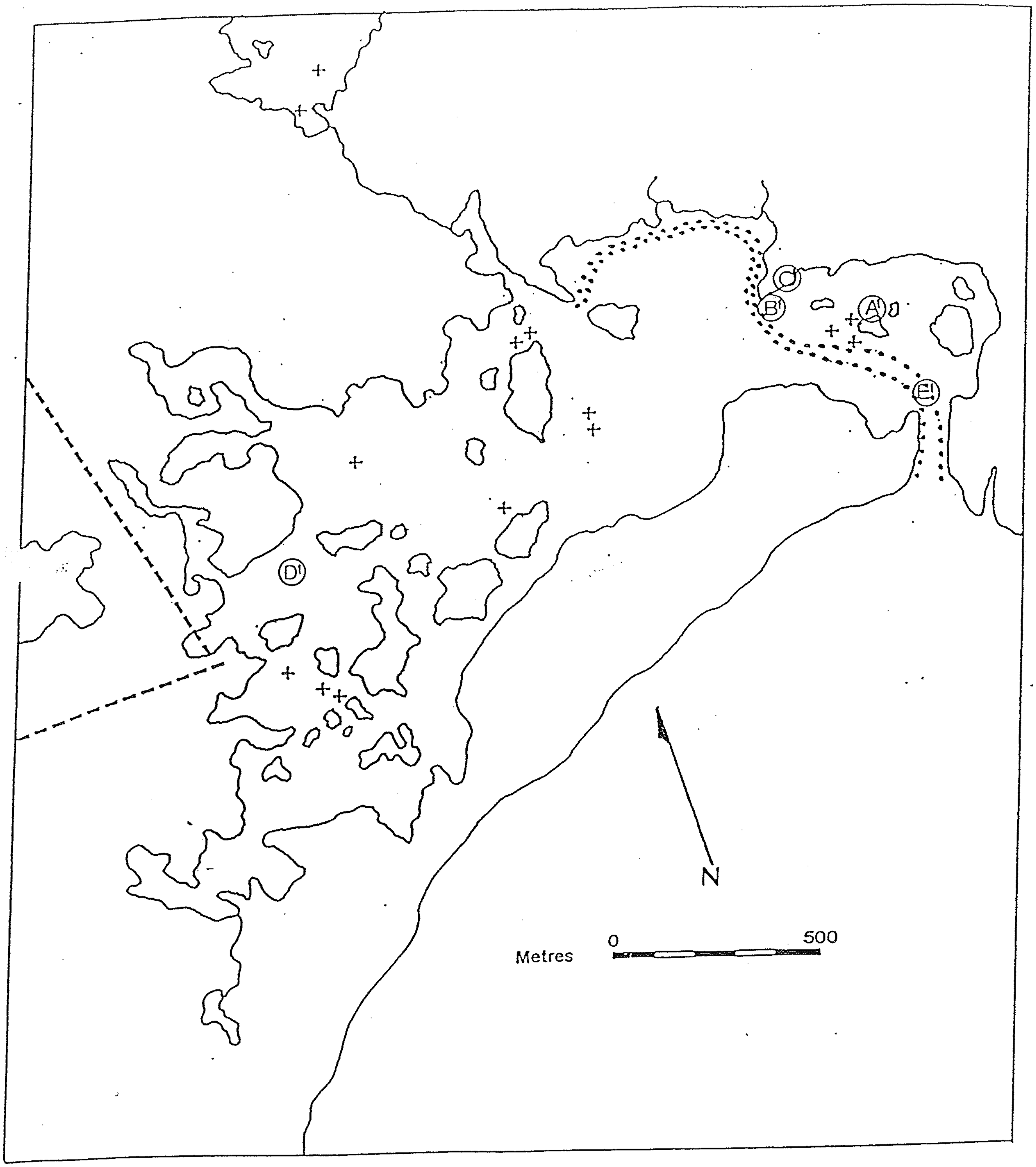
Transect location at Little Port Joli Basin



Transect location at St. Catherines River Basin



Station locations of assorted seine, benthic, hand collections at Little Port Joli Basin (June, 1987)



tation locations of assorted seine, benthic, hand collections at St, Catherines River Basin (June, 1987)