MARINE ENHANCEMENT OPTIONS FOR THE NORTH SHORE OF PRINCE EDWARD ISLAND

DALE CONROY

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Marine Enhancement Options for the North Shore of Prince Edward Island

By

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Abstract
Marine Habitat Enhancement projects have been conducted in the southern Gulf of St. Lawrence for the last fifty years. In recent years, habitat enhancement has been required as a compensation measure for the loss of habitat due to marine or coastal destruction. The compensation has been required by Fisheries and Oceans Canada under Section 35 of the *Federal Fisheries Act*. The policy for managing compensation prefers enhancement to be conducted in 'like for like' habitat, in the same ecological unit. This research includes information from local fish harvesters from coastal communities along Cascumpec and Tracadie Bays along the north shore, non-government organizations, and provincial and federal agencies. Suitable enhancement practices for Tracadie Bay include salt marsh creation and sea lettuce abatement. Suitable enhancement practices for Cascumpec Bay include shellfish enhancement in the upper estuaries, salt marsh creation, and sea lettuce abatement. Beach nourishment for sedimentation abatement in the inner estuaries was not a viable option for either Tracadie or Cascumpec Bay. The stable barrier dune system along Tracadie Bay is within Prince Edward Island National Park. At Cascumpec Bay, the barrier dune system was considered to be too unstable, making the enhancement efforts a major gamble. Socio-economically, salt marsh enhancement and sea lettuce abatement were the two most beneficial options, as they would help enhance the commercial and recreational fisheries in both areas.

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1. Introduction

Throughout the world, the loss of coastal ecosystems is a major problem. Estuaries have suffered the brunt of the degradation as they have been subject to environmental and human activity. Impacts have included habitat loss and degradation, pollution, eutrophication, changes in freshwater tributaries or tidal patterns, loss of fish and shellfish habitats and populations, problems with invasive species, and changes in the overall marine community structure (Beck *et al.* 2003). To mitigate for the loss of fish habitat, Fisheries and Oceans Canada (DFO) has implemented the Federal *Fisheries Act,* which prohibits the destruction of fish habitat. Under the Federal *Fisheries Act* (Section 34), "fish habitats" are defined as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life process". Section 34(2) further defines "fish" to include all stages: "shellfish, crustaceans, marine animals, the eggs, sperm, spawn, spat and the juvenile stages of fish and marine plants" (DFO 1998; House of Commons of Canada 1985).

Marine Habitat Compensation Measures (MHCM) are required whenever fish habitat is altered, disrupted and/or destroyed (HADD). The fish and fish habitat protection provisions of the Federal *Fisheries Act* provide mechanisms which allow development of projects to occur while providing for the protection of fish and fish habitat. Section 35 of the *Act* prohibits the harmful alteration, disruption or destruction of fish habitat. These include projects in or near the marine environment that could possibly harm fish habitats, (either by chemical, physical or biological means) thereby potentially undermining economic employment and other benefits that flow from Canada's fisheries resources (DFO 1986).

Since the mid 1990s on the east coast of Canada, the Habitat Management Branch (HMB) of DFO has been making determinations for compensation purposes concerning all projects and activities (both large and small) in or near the marine environment. Under section 35(2) of the *Fisheries Act*, HMB can authorize fish habitat alteration, disruption or destruction for a specific marine project, if there are no other viable alternatives (e.g. relocation, redesigning or mitigation of the project). When authorization is given for HADD to occur, it then becomes necessary for some type of marine habitat compensation. Marine habitat compensation becomes part of the authorization for HADD by HMB. The marine habitat compensation measure that is authorized is required to meet DFO-HMB Habitat Policy the guiding principle of "No Net Loss" (NNL) in the productive capacity of fish habitat (DFO 2002).

Prince Edward Island (PEI) had a total population of 138,100 in 2005 (Statistics Canada 2005) and a total area of 5660 km^2. The Mi'kmaq name for the island, 'Abegweit', translates as 'land cradled on the waves'. The economy of the island is geared to agriculture (especially of potatoes), tourism, and fisheries. In coastal communities, HADD thus represents socio-economic losses as well as ecological damage, lessening the quality of life for residents. Consequently, fishery-dependent communities have substantial stakes in habitat enhancement, particularly for commercial species.

1.1 Objectives

The objectives of this research are:

- to identify viable enhancement ideas through interviewing local fish harvesters and environmental groups;
- to analyse enhancement ideas that could be beneficial to the local environment, that could have a positive effect on the coastal marine environment;
- to evaluate the ideas revealed through the interview process and determine if they could possibly be implemented in the estuaries and bays along the north shore of PEI; and,
- to consider options that are socio-economically beneficial for the local community and PEI.

The two areas that were looked at for this research project were chosen for two reasons:

1) DFO-Small Craft Harbour (SCH) could possibly be conducting work within these harbours in the near future that may require MHCM; and
2) The two localities represent different types of coastal and estuarine environments that together are representative of those found along the entire north shore of PEI.

1.2 Location of Study Areas

The two areas selected for study were Tracadie Bay and Cascumpec Bay, along the north shore of PEI (Fig. 1.1). Tracadie Bay is approximately 25 km northeast of Charlottetown, adjacent to PEI National Park. Cascumpec Bay is approximately 200 km west of Charlottetown, south of North Cape. Both areas have very large fishing ports, and both estuaries are used extensively by commercial shellfish harvesters. Tracadie Bay is predominantly

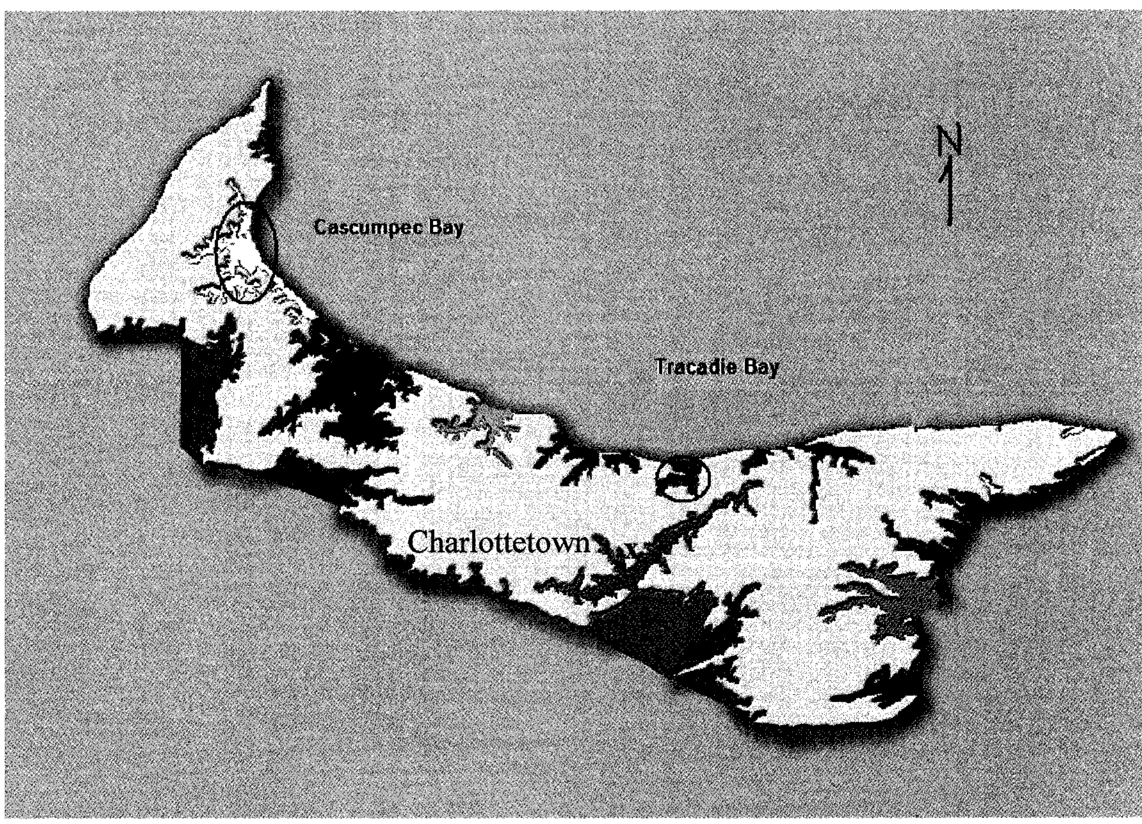

Figure 1.1 - Prince Edward Island showing the location of Tracadie Bay watershed and the Cascumpec Bay watershed and a black "x" designating Charlottetown. Map courtesy of Jacques Whitford Limited, Charlottetown, PEI.

used for blue mussel (*Mytilus edulis*) aquaculture, and has only one main tributary. In contrast, Cascumpec Bay has minimal aquaculture within the main bay, but oyster (*Crassostrea virginica*) aquaculture occurs in most of the multiple tributaries. As well, both areas had fish harvesters and local environmental groups that were very willing to participate in the research project to consider and suggest enhancement ideas.

1.2.1 Tracadie Harbour

Tracadie Harbour is located on the central north shore of PEI, approximately 25 km north of Charlottetown (46° 25' 00" N, 63° 02' 00" W) (Fig. 1.2). It is one of the major commercial fishing harbours in Queens County, providing a full range of services for the commercial fishing fleet. The harbour serves lobster (*Homarus americanus*), shellfish and ground fisheries, with the lobster and mussel fisheries being the most prominent. There is a home fleet of 19 lobster vessels and 28 mussel handling vessels that use the facility for the landing and unloading of fish from early April to freeze up in the fall (November/December). In addition, Tracadie Harbour is home to one of the largest mussel-processing center on PEI's North Shore. In addition to the locally-landed product from Tracadie Bay, mussels from Covehead, Malpeque, Savage Harbour and Stanley Bridge are regularly brought by truck to be processed.

The nearest community to Tracadie Harbour is Grand Tracadie, with a population of 1,536 in 2001 (Statistics Canada 2005). The land area of Grand Tracadie is approximately 78 km^2, and the population density is 19.6 people/km^2. Grand Tracadie was settled by the French in the early 1700's due to the rich cod fishing grounds located directly off shore. The entire community would dry and salt the cod and ship it to Louisbourg or France (Grand Tracadie GrassRoots Committee 2000).

The Tracadie area has diversified from strictly a fishing community to include both agriculture and aquaculture. Currently there are approximately 45 aquaculture leases within the Tracadie and Winter Bay watershed, after aquaculture began in 1986 (Shaw 1998). The distribution of land in the Tracadie Bay watershed is 38% cleared, 41% forested, 12% estuary, 5% ponds and 4% marsh. The Winter River watershed is 53% cleared, 44% forested, 1% ponds, 1% marsh and 1% estuary (EC and PEIDEFW 1990a).

Highway 6 follows the western side of the bay and crosses over the Winter River estuary by the Corran Ban Bridge (Fig. 1.2). The bridge, which separates the upper estuary and Winter Bay, was built in 1972, and is the only bridge adjacent to Tracadie Bay. There are some smaller bridges upstream in the freshwater section of the Winter River. Route 219 follows the south and east sides of the bay. The terrain is low-lying rolling hills, with short river systems and relief of less than 50 m. Agriculture occurs mostly between the highways and the coast, with potatoes being the major crop in the area. In the late 1970's to the 1990's a majority of the coastal areas were transformed from farmland to cottage developments causing an influx of tourists and cottagers to the area for the summer months.

Figure 1.2 - Ortho-rectified aerial photos of Tracadie Harbour in relation to Tracadie Bay, Winter Bay and the Winter River. (Photos courtesy of the Prince Edward Island Department of Environment Energy and Forestry (PEIDEEF) Orthomap Nos. 111, 112, 113, 118, 119 and 120).

1.2.2 North Port Harbour

North Port (Alberton) Harbour is located on Cascumpec Bay, PEI, approximately 130 km west of Charlottetown (46° 47' 59" N, 64° 2' 60") (Fig. 1.3). North Port is a major commercial fishing harbour, providing a full range of services for the commercial fishing fleet. The harbour serves the lobster, shellfisheries and ground fisheries, with the lobster being the most prominent. There is a home fleet of 82 vessels that use the facility for the landing and unloading of fish from early April to freeze up in the fall (November/December) (personal communication, Robert Leard, North Port Harbour Authority).

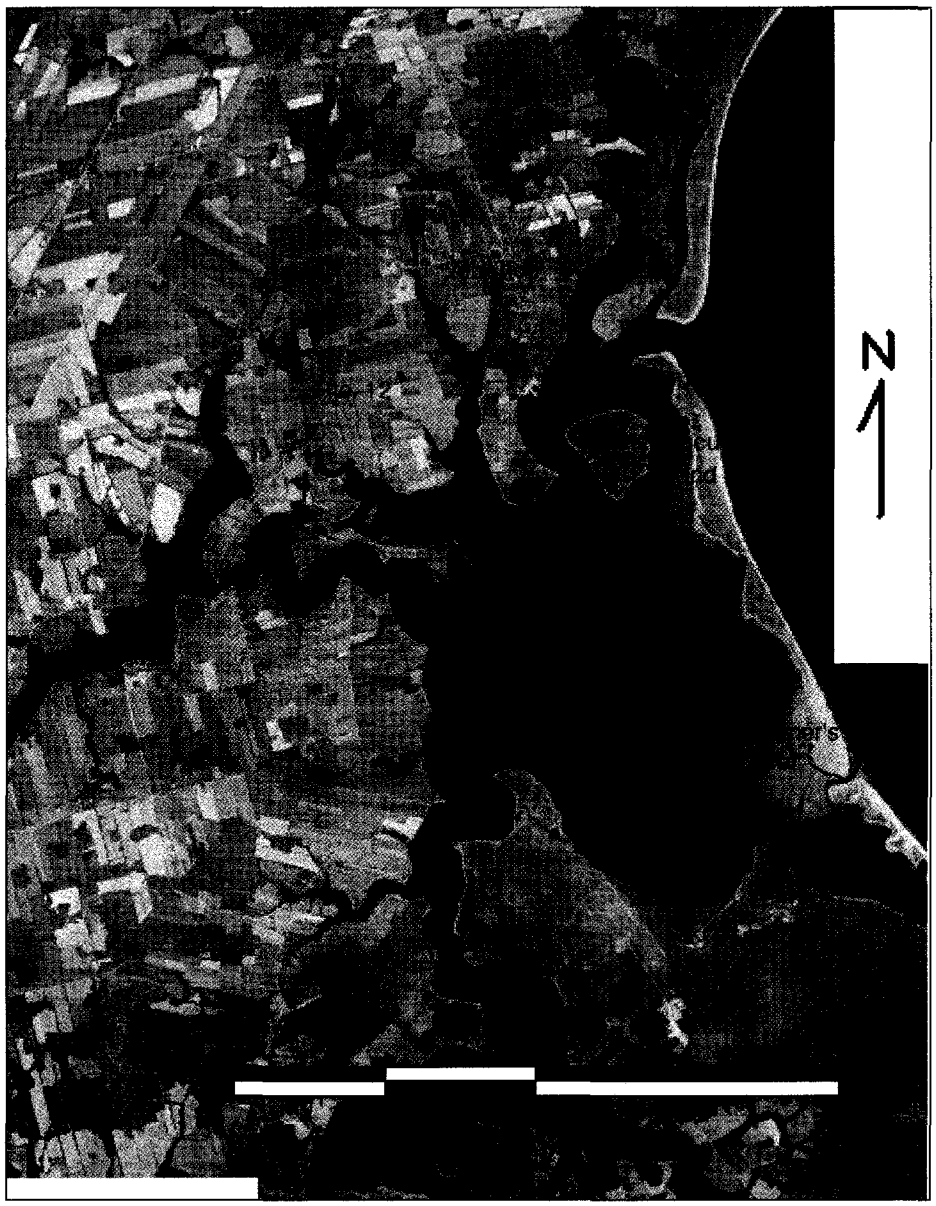

Figure 1.3 - Ortho-rectified aerial photos of Northport Harbour area in relation to the Cascumpec Watershed. (Photo courtesy of the PEIDEEF Orthomap Nos. 017, 018, 019, 030, 031, 032, 033 and 034).

The nearest community to North Port Harbour is Alberton, with a population of 1,115 in 2001 (Statistics Canada 2005). The land area of Alberton is approximately 4.5 km^2 giving a population density of 247 people/km^2. Alberton is a small town, in contrast to the dispersed rural community of Grand Tracadie. Highway 12, which runs through the entire Cascumpec watershed, extends from east of the Trout River westward over the Trout River and Mill River, through Alberton, and across the Kildare River towards North Cape (Fig. 1.3).

There are three large bridges along Highway 12, spanning the Trout River (Goffs Bridge, built in 1960 and rebuilt in summer 2005), the Mill River (Cascumpec Bridge, built in 1969) and the Kildare River (Kildare bridge or causeway, rebuilt in 1987). These bridges have been in place for more than 40 years and have become part of the landscape. In addition, there are number of smaller roads, bridges and causeways built throughout the watershed. According to EC and PEIDEFW (1990b), there are at least 51 structures that are over 1.2 m in length where a road intersects a river or stream within the Trout River and Mill River watersheds alone. As is most of PEI, the terrain is low lying rolling hills, with short river systems and relief of less than 50 m. The Mill and Trout River watersheds are 49% cleared, 37% forested, 6% estuary, 4% marsh and 1% pond (EC and PEIDEFW 1990b).

As in the Tracadie area, agriculture occurs mostly between the highways and the coast, with potatoes being the major crop. The majority of the coastal areas around Cascumpec Bay have been transformed from farmland to cottage developments, causing a high influx of tourists and cottagers to the area for the summer months.

1.3 Physiography and Bedrock Geology

PEI lies within the Maritime Plain of Atlantic Canada (Bostock 1970 and Graf 1989), and is characterized by planar to gently rolling topography, with many flat plains. Relief is extremely limited with the highest point on the island located in the southeast near Caledonia at 142 m above sea level (asl). The northern coastal region is generally lower than the southeastern part of the island, with a maximum relief of approximately 60 m. Most of the topography is the result of post-glacial downcutting by the numerous small streams (many now diminished in volume or diverted due to agricultural activity) that developed on the terrain following deglaciation. The absence of major river valleys and other significant topographic features inland has resulted in the gently undulating landscape characteristic of much of PEI.

The bedrock geology that underlies PEI is part of the PEI Group, ranging in age from the late Pennsylvanian Stephanian epoch to late Early Permian, and decreasing in age from south to north (van de Poll 1989). The PEI Group consists of five largely undeformed and non-resistant sedimentary redbed formations (Miminigash, Egmont Bay, Kildare Capes, Hillsborough River and Orby Head formations, listed from oldest to youngest). The Miminigash and Egmont Bay formations formed during the Stephanian epoch, and the Kildare Cape, Hillsborough River and Orby Head formations are late Early Permian. All five formations are composed of cyclic fining upward redbed strata, ranging from pebble conglomerate to fine mudstone (van de Poll 1989), with the rocks generally dipping to the north.

The Orby Head Formation underlies the central northern and northeastern part of the Island extending from Profitts Point in the west to East Point in the east (van de Poll 1989). Conglomerate and coarse to medium sandstone of the Orby Head Formation crops out around Tracadie Bay.

The Cascumpec Bay area is underlain by the Kildare Capes Formation, which extends from North Point in the west to south of Souris at the eastern end of PEI (van de Poll 1989). The Kildare Capes Formation is made up of fine sandstone and siltstone, has a low resistance to weathering and erosion and is mainly obscured by surficial deposits in low lying coastal and inland regions, including the Cascumpec Bay area.

1.4 Quaternary history and sediments

PEI was ice-covered during the last major glacial period in Eastern North America, with several advances recorded from ca. 110,000 BP (OIS 5d) to the conclusion of the Late Wisconsinan (OIS 2) glaciation (Prest 1973; Grant 1989; Stea *et al.* 1992, 1998, 2005; Stea 1994; Catto 1998; Catto *et al.* 2005). The first advance (OIS 5d-OIS 4) involved eastward-northeastward ice movement from mainland New Brunswick that covered all of PEI. During OIS 2, PEI was initially glaciated by ice ca. 20,000 BP from the Escuminac Ice Centre (Rampton *et al.* 1984), moving southward from the area now submerged by the Gulf of St.

Lawrence. A subsequent phase of ice movement involved northward flow from Nova Scotia, crossing eastern PEI and diverging through northern Northumberland Strait around western PEI (Catto *et al.* 2005). Ice cover persisted over Cascumpec Bay until ca. 12.5 ka (conclusion of the Younger Dryas Collins Pond Phase, Stea *et al.* 1998, 2005) and over Tracadie Bay until ca. 12 ka.

Sandy glacial till covers the bedrock strata in the Cascumpec Bay watershed (Prest 1973). There are some areas of clayey-sand till and clayey-silt phase till near the western end of the Mill River and near Alberton. In addition, there are some areas of loose, stony to bouldery sand till at the western end of the Mill River with glaciofluvial and glaciolacustrine deposits and a small area of exposed bedrock (Prest 1973). The surficial deposits surrounding the Foxley River are a mix of sandy till, glaciomarine and early postglacial marine deposits (sand with minor amounts of silts and clays), bedrock, and postglacial deposits including salt marshes, peatlands, swamps and bogs (Prest 1973). The Trout River area is covered by sandy till with some clayey-sand clayey-silt till near the western end of the river, with exposed bedrock, sand glaciofluvial and glaciolacustrine deposits, and post glacial saltmarshes (Prest 1973). The Kildare River area is covered with sandy till, with small areas showing bedrock, postglacial deposits, glaciomarine deposits and a very large esker at the southwestern side of the river (Prest 1973).

The surficial deposits in the Tracadie Bay area are mostly loose, stony to bouldery sand till with smaller areas of clayey-sand till, glaciofluvial and glaciolacustrine deposits, and postglacial saltmarshes and barrier bars (Prest 1973). The Winter River watershed contains sandy and clayey-sand till. The majority of the watershed is covered with glaciofluvial and glaciolacustrine deposits and saltmarshes (Prest 1973).

Approximately 12 ka, sea level was at or near its present position along the western part of the PEI North Coast, from Malpeque Bay west to North Cape (Shaw *et al.* 2002). Relative sea level decreased to the east, reaching ca. -10 m at Tracadie Bay and -15 m east of East Point. Subsequently, relative sea level fell as PEI underwent glacioisostatic uplift. By 10 ka, Northumberland Strait was dry land, with relative sea level approximately at -20 m offshore of Cascumpec Bay and approximately -30 m offshore of Tracadie Bay (c.f. Shaw *et al.* 2002). The emergent areas north of PEI reached their greatest extent approximately 9,000 years ago, with the shoreline located approximately 15 km north of Tracadie Harbour and approximately 40 km east of the Cascumpec Sand Hills.

After ca. 9,000 years ago, glacioisostatic rebound was replaced by depression, as the crust continued to respond to the removal of the glacial load. Relative sea level rose progressively in response, reaching approximately its modern position ca. 5,000-6,000 years ago (Shaw *et al.* 2002). However, sea level rise has continued since that time, and has become a major problem along most of the coast of PEI.

Due to the low relief and the friable bedrock, the coasts of PEI are highly sensitive to impacts from sea-level rise (Shaw *et al.* 1998). Relative sea-level in

Charlottetown has been rising at approximately 3.55 mm/a (LRIS 1988; Shaw *et al.* 1998), and together with storm surge activity now poses a considerable hazard (Bruce 2002, McCulloch *et al.* 2002). Coastal erosion is facilitated by both the rise in relative sea level and the friable bedrock. Erosion of bedrock locally exceeds 80 cm/a (Genest and Joseph 1989; Catto 1998). Many coastal bluffs are composed of unconsolidated Quaternary sediment, which is subject to even more rapid erosion. Surveys have suggested a mean range of shoreline retreat throughout PEI at ca. 30 cm/a, with maximum rates in excess of 300 cm/a (LRIS 1988; Shaw *et al.* 1998; McCulloch *et al.* 2002).

Combining ongoing glacioisostatic subsidence, in progress since ca. 9,000 years ago, with projected relative sea level rise associated with global changes in climate, modal relative sea level rise along the coast of PEI has been projected to be between 3 and 7 mm/a over the next 100 years (McCulloch *et al.* 2002). In addition, water levels during storm surges at Charlottetown can be expected to exceed 1.9 m above geodetic datum approximately every 7 years, and water levels during storm surges may be expected to exceed 2.3 m above geodetic datum every 10 years by the year 2100.

1.5 Climate

The climate of PEI is classified as mid-boreal (Köppen-Geiger Dfb), cold, snowy and boreal. The surrounding seas of PEI moderate the climate, drawing warmth from the land in the fall and early winter and cooling the air for a greater part of the spring and summer seasons. The prevailing winds are from the west in the winter and from the southwest in the summer months (Environment Canada 2004).

PEI has fourteen weather stations that have been recording daily data since 1971. The closest weather station to Tracadie Harbour is Stanhope, located approximately 5 km from Tracadie (46° 25'N, 63° 04'W), with an elevation of 3.00 m above sea level. The daily mean temperature ranges from 19.2°C in July to -7.2°C in January and February (Environment Canada 2004). The total mean precipitation is 1160 mm/year with 875 mm falling as rain and 285 mm falling as snow (Environment Canada 2004).

Alberton, the closest weather station to North Port Harbour, is located approximately 1 km from the harbour (46° 51'N, 64° 10'W). The elevation of Alberton is 3.00 m above sea level. The daily average ranges from 18.6°C in July to –8.4°C in January (Environment Canada 2004). The total mean precipitation is 1070 mm/year, with 798 mm of rain and 273 mm of snow (Environment Canada 2004).

The data tabulated by Environment Canada indicated that there is little difference between temperatures recorded at the two locations. The largest difference between the two stations is the amount of precipitation, with an additional 90 mm of rain falling in the Stanhope area. In both areas the spring and fall months have the largest amount of rain. The period October-January has the largest amount of precipitation, including both rain and snow (Environment Canada 2004).

1.6 Oceanology

The Gulf of St. Lawrence is connected to the Atlantic via the Cabot Strait and Strait of Belle Isle. To the west is the St. Lawrence estuary, connected to the Cabot Strait by the deep Laurentian Channel. Directly south of the Laurentian Channel is a large expanse of shallow water, the Magdalen Shallows. The St. Lawrence estuary contributes a majority of the freshwater that runs into the Gulf to meet the colder Atlantic Ocean through the Cabot Strait and Strait of Belle Isle. This causes significant estuarine circulation with the warmer freshwater on the surface heading towards the ocean and the colder saltwater at depth in the Laurentian Channel heading towards the estuary (Lu *et al.* 2001). In the winter, due to wind and convection, there is less stratification and more mixing in the surface waters but the deeper water is still very stratified. In the Gulf of St. Lawrence the most dominant tidal constituent is semi diurnal lunar tide (M2 oscillation). According to Lu *et al.* (2001), tides are forced through the Cabot Strait with little influence coming from the Strait of Belle Isle.

1.6.1 Tides

PEI has two distinct tidal regimes. Most tides on PEI are predominately mixed, semi-diurnal tides, with two low and two high tides daily with marked inequalities in the height of the tides (Owens 1979). Mixed, dominantly semi-diurnal tides affect Northumberland Strait east of the Confederation Bridge and the eastern end of PEI.

In contrast, the northern shore of PEI shows a variety of tidal characteristics, with semi-diurnal influence decreasing from North Cape eastward to St. Peters Bay. At Tracadie Harbour, the tide is predominately mixed, mainly diurnal (K1 oscillation). There is marked inequality in daily tides, and some 24 hour cycles have only one high and one low tide (Owens 1979). Cascumpec Bay shows an intermediate mixed pattern, with seasonal variations in the strengths of the diurnal and semi-diurnal components. Both Tracadie Bay and Cascumpec Bay are microtidal areas, with mean tidal ranges not exceeding 0.7 m at any locations.

1.6.2 Ice Cover in the Southern Gulf of St. Lawrence

Ice cover has been monitored in the Gulf of St. Lawrence by the Canadian Ice Service (CIS) since the 1950's (McCulloch *et al.* 2002). Each winter the first area of PEI to see ice formation is the coastal zone of the Northumberland Strait, developing in the second half of December, with the formation of ice along the north shore not starting until the end of December (McCulloch *et al.* 2002). Ice generally starts to melt from the center of the Gulf around the second week of March, and melting slowly spreads south (McCulloch *et al.* 2002). The Southern Gulf of St. Lawrence will normally remain ice covered until sometime in late March, with low concentrations by the first week of April. The entire southern Gulf of St. Lawrence is usually ice free by mid-April (McCulloch *et al.* 2002).

The presence of ice along the coastal areas, especially the shore zone, is an important limiting factor on the coastal processes of PEI (Owens 1979). The ice cover of the coastal zone of PEI for approximately four months each year has a significant effect on the coastal processes, limiting wave generation, dampening existing waves, and protecting the shore zone from wave action (Owens 1979). This is very important to the coastal zone of PEI, as ice cover and wave dampening occurs during the time of year when wind and wave action would normally be at a maximum.

1.7 Shoreline Characteristics

The total coastline of PEI is approximately 1,260 km with approximately 800 km of beaches. It is mainly low lying with elevations exceeding 20 m in only a few areas along the coast.

The general configuration of the shoreline of PEI is dominated by the underlying structure of the PEI Group with the detailed coastal morphology being a product of a number of dynamic forces such as wind, waves, tides, currents and sea ice (Taylor and Frobel 1992). Along the coastal margins of Cascumpec and Tracadie Bays, the coastline parallels the geological structure and the shoreline is relatively straight, in contrast to the indented shoreline of southeastern PEI (Taylor and Frobel 1992).

Owens (1979) divided the PEI coastline into eight different coastal environments on the basis of shore-zone sediment transport systems, with Cascumpec and Tracadie Bays being found in the North Coast environment. The north coast section, located between North Point and Cable Head, is made up of broad embayments with sandy barrier beaches separated by rocky headlands (Owens 1979; Taylor and Frobel 1992). Throughout the north coast area the wave energy conditions are the highest along the coast of PEI. These wave conditions, together with a tidal range of approximately 1 m in the fall and winter and an abundant supply of sediment cause dramatic shoreline changes. The most predominant changes occur at the tidal inlets that cut through the barrier beaches. Another characteristic of the north coast section is the large bays, including Cascumpec, Malpeque, and Tracadie, with inner shores made up of low bluffs, mixed sediment beaches, marshes and extensive peat deposits (Taylor and Frobel 1992).

In November 1988 and October 1990 an aerial video survey was completed for the coastline of PEI by the Geological Survey of Canada. The video was shot from a Canadian Coast Guard Helicopter flying at a height of approximately 100 to 150 m at a distance of approximately 0.5 km from shore (Taylor and Frobel 1992). The flying speed varied between 60-90 knots with the video taping coinciding with low tide whenever possible in order to document the maximum extent of the intertidal zone (Taylor and Frobel 1992).

1.8 Tracadie Harbour

Tracadie Harbour is located on the central north shore of PEI, approximately 25 kilometres (km) north of Charlottetown (46° 25' 00" N, 63° 02' 00" W). The Small Craft Harbour is located near the mouth of Tracadie Bay, which empties into the Gulf of St. Lawrence. The Tracadie Bay watershed is fed from Black, Trout and Winter Rivers. The total area of watershed drainage is 150.63 km^2 or 11,286 ha (EC and PEIDEFW 1990a; CEAA 2002a). The barrier dune system of Tracadie Bay (Blooming Point) that shelters the inner bay from the Gulf of St. Lawrence is part of the PEI National Park.

The Barrier dune system is made up of a wide fringe sand beach, with low foredunes approximately 2 m in height. Along the back side of the barrier dune system there are older dunes with large blowouts (Taylor and Frobel 1992). Taylor and Frobel (1992) noted infilled over-wash channels throughout the barrier dune system possibly indicating former inlets into the bay. Towards the mouth of bay at the western end of the dune system there is a narrow spit transitional into a larger tree-covered foredune, indicating stability. There is an old breakwater extending in the channel on the western tip of the barrier dune system, which formerly lessened wave action in the inner bay. The breakwater was constructed prior to 1935, as it is visible on the 1935 aerial photo of Blooming Point Barrier Dune.

The Tracadie Bay entrance has strongly hooked spits along the front leading up to the delta, indicating the strength of the current (Taylor and Frobel 1992). The south side of the entrance is flanked by low lying sand from the outlet to the harbour, which lies in the centre of the delta. In addition a controlled channel has been dredged through the delta for use as the harbour entrance (Figure 1.2). South of the harbour the land extends out to a peninsula extending to the west. The coastal area is made up of sand with Orby Head bedrock outcrops along the shore (Taylor and Frobel 1992). Gravel substrate is present further off-shore, reflecting former sea level positions, with an erosional scarp of approximately 3 m in height in some areas. Marine vegetation is attached to the substrate and there are two large sand flats in the delta that are exposed during low tide and extend 1.5 km into the bay.

The Tracadie Bay embayment, including both Tracadie Bay and Winter Bay, has a sandy intertidal zone with a vegetative shore. There are erosional bluffs approximately 4 m high developed in bedrock on the southeast side of the embayment but the majority of the embayment shoreline is classified as low shore, vegetative with intermittent marsh development (Taylor and Frobel 1992). Both sides of Winter Bay have some extensive marshlands but the majority of the area is classified the same as Tracadie Bay, low shore vegetative with marsh development.

The Winter River is the main tributary of Tracadie Bay, emptying into Winter Bay at the western end of Tracadie Bay (Figure 1.2). The Winter River Watershed supplies the municipal drinking water for the City of Charlottetown. The combined surface area of the Tracadie and Winter Bays is approximately 18.7×10^6 m^2 (CEAA 2002a). The tidal range is 0.6 metres, the total estimated estuary volume is approximately 4.58×10^7 m^3, and the flushing time was calculated to be approximately 81.5 hours (CEAA 2002a). The deepest point in the bay is approximately 7.0 m with the total coastline of the bay being approximately 35.4 km (DFO 2003).

Water Quality monitoring in Tracadie Bay shows that from January to December, surface water temperature typically ranges from 0°C (February) to 22.5°C (August) while bottom water temperatures range from 0°C (February) to

21°C (August). Maximum water temperatures are reached in late July to early August. Surface salinity ranges from 1.3 mg/l to 28.5 mg/l while bottom salinity ranges from 25.9 mg/l to 30.9 mg/l (CEAA 2002a). Dissolved oxygen ranges from 7.8 mg/l to 12.7 mg/l in bottom water. Suspended particulate matter ranges from 12.0 mg/l to 50.0 mg/l. Particulate organic carbon ranges from 3.7 mg/l to 8.8 mg/l while particulate inorganic carbon ranges from 5.8 mg/l to 12.5 mg/l. Total chlorophyll in the water ranges from 0.0μg/l to 5.3 μg/l (CEAA 2002a).

Water quality monitoring in Winter Bay shows that surface water temperature typically ranges from 4.5°C (November) to 24°C (August), while bottom water temperature ranges from 5.5°C (November) to 22 °C (August) (CEAA 2002a). Maximum water temperatures are reached in late July to early August.

The substrate of Tracadie Bay consists of soft mud with areas of hard sand around the shoreline. There are light to moderate concentrations of eelgrass (*Zostera marina*) distributed around the Bay. Bottom cover of Winter Bay and Winter River leading into Tracadie Bay consists of mostly soft mud with hard mud and sand along the shore. Along the shallow areas around the shore there are sparse populations of eelgrass (MacWilliams 1974a).

At the entrance to Tracadie Bay, there are fishing grounds for lobster and rock crab (*Cancer irroratus*). Mackerel (*Scomber scombrus*) fishing grounds are found 5 km offshore, herring (*Clupea harengus*) at 2 km, and the former cod

(*Gadus morhua*) fishing grounds, prior to the 1992 moratorium, at 7 km (Legault 1998).

Information from the PEI Ministry of Agriculture, Fisheries, and Aquaculture (PEIAFA) indicates the presence of smelts (*Osmerus mordax*), Atlantic mackerel, winter flounder (*Pleuronectes americanus*), silversides (*Menidia menidia*), gaspereau (*Alosa pseudoharengus*), American eel (*Anguilla americana*), rock crab, perch (*Sebastes marinus*), white hake (*Urophysis tenuis*), trout (*Salvelinus fontinalis*) and lobster in both Tracadie Bay and Winter Bay. Winter Bay also has Atlantic salmon (*Salmo salar*), while Tracadie Bay has sculpin (*Artediellus atlanticus)* and herring (CEAA 2002a).

There are many long term shellfish leases in Tracadie Bay and an oyster lease is located approximately 125 m to the south of the Small Craft Harbour wharf. The greater Tracadie Bay area also contains many suspended mussel leases, with mussel lines suspended in the water column from buoys. Approximately 37.4% of the area of the bay has existing suspended mussel leases (45 sites) and 0.5% of the bay has existing off-bottom oyster leases (CEAA 2002a) (Figure 1.4).

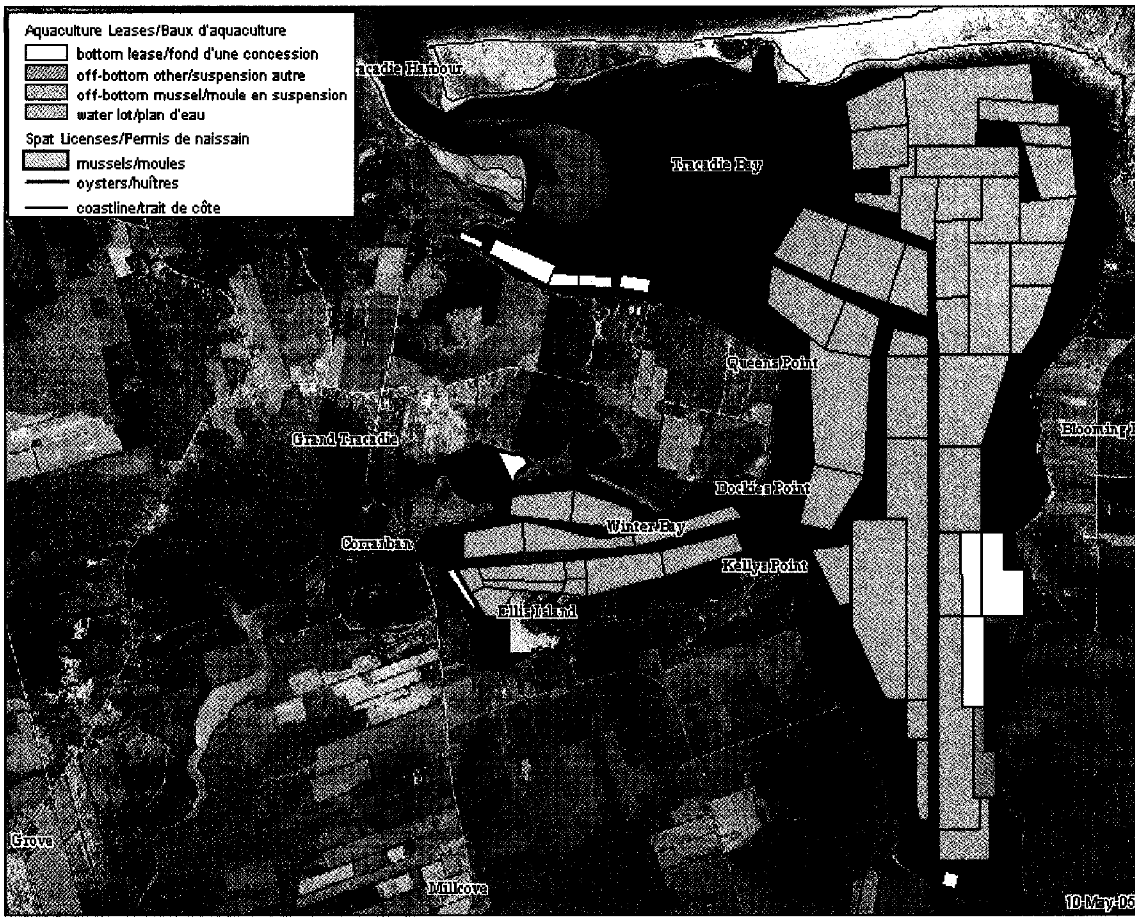

Figure 1.4 – Mussel and oyster leases located in Tracadie and Winter Bays. This map is a Graphic Representation. It is not intended to be used for Legal Description or to calculate exact dimensions or Area. Photos courtesy of Fisheries and Oceans Canada, Aquaculture Leasing Division, Charlottetown, PEI.

1.9 Cascumpec Bay and North Port Harbour

As is Tracadie Bay, Cascumpec Bay is also protected from the Gulf of St. Lawrence by a barrier dune system, the Cascumpec Sand Hills. The barrier dune system at Cascumpec Bay is a true barrier island, not attached to land as is the Blooming Point dune system protecting Tracadie Bay. There are two inlets into Cascumpec Bay: Palmer's Inlet in the east, and Alberton Channel in the west. Palmer's Inlet separates the Cascumpec Sand Hills from the Conway barrier dune system which extends east along the coast to Malpeque Bay. The barrier is less than 30 m wide in places with a very straight foredune ridge along the seaside, where the backside is a lagoon shore with extensive sand deposits. There are also many curved beach and dune ridges throughout the barrier. The eastern end of the dune has a larger scarp approximately 1 m, supported by peat with a somewhat irregular shoreline and high steep foredune ridges. Historically, there is evidence of two old inlets with intermittent vegetation located along the barrier dune (Taylor and Frobel 1992). At the western end of the Cascumpec Sand Hills the dunes are more linear, with some tree growth on the older dunes adjacent to the Alberton Channel entrance.

Palmers Inlet contains a large tidal delta with an ebb shield (Taylor and Frobel 1992). Across from Palmers Inlet the coastline is low shore vegetative with a marsh shoreline and an upland peat farm. Black Banks Cove, a low marshy shore with peat, flanks the peat farm east of the Foxley Bay entrance. Closer to the entrance of Foxley Bay the coast is primarily sand with a vegetative high tide zone and some low scarps. According to Taylor and Frobel (1992), the Foxley Bay coastline can be characterized as mostly low sandy shore with erosional scarp on the head lands, scattered cobbles at the promontory and some marsh development.

The head of Cascumpec Bay is considered to be low shore with Kildare Capes Formation outcrops near the treed areas, extending to the mouth of the Mill River (Taylor and Frobel 1992). The watershed is mostly very low shore with infringing sand beaches and a vegetative mat at high tide. The Dock River area, located on the west side of Mill River and Fox Island, shows a continuation of the low sand shore with some rock out crops and coarser material seaward towards the peninsula that separates Dock River from the Alberton Embayment (Figure 1.3 and 1.5). The Alberton embayment, where North Port Habour is located, has a wider intertidal zone, with sand shores and very low lying shoals (Taylor and Frobel 1992). There is an extensive tidal deposit located west of the harbour entrance with a well-developed marsh, over flood deposits which flank the entrance to Kildare Bay. Kildare spit, west of Alberton Channel, is made up of low, weakly developed dunes approximately 1 m in height and with intermittent blowouts. Taylor and Frobel (1992) stated that the dunes on the back shore were linear with extensive marshes which developed on old flood tide deposits.

Within Cascumpec Bay there are two large islands. Oultons' Island is located just east of the Alberton Channel entrance, and is tree-covered and low lying. The area between the island and the Cascumpec Sand Hills is a lagoon shore with extensive sand deposits that almost completely surround the island, and extend along the back shore of the barrier dune. Fox Island is located west of the mouth of the Mill River and is mostly low lying farmland with a causeway to the mainland on the western side.

The Cascumpec Bay watershed is fed from Mill, Trout, Kildare, Dock and Foxley Rivers, Freeland Creek, Brooks River and Conway Narrows. Each stream is fed by a number of smaller tributaries (EC and PEIDE 1990b). The watersheds of the Mill and Trout Rivers drain an area of 305 km^2 through 240 km of streams and rivers (EC and PEIDE 1990b). The Cascumpec Sand Hills barrier dune system shelters the inner bay from the Gulf of St. Lawrence. Cascumpec Bay is connected to the open gulf through Alberton Channel at the western end and Palmers Inlet at the eastern end.

The combined surface area of the Cascumpec Bay watershed is approximately 69.7×10^6 m^2 (CEAA 2002b). The tidal range is 0.7 m, the total estimated estuary volume is approximately 9.6×10^7 m^3, and the flushing time was calculated to be approximately 37.3 hours (CEAA 2002b). The deepest point in the bay is approximately 11.9 m with the total coastline of the bay being approximately 105 km (DFO 2003).

Water quality monitoring in Cascumpec Bay shows that in July and August 1998, surface water temperature typically ranges from 21.5°C to 24.7°C while bottom water temperatures range from 16.5°C to 24.7°C (CEAA 2002b). Surface salinity ranges from 16.9 mg/l to 25.3 mg/l and total chlorophyll sampled in July and August in Kildare, Mill and Foxley Rivers ranges from 1.8 µg/l to 22.1 µg/l (CEAA 2002b).

MacWilliams (1974b) conducted an Estuarine Resource Inventory for specific bays throughout PEI. The substrate of Kildare River west of the causeway consisted of soft mud along the center with moderate amounts of eelgrass throughout. East of the causeway, shoreward to the end of the tidal flats at the entrance of the Alberton Channel there is soft to firm mud with a band of hard sand along the shoreline. The substrate in the Mill, Foxley, and Trout Rivers was soft mud with a band of hard sand along the shoreline. There is a moderate to heavy growth of eelgrass in all three rivers and large amount of sea lettuce in Mill River (CEAA 2002b). Substrate types in the Cascumpec Bay area are principally soft mud and firm sand, with eelgrass beds distributed throughout the intertidal areas of the bay (CEAA 2002b).

Cascumpec Bay contains both lobster and rock crab, and fisheries for both species are located in the mouth of the bay and in the channel area (CEAA 2002b). Mackerel, cod, winter flounder, hake and toad crab fishing grounds are located between 5 and 10 km offshore, with herring fishing grounds at the entrance to the bay (Legualt 1997 and 1998). Smelts, Atlantic mackerel, silversides, gaspereau, American eel, rock crab, perch (*Sebastes marinus*), hake, trout, flounder, tomcod (*Microgadus tomcod*), gunnels (*Pholis sp.*), starfish, oyster drills (*Urosalpinx cinerea*), seals and lobster are present in the Cascumpec Bay area (Legault 1998).

Within the Cascumpec Bay watershed there are numerous bottom oyster leases (Figure 1.5), although there are only approximately 20 water column-oyster leases (approximately 1.8% of the Bay) (CEAA 2002b). Within Foxley River there are numerous bottom oyster leases, approximately 9 water column-oyster leases and multiple oyster spat leases (Figure 1.6). There are only 2 water-column mussel leases (approximately 0.2% of the bay) and only one area designated for mussel seed collection (located in the Kildare River, approximately 0.4% of the bay) (CEAA 2002b). Figure 1.7 shows the mussel leases and mussel seed collection areas in Kildare Bay. There is currently one sewage lagoon that empties into a tributary of the Dock River. Another, which was located at the head of the Mill River estuary, has been reconstructed in the last two years with the sewage being treated on site at the Mill River Golf Course.

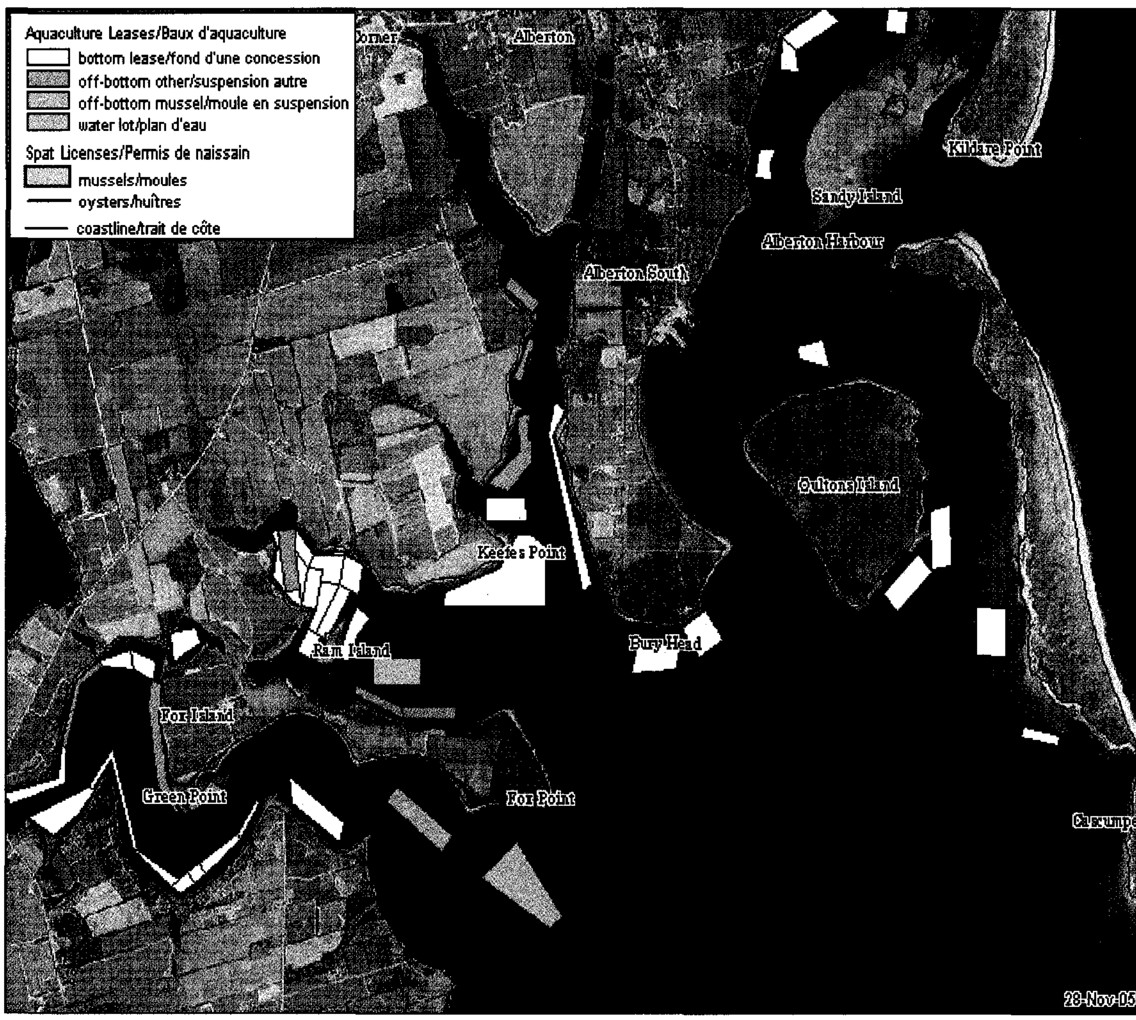

Figure 1.5 – Oyster leases in Cascumpec Bay. This map is a Graphic Representation. It is not intended to be used for Legal Description or to calculate exact dimensions or Area. Photos courtesy of Fisheries and Oceans Canada, Aquaculture Leasing Division, Charlottetown, PEI.

Figure 1.6 – Bottom, water-column and spat collection oyster leases in the Foxley River. This map is a Graphic Representation. It is not intended to be used for Legal Description or to calculate exact dimensions or Area. Photos courtesy of Fisheries and Oceans Canada, Aquaculture Leasing Division, Charlottetown, PEI.

Figure 1.7 – Mussel spat leases of the Kildare River. This map is a Graphic Representation. It is not intended to be used for Legal Description or to calculate exact dimensions or Area. Photos courtesy of Fisheries and Oceans Canada, Aquaculture Leasing Division, Charlottetown, PEI.

2. <u>Previous Research</u>

Habitat Compensation/Enhancement within Atlantic Canada is a practice that, as of 2000, has become an important requirement when working in the marine environment. Projects that are proposed to be undertaken within the marine environment must be reviewed by DFO-HMB. This agency is responsible for making the determination of whether or not Habitat Alteration, Disruption and/or Destruction (HADD) will occur, with regards to marine fish habitat in the proposed project area.

2.1 Atlantic Canada

Habitat compensation in Atlantic Canada has only been conducted for approximately the last 15 years, although habitat enhancement commenced as early as the 1960s. Throughout this period, the only types of habitat compensation that have been conducted within Atlantic Canada were associated with shellfish and fish habitat enhancement. Shellfish habitat enhancement is the most common, involving both artificial reef construction for lobster and crab habitat and shellfish enhancement for oysters, mussels and soft-shell clams. Fish related enhancement in Atlantic Canada deals mostly with Atlantic salmon and smelts, where the majority of the work is undertaken in the estuaries and upper sections of the rivers, which include de-silting streams, creating rocky substrates for spawning, and fixing culvert elevations to allow migration. These measures were not undertaken in marine environments.

Efforts to enhance lobster populations and commercial harvests through the addition of new (artificial) habitat started in the mid 1960s, but have become more widespread since the 1990s (Comeau 2003). The earliest account of a project that required lobster habitat compensation within Atlantic Canada dates to 1990-1991 in Belledune, N.B (unpublished work cited in Welsford and Scarrett 1995). Prior to the Belledune compensation, the only other major attempt to enhance lobster was conducted in 1965 in Kouchibouguac Bay N.B. (Scarrett 1968; Welsford and Scarrett 1995). This reef is considered to be the first artificial reef for lobster habitat to be constructed in Atlantic Canada, but was not constructed for compensation purposes. The rock reef covered approximately 2740 m^2. The lobster biomass after two years was smaller than adjacent lobster grounds and there appeared to be no evidence of larval settlement (Scarrett 1968).

The artificial reef constructed at Belledune, N.B. is similar to the other types of lobster habitat compensation that have subsequently been conducted within Atlantic Canada. The idea of using the dredged material as material for reef creation has been used at three other locations within Atlantic Canada: (1) Amherst Cove, PEI; (2) Middle Shoal, Cape Breton, NS; and (3) Newporte, Gaspé (Comeau 2003; Tremblay and Hurlburt 2003). In all four locations, the artificial reefs were constructed in sandy mud substrate areas that were considered to be marginal low productivity habitat for lobster (Welsford and Scarrett 1995).

The reef constructed at Belledune was comprised of individual piles of rock that were distributed more or less randomly within an area of 0.8 km^2, approximately 1.5 km east of the harbour. This area was considered to be an area of low productivity for lobster due to the fact that the benthos was composed of sandy mud. Only one survey was conducted at this reef, within 2 years of initial construction.

During the construction of the Confederation Bridge (1994 and 1996) which links New Brunswick and PEI, it was necessary to excavate overburden material overlying the bedrock for many of the piers (Comeau 2003). Strait Crossing Joint Venture (SCJV) received a permit from Environment Canada to dispose of 473,000 m^3 of dredged material in a marine disposal site in the inshore waters of Amherst Cove PEI (Comeau 2003). The dredged material consisted mainly of sand and silty sand with gravel, boulders and pieces of bedrock (Strait Crossing Joint Venture 1995, in Comeau 2003).

One of the major benefits of the Amherst Cove reef construction was that the area had been surveyed prior to creating the artificial reef, making it an excellent location for evaluation of the success/failure of the enhancement efforts. It was recorded in 1994, through bathymetric surveys, multi-beam mosaics and underwater SCUBA surveys, that the benthos of Amherst Cove was a fairly smooth and featureless seafloor with no lobster or rock crab in the area (Comeau 2003). In 2001, a follow up multi-beam survey was conducted in addition to a video survey of the bottom. The 2001 survey showed that the dredged material created very identifiable mounds that were separated by flat seafloor sections

(Comeau 2003). The video survey recorded a total of three lobsters for an estimated 74 lobsters per km^2, with a total of twenty rock crab observed for an estimate of 494 rock crab per km^2 (Comeau 2003). Unfortunately the sizes of the lobsters and crab are unknown, but the total numbers were comparable to other areas of similar lobster habitat. Comeau (2003) states that the way the video equipment was used in the survey made it hard to get a correct estimate of the total number of lobster. In order to determine if viable lobster/rock crab habitat has been constructed, additional sampling and monitoring must be conducted in the future.

In 1996 dredging was conducted in the Middle Shoal Channel, the entrance to the Bras d'Or Channel, in order to improve navigation (Tremblay and Hurlburt 2003). During the project's environmental assessment, some mitigation measures were implemented to offset the negative effect that the dredged area would have on fishing success. One of the mitigation measures was to deposit the dredged material at two nearshore sites with the objective of creating lobster habitat (Tremblay and Hurlburt 2003). The two sites were selected primarily because they were known to be poor fishing grounds, both flat and featureless. However, during monitoring, both lobster and rock crab were trapped. Despite this, the areas were still considered to be unable to support certain critical life history stages (i.e., overall habitat was poor) (Tremblay and Hurlburt 2003).

Unfortunately, subsequent monitoring of these two sites has not been extensive. The work done by Environment Canada (EC) shows the presence of larger substrate, but as no scale was used in the photos it is hard to determine the size of the cobbles and boulders (Tremblay and Hurlburt 2003). In addition, according to Tremblay and Hurlburt (2003) Natural Resources Canada (NRCAN) conducted surveys in 2002 of the two locations, and found different results. The 1997 images from the EC video indicate a high percentage of cobbles (42%) and boulders (15%) whereas the NRCAN images indicate only 9% cobbles and 1% boulders (Tremblay and Hurlburt 2003). Overall there has not been sufficient follow-up research done at the Middle Shoal locations. In order to determine if the artificial reefs had an effect on the local area it would be necessary to conduct trapping and tagging, bottom video surveys, and seasonal density estimates using SCUBA.

In addition to the sites listed above there have been other areas within Atlantic Canada where artificial lobster reefs were constructed (Souris PEI; Burgeo Islands NL; Caraquet and Val Comeau NB; Fox Harbour NS; and Cascapedia Bay and Cap-d'Espoir, Gaspé). Three of these were constructed for compensational purposes (Souris, Caraquet, and Fox Harbour), and the remainder have been created to try and enhance lobster populations in the specific areas.

Locating an ideal location for an artificial reef can be time consuming and costly. Prior to implementing a reef an area must first be located that has the proper water depth (7 to 10 m), with a benthos that can support heavy structures (cobble substrate, with lesser amounts of sand, silt and clay) that will not be covered with sediment from lateral drift or sink into the sediment. In addition, the structures (large rock or prefabricated concrete blocks) can be very expensive and difficult to manipulate. Currently in the Southern Gulf of St. Lawrence a cement structure developed by Michel Comeau (DFO-Science) has been used with great success (at Caraquet, Val Comeau and Fox Harbour) but many hours of work are required to locate and implement a successful reef. Fortunately, in recent years, time has been devoted to lobster enhancement in the Northumberland Strait and the process is becoming streamlined and potentially less expensive. The benefit of the Comeau structure is that it is designed to provide shelter for the juvenile lobsters in areas where habitat has been diminishing for many different and mostly unknown reasons.

Another type of enhancement project conducted in Atlantic Canada is soft shell clam enhancement at Kouchibouguac National Park in the spring 2005 (Peter Curley, PWGSC, personal communication). The enhancement project included constructing clam tents and placing them in the intertidal zone to collect soft shell clam larva during their planktonic stage (i.e., spat set). The clam tents were then intended to protect spat from predators by providing a protected area to mature (Peter Curley, PWGSC, personal communication). Refer to Fig. 2.1 and 2.2 showing a close up of the clam tents in the intertidal zone and an aerial view, respectively. Unfortunately, the follow-up monitoring conducted in 2006 showed that the clam tents had zero recruitment from the previous years spat set (Peter Curley, PWGSC, personal communication). Some causes of the zero recruitment could be due to the effect of winds and tides on larvae during the larval stage (Sea Grant Program 1998). An example would be if an off shore

Figure 2.1 – Placement of the clam tents used for soft-shelled clam enhancement near Kouchibouguac National Park. (photo courtesy of Fisheries and Oceans Canada – Small Craft Harbours).

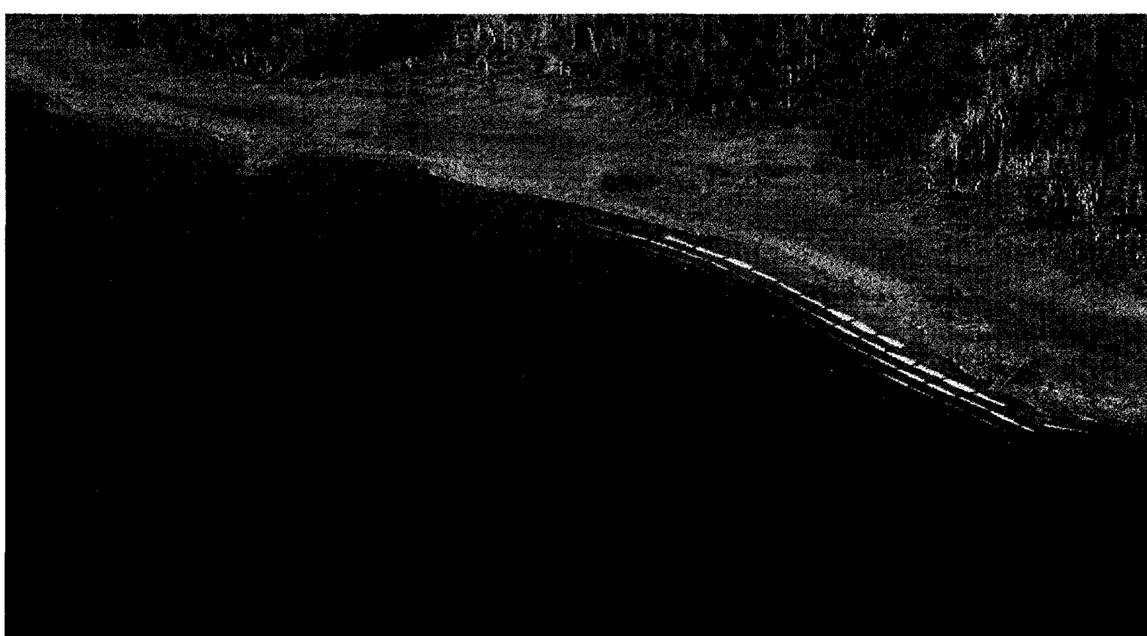

Figure 2.2 – An aerial photo showing the clam tents used for soft-shelled clam enhancement near Kouchibouguac National Park. (Photo courtesy of Fisheries and Oceans Canada – Small Craft Harbours).

wind blows for the entire week during the spat set period the entire spat set would be lost as the larvae would be transported in the current out to sea (Sea Grant Program 1998).

Oyster enhancement was conducted in Shediac Bay, New Brunswick, which included spat collection and relaying to areas of minimal oyster quantities. One of the biggest enhancement projects that occurred in Newfoundland for the purpose of habitat compensation was the White Rose habitat compensation program in Bonne Bay, Gros Morne National Park. The project required the restoration of a former eel grass bed that was destroyed from a diesel spill of approximately 38,000 litres in 1999 (JWL 2003). The project consisted of manually removing eel grass plugs from a near by donor site. Wire mesh frames called TERFs were used, and 25 pairs of eel grass shots were tied with biodegradable twine to each TERF (JWL 2003). Approximately 3,600 TERFs were placed over a 8,749 m^2 area in water from 3 to 10 m in depth. The TERFs remained for 10 to 13 weeks before removal (JWEL 2003). According to the post-transplant monitoring which occurred during the 13th week, the eel grass that survived doubled and tripled in size. Approximately 25,000 plants survived, representing 13.4% of the original amount transplanted (JWL 2003). The post survey also discovered that the best area to place the TERFs was on silty sand and not cobble substrate, because the cobbles raise the TERF off the bottom and prevents the eel grass roots from anchoring.

A large tidal marsh restoration project has been proposed for Cheverie Creek NS, a joint project of the NS Department of Transportation, DFO-SCH and

DFO-HMB (Peter Curley, PWGSC, personal communication). The proposed project includes increasing the size of a culvert to allow saltwater inundation into an area that was once salt marsh prior to the construction of a highway. The area being converted from freshwater marsh to saltwater marsh is approximately 26 acres. Work is being conducted to compensate for permitted activities that harmed saltmarshes and fish habitat along the coast of Nova Scotia.

2.2 Prince Edward Island

Historically, marine habitat enhancement on PEI has been conducted on a small scale with a focus on only a few species, primarily oyster. There are three types of oyster enhancement: (1) Relaying, (2) De-silting or Shellbed Cultivation, and (3) Shell Mining.

Relaying is preferably conducted by removing oysters from a very high recruitment area and transporting them to a low recruitment area in hopes of creating higher recruitment in the new location. Currently, 60% of the oysters that are fished on PEI have come from Bedeque Bay or Summerside Harbour (Allan Morrison, PEI Department of Agriculture, Fisheries and Aquaculture (PEIDAFA), personal communication). From 2001 to 2003 relaying has been conducted by the PEI Shellfish Association (PEISA) in the East River (all three years) and in the West River (2003). A shore relay, with shell relayed to deeper water was conducted in Bedeque Bay (PEISA 2001, 2003a and 2003b).

Another type of relaying which is a more recent technique developed by members of the PEISA in the late 1990's is the relaying of spat from collectors

(Frank Hansen, PEISA, personal communication). The spat collectors are small plastic tile pipe or 'elephant trunk', and are connected together. These collectors were dipped in cement and placed in the Bideford River (PEISA 2001, 2003a and 2003b). The collectors remained in place throughout the summer and were periodically inspected to check spat set and to remove invasive species (i.e., starfish). During 2001, this activity was not very productive and the spat that was collected was relayed back into the Bideford River (PEISA 2001). The following year the amount of oyster seed collected was found to be above average, with 1,838 tubs of seed harvested in September and October (PEISA 2003a). The seed was then spread throughout rivers and bays in PEI, with the largest amount of tubs spread in Egmont Bay (448 tubs), Cascumpec Bay (243 tubs), Hills River (233 tubs), and Mill River (230 tubs) (PEISA 2003a). The following year only 1,274 tubs of spat were collected, with the largest amount of tubs spread in the Wilmot area (409 tubs), Bedeque Bay (386 tubs), Grand River (200 tubs) and the Mill/Hill Rivers (98 tubs) (PEISA 2003b).

De-silting or shellbed cultivation was started by the provincial government in the 1970's when oyster landings were depressed (Allan Morrison, PEIDAFA, personal communication). Currently there are two types of shellbed cultivation that have been adopted and are being performed. The original type dealt with raking existing shellfish beds to clean the surface shells of fouling organisms or silt. A fouling organism is any type of seaweed or other marine organism that would attach itself to a shell. This work was first started in the East River in the early 1970's, and is currently being conducted in bays and rivers by the PEISA

(Allan Morrison, PEIDAFA, personal communication; PEISA 2001, 2003a, and 2003b).

Another type of de-silting is performed by the oyster fishers, associated with oyster harvesting conducted during the spring fishery. Oyster harvesting is performed by hand using two tongs that are suspended over the side of a boat. The movement of the racks through the beds helps remove sediment that has built up from the spring runoff and diminishes the amount of fouling organisms in the area. This removal of organisms and silt during the spring fishery cleans the shell in an area giving the new spat (which is released during the summer months) a place to adhere and grow (Lee Murphy, DFO-HMB, personal communication).

The third type of enhancement preformed on oyster beds throughout PEI is shell mining. Shell mining is performed to increase the size of productive beds, or in some cases to ignite possible oyster growth in historically productive beds that have stopped producing oysters. Shell mining is the dumping of old oyster shells to produce new areas for spat. This technique has been used for many years and is probably one of the oldest types of oyster enhancement. Mackenzie (1973) performed this type of enhancement on PEI by using leading fishers in the area to point out beds on which to both spread shell and oysters. MacKenzie (1973) noted that the work was conducted from 1972 through 1986, and as a result of the program oyster production more than tripled. In 2002 and 2003, shell mining was conducted by the PEISA in the Bedeque Bay as a form of marine habitat compensation for the construction of the new Summerside Park located at the west end of Summerside (PEISA 2003a and 2003b).

Lobster habitat enhancement has also been conducted on PEI. Currently there are two documented cases where marine habitat enhancement has been performed to increase the amount of lobster habitat in the waters around PEI: Colville Bay, Souris and Amherst Cove, Borden-Carleton.

In Colville Bay, artificial reefs were constructed as compensation for the construction of the Transport Canada wharf and channel dredging. A total of two reefs were proposed and later constructed to compensate for the destruction of marine habitat. The total foot print of destruction was approximately 36,000 m^2, which included the dredge area, dock decking area and the dock footprint (Abutment and Piles) (JWL 1998). The design was considered after evaluating other reefs that had been constructed in the Gulf of St. Lawrence. From the information collected the design that appeared to have created a habitat with the most crustacean colonization consisted of habitat:

- on a substrate that would support the hard material (sand or gravel till);
- in an area adjacent to existing crustacean habitat;
- where hard material was placed on the substrate, designed to maximize the edge effect of hard material surrounded by softer substrate which crustaceans could burrow under; and,

- with a diversity of hard material sizes (gravel to boulder), which appears to offer a better variety of crevice spaces within the hard material placed (JWL 1998).

Using the above criteria, two reefs were constructed by placing up to approximately 3 m^3 of quarried stone creating a mound covering an area of approximately 3 m^2. The two areas covered approximately 8,000 m^2 each and had a total of 610 mounds in each area (JWL 1998). The locations were selected considering depth, as they could not create a hazard to navigation in the local area, and after consultation with local fish harvesters. A mix of gravel, cobble and boulders were used to construct the reefs with the objective of having a variety of material sizes to promote a variety of crevice sizes and therefore the potential for an increased diversity of lobster sizes (JWL 1998). Follow-up monitoring has been conducted on both reefs and flora and fauna have been noted using the reefs, but unfortunately no follow-up reports have been written with regards to the biodiversity or productive capacity (Andrea Locke, DFO-Science, personal communication).

Historically, there have been other types of lobster enhancement conducted around the waters of PEI, but there is no written documentation. An example is a tire reef that was constructed along the southern shore of PEI near Argyle Shore (Neil McNair and Brian Gillis, PEIDAFA, personal communications). The reef was built of old rubber tires and placed in conjunction with provincial government and local fishermen. The reef was intended to help increase the lobster habitat in the area. Unfortunately, nothing has been written with regards to the type and size of the reef, the exact coordinates are not known, and there has not been any monitoring of the reef since it was put in place (Neil McNair and Brian Gillis, PEIDAFA, personal communication). Other types of artificial marine enhancement have been conducted by the local fisher harvesters in the past, mostly dealing with placing old traps and tires on the bottom to help promote lobster colonization within their fishing areas (Barry MacPhee, PEIDAFA, personal communication).

Sherman and Spieler (2006) investigated an artificial reef constructed off the east coast of Florida, and concluded that the use of tires is not suitable for artificial reefs. Approximately two million tires were used to create an artificial reef in the late 1960s. Over the years the banded tires separated and washed ashore or continue to move with the current. Recent studies have shown that the seafloor in the area of the tire reefs resembles a junkyard with numerous moving tires. The tires are adding to the natural and anthropogenic stresses of the coral reefs in the area (Sherman and Spieler 2006).

Another type of marine enhancement that is being attempted on PEI is enhancement or construction of salt marshes. Currently, there are two salt marsh enhancement projects being conducted on PEI. One project is in the process of being constructed along the Souris River by a local watershed group, after receiving a water course alteration permit from the provincial government (Bruce Raymond, PEIDEEF, personal communication). The idea was proposed to try and diminish the anoxic conditions that occur in the area due to an accumulation of sea lettuce. The area is approximately 500 m^2 and is located in a small tributary of the Souris River. The area is very shallow with a depth of only 30-50 cm at high tide (Cindy Crane, PEIDEEF, personal communication). The proposed project includes building a berm and backfilling the area. An alternate method using brush mats to slow the water flow and causing sediment to drop out and build up, was suggested but never implemented at this location. As of September 2006, the berm and backfill were in place, but no planting of native salt marsh flora has been conducted (Cindy Crane and Bruce Raymond, PEIDEEF, personal communication). A site visit conducted by the PEIDEEF in late August 2006 indicated growth of salt marsh plants in the infill area despite the lack of planting of salt marsh plants in the infill area. Figures 2.3, 2.4 and 2.5 show the area after the infill in 2003, 2004 and the area in August 2006.

Figure 2.3 – A 2003 photo showing the salt marsh enhancement project in Souris, Kings County, PEI. (Photo courtesy of PEIDEEF).

Figure 2.4 – A 2004 photo showing the salt marsh enhancement project in Souris, Kings County, PEI. (Photo courtesy of PEIDEEF).

Figure 2.5 – A 2006 photo showing the salt marsh enhancement project in Souris, Kings County, PEI. (Photo courtesy of PEIDEEF).

The other salt marsh enhancement project was conducted near Malpeque Harbour in Malpeque Bay. The project consisted of reshaping terrestrial habitat directly upland of an existing salt marsh to promote saltwater inundation during periods of high tide and thus promoting a natural succession of dry land to salt marsh habitat (PWGSC 2004). The area being enhanced was approximately 1000 m^2 with the upland being reshaped to the topography of the existing *Spartina patens* (PWGSC 2004). To help expedite the natural succession, approximately 250 *Spartina patens* plugs were transplanted from the surrounding salt marsh and placed at equidistances throughout the newly created marsh (PWGSC 2004). This project was conducted in the Fall of 2004, and monitoring in the summer of 2005 and 2006 showed that the *Spartina patens* plugs have migrated and colonized the marsh. Figures 2.6, 2.7 and 2.8 show the migration/growth over the last three years.

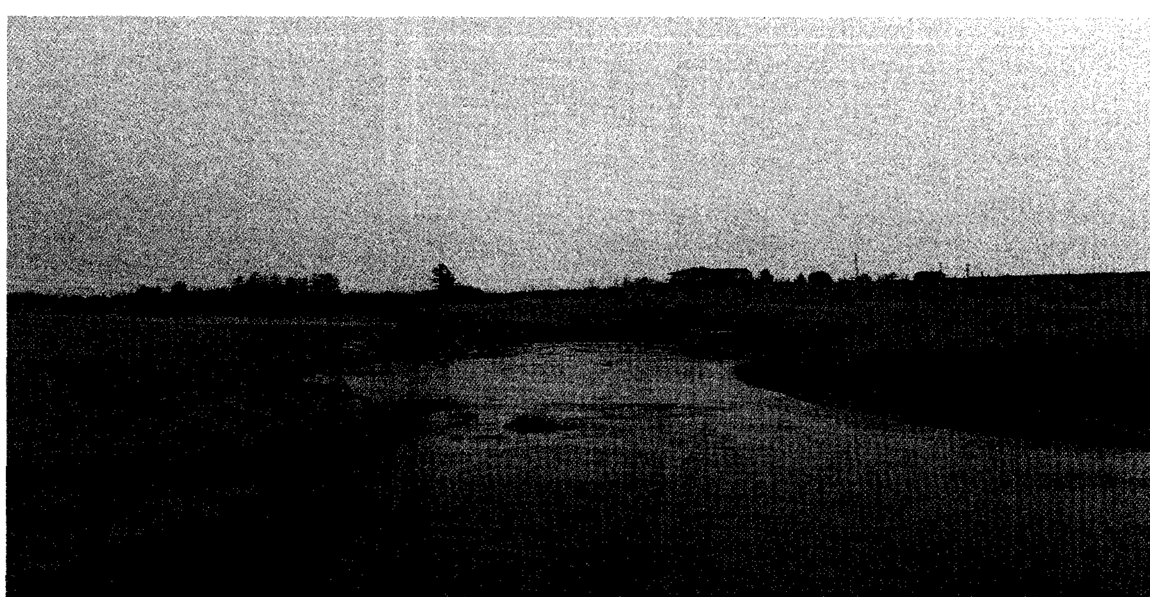

Figure 2.6 – A 2004 photo showing the newly reshaped embankment that was subsequently inundated with tidal waters near Malpeque Bay, PEI. (Photo courtesy of Fisheries and Oceans Canada – Small Craft Harbours).

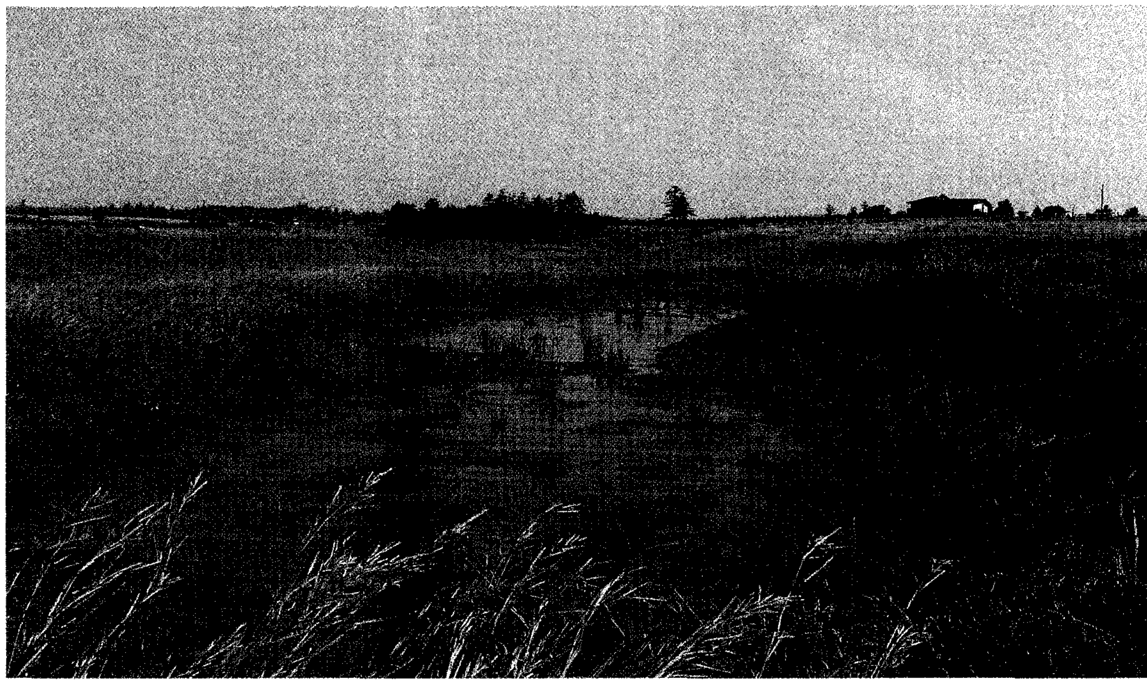

Figure 2.7 - A 2005 photo showing the created salt marsh and the *Spartina sp.* plugs near Malpeque Bay, PEI. (Photo courtesy of Fisheries and Oceans Canada – Small Craft Harbours).

Figure 2.8 - A 2006 photo showing the created salt marsh and the flourishing *Spartina sp.* plugs near Malpeque Bay, PEI. (Photo courtesy of Fisheries and Oceans Canada – Small Craft Harbours).

Other types of enhancement that have been conducted on PEI have dealt mainly with riverine enhancement. Although none of the work has been conducted directly in the estuaries, most environmental groups and government scientists believe that the work is benefiting both the marine and freshwater environments.

In addition, representatives of the provincial government have stated that in the last 20 years much work has been conducted with regards to finding ways to enhance and harvest many marine species that are native to PEI waters. Unfortunately, it has been stated that the socio-economic benefits from growing or enhancing these species (club tunicate, quahogs, soft shelled clams) are insufficient to merit continuing in the endeavors in particular estuaries of PEI (Neil MacNair and Bryan Gillis, PEIDAFA, personal communications).

2.3 North America

In the United States marine habitat enhancement has been conducted for many years, but enhancement for the purpose of compensation is a relatively new requirement. Along the east coast of the US one of the first types of enhancement was conducted on shellfish beds. In the early 1950s to the mid 1960s, oyster harvests diminished drastically in Connecticut and New York Bays. MacKenzie (1989) conducted a five year study in Long Island Sound between 1966 and 1972 and found that the fishing areas were being suffocated by silt, that there were areas of insufficient shell or sandy bottoms with no shell, significant predation (oyster drill and star fish) and fouling of shell. Recommendations included earlier transplantation to avoid silting, placing concentrations of available shells on the best beds, harvesting with hand dredges, spreading shell over bottom where no shell existed and implementation of poly-stream application and quicklime to abate predation. According to MacKenzie (1989) the result of the implementation of his recommendations were that oyster abundance increased several times over and that oyster production increased enough to be considered as a "yield take-off".

The National Oceanic and Atmosphere Association (NOAA) and stakeholders of east coast states have been conducted numerous oyster bed rehabilitation/restoration projects from the coast of Maine to the Gulf of Mexico. The majority of the enhancement/restoration techniques are the same as the enhancement techniques conducted in the southern Gulf of St. Lawrence. The newer techniques that have not been adopted on PEI use different types of hard substrate (stone, crushed concrete, limestone-marl, crushed porcelain, cobbles, clam and oyster shells) with irregular surfaces and pore spaces of particular material providing small oysters the best protection from predation (Takacs *et. al.* 2005; Hargis and Havens 1999). Hargis and Havens (1999) indicate that using these materials as cores for oyster reefs in deeper water with a layer of clean oyster used as the veneer is preferable. Other rehabilitation/restoration techniques deal with developing disease resistant strains of oysters, sanctuaries where no harvesting is allowed, and managed reserves which are areas that are restored and regulated to be opened to harvesting on schedules that are both environmentally and economically beneficial (Takacs *et. al.* 2005).

Other types of enhancement that have been conducted in the US deal with coast restoration. In the Gulf of Maine, restoration has been conducted on tidal marshes to restore tidal flow, the removal of freshwater impoundments improving fish passage and spawning grounds and transplantation of seagrass (Cornelisen 1998). Cornelisen (1998) created a database of restoration projects that have occurred in recent years throughout the Gulf of Maine, in order to help facilitate, maintain and enhance environmental quality helping to allow sustainable resource use for existing and future generations. In New Hampshire, Massachusetts, Maine, New Brunswick and Nova Scotia, 111 tidal marsh restoration projects, 107 freshwater impoundments, 4 tidal flats and 3 seagrass enhancement/restoration projects had been conducted. Of the 111 tidal marsh projects, all were conducted in the US and 44 were conducted as compensation for habitat loss due to unavoidable adverse impacts, with approximately 28 of the projects occurring in Massachusetts (Cornelisen 1998). The other tidal marsh projects were considered proactive, meaning they were conducted to restore degraded habitats to offset historical and/or cumulative impacts instead of compensating for permitted activities (Cornelisen 1998). Tidal marsh restoration in New Hampshire has been ongoing since 1990. The majority of the work involved fixing culverts, ditches and waterways to allow tidal flushing into areas that had been blocked due to construction in the past (Natural Resources Conservation Service 2006). New Hampshire conducted an inventory of the coastal environment in 1993 and discovered that approximately 700 acres of once viable salt marsh could be restored. As of March 2003, approximately 600 acres of that area has been restored (Natural Resources Conservation Service 2006).

The San Francisco Estuary has been a site of salt marsh enhancement/restoration in recent years to make up for the large scale loss of tidal marshes over the last 150 years due to a sustained period of anthropogenic growth (Orr *et al.* 2003). The restoration approach used consists of strategically removing section of dikes allowing tidal flow and estuarine sedimentation to build mudflats to tidal elevations that marsh vegetation will colonize. To help speed up the restoration process, dredge material is placed over the mud flats prior to breaching to give the area the proper tidal elevation to promote salt marsh growth (Orr *et al.* 2003).

The tidal flat and seagrass restoration projects that have been conducted in the Gulf of Maine are low in number with minimal information on the projects. In total approximately seven (7) restoration projects including four (4) tidal flats and three (3) seagrass beds have been conducted in Massachusetts, New Hampshire and Maine with none recorded for New Brunswick and Nova Scotia (Cornelisen 1998). An intertidal mud flat was constructed in 1960 and 1988 near Janesport ME using dredge material. The 1988 project involved the placement of approximately 76,500 m^3 of fine sands onto three acres of shallow sub-tidal sand and gravel for the following reasons: 1) provide beneficial use of dredge material and 2) to create habitat suitable to for commercially important species

(Cornelisen 1998). In 1990, 1991 and 1992 follow up monitoring was conducted at the site along with near by reference sites to help determine the long-term conditions with the constructed flats (Cornelisen 1998). Ray *et al.* (1994) noted that the use of dredge material for mud flat creation was a positive environmental alternative for alternative uses of dredge material/disposal.

The US Army Corps of Engineers (USACE) has conducted beneficial use projects (i.e., using dredged material) in association with navigation improvement projects along all the US coastlines and the Great Lakes (Yozzo *et al.* 2004). The projects have included intertidal marsh and mudflat creation, bird and wildlife island establishment, beach nourishment, land reclamation, erosion control, and underwater reef and berm construction (Yozzo *et al.* 2004). Recently, the USACE created a dredge management plan (DMP) for New York harbour which includes seven potential categories of habitat restoration/creation using dredge material (Yozzo *et al.* 2004). Of the seven options listed for the beneficial use of dredge material, three of the ideas included the creation of artificial reefs and shoals, oyster reef restoration, and the creation/restoration of intertidal marshes and mudflats.

Langan (1988) noted that artificial shoals and/or berms composed of dredge material have been constructed in the US, South Africa, Netherlands, and Australia. The USACE developed two types of underwater berms primarily for protecting eroding shorelines which include feeder berms and stable berms (Yozzo *et al.* 2004). The feeder berms are constructed in shallow, near shore waters and provide a source of sand to eroding beaches with the stable berms constructed in the deeper water which help provide protection of the beaches by reducing the energy in the long-period storm waves (Yozzo *et al.* 2004).

The use of dredge material for constructing oyster beds has been conducted in the Chesapeake Bay area by depositing dredge material in historically productive oyster areas and capping the dredge material with a layer of oyster shell (Earhart *et al.* 1988). The vertical relief of the newly constructed bed must be at least 1 m in height and there must be approximately 1 m of water above the reef to protect it from wave action and ice shear (Yozzo *et al.* 2004). The DMP for New York/New Jersey Harbour looked at using dredge material for habitat restoration for the benefit of the marine environment and not restoring the historic oyster fishery. Unfortunately, the public considered that the dangers that could arise, particularly the spreading of human pathogens from illegal harvesting of the oyster beds constructed with contaminated dredge material, was too great to permit construction (Yozzo *et al.* 2004).

In the US the use of dredge material to restore/create intertidal marshes has been common for many years. Salt marsh construction has recently received attention, due to the acreage of tidal marshes that have been lost along the coast, the ecological benefits provided by the salt marshes, and the relative ease at which salt marsh vegetation can propagate on dredge material. Along the south Atlantic coast in the 1960s and 1970s techniques were developed for establishing smooth cordgrass (*Spartina alterniflora*) on dredge material disposal sites (Yozzo *et al.* 2004). The objectives of the early studies were to promote shoreline stabilization and to restore habitat lost due to anthropogenic growth in coastal areas. According to Yozzo *et al.* (2004), the technique of marsh creation using dredge material has been successful at locations along the Atlantic, Gulf and Pacific coasts.

3. Methodology

3.1 Field Research

The field research and interviewing component of this study occurred from January 18, 2004 through December 31, 2005, with the field research divided into two phases and the interviewing divided into three phases. The first phase of the field research was a preliminary site visit to both project locations to get an understanding of the biophysical aspects of each area. Previous data and research collected within the two study sites over the last 20 years was analyzed. This was done by collecting data from the provincial and federal regulators that are affiliated with the marine and terrestrial environments of PEI (DFO, PEIDAFA, and EC). After the data was collected for each location a comparison was conducted of the two study sites.

In addition to the preliminary site visits, more detailed site visits were conducted in August 2005, which included an aerial survey of both areas. To understand the coastal changes that had occurred in each area, an aerial photo comparison was conducted using digital photos supplied by the Prince Edward Island Department of Environment, Energy, and Forestry (PEIDEEF). PEIDEEF supplied orthorectified digital aerial photos from the years 2000, 1990 and 1974. The information provided by PEIDEEF was uploaded to geographic information system software (MapInfo Professional 6.0) in order assess coastal changes over the last 30 years.

3.2 Interviewing

The first phase of the interviewing component dealt with contacting the Harbour Authorities (HA) and fish harvesters at each study site, as well as local environmental groups and watershed groups. Potential participants were asked to participate in an interview process and fill out a questionnaire with regards to past, present and future enhancement work for the study sites and surrounding areas.

As this research project deals with interviewing human subjects, it was necessary to get approval from the Interdisciplinary Committee on Ethics in Human Research (ICEHR) from Memorial University of Newfoundland in order to conduct research. Approval was given on April 14, 2004 (ICEHR No. 2003/04-062-SC). Once approval was granted from the ICEHR, the local HA for each study site were contacted and asked if they would be willing to participate in a habitat compensation/enhancement research project that was being conducted within their area. Upon agreement, a "Letter of Intent" was mailed to each participant to outline the purpose of the research project, what type of information would be collected, and how the information would be used.

In addition, during phase I, the HAs were asked if they would produce a list of the local fish harvesters that could possibly have some local knowledge that would help in this research project. Each fish harvester listed was contacted and invited to participate under the conditions outlined above. Nine fish harvesters were interviewed: four from the Tracadie area and five from the Cascumpec area.

As well, nine Non-Government Organizations (NGO's), three provincial regulators and three federal regulators were interviewed.

The second phase included the interviewing and questionnaires. The interviews were conducted in person and lasted on average approximately one hour each. During the interview process, the interviewer recorded verbal information about the specific areas as expressed by each interviewee. The verbal part of the interview involved manually recording the information expressed by each individual interviewee.

After the verbal interview process, each person was then given a "Habitat Assessment Questionnaire" which they were asked to fill out (Appendix A). In order to maintain confidentiality each questionnaire and the verbal information recorded by the interviewer was issued an identification number. In the first section of the questionnaire the candidates were asked to list their occupation, what harbour/watershed they worked in, and what type of work they conducted.

The second part of the questionnaire dealt with questions concerning historical enhancement work performed in/around the local area: (1) When was the work conducted?, (2) Where was the work conducted?, (3) How was the work conducted?, and (4) Who conducted the work? The third part of the questionnaire asked each participant if they have any ideas for potential habitat enhancement work that could be conducted within the vicinity of the harbour/watershed in question. Each participant was asked to sign and date the confidentiality agreement.

The third phase was the evaluation of the interviewees' responses to the questionnaires, to assess viable enhancement ideas. The selection process for further review required meeting the socio-economic and environmental concerns of the surrounding communities, local fish harvesters, provincial and federal regulators, local watershed groups and environmental groups.

Each idea that was volunteered by the participants was evaluated to see if it could be integrated into the areas. Evaluation included historical research and review of aerial photos, as well as a review of the physical and biological features of the bay. From the evaluation enhancement ideas were selected, so that locations could be proposed for each type of enhancement. In addition to the ideas presented by the participants, each habitat compensation/enhancement idea was ranked based on the following two main broad themes: (1) economic impact; and, (2) environmental impact. These two main themes incorporate various criteria including:

- Impacts to local communities (economic, environmental, aesthetics, etc.);
- Overall economic implementations (i.e., cost effective to establish/build and low monitoring/maintenance costs); and,
- Track record of the type of MHCM from existing data.

Once this evaluation was conducted the enhancement ideas were ranked showing the most favorable to most unfavorable types of habitat compensation/enhancement for each project site.

4. **Interview Results**

Interviews were conducted from early winter 2004 through early winter 2005. This chapter is a summary of the themes and issues compiled from the interviewees. The two regions along the north shore of PEI were used in order to acquire an overall picture of the type of enhancement and/or remediation that could best benefit each region. The common themes and issues are compiled and organized by first considering comments from fish harvesters in each region, then comments from NGOs throughout the province, and finally information from provincial and federal government representatives.

4.1 Fish harvesters of Tracadie Harbour

The ideas raised by the local fish harvesters in the Tracadie Bay area varied depending on the type of fishing practiced (finfish, lobster, or shellfish). Although only four fish harvesters were interviewed, the selection process ensured that these people were representative of the views and ideas of the community as a whole. The interviewees were selected with help from the president of the local Harbour Authority, and were considered by the president to be the people to best represent the local fishing community and surrounding area with regards to understanding the local environment.

The most common theme was the subject of very poor water quality in and around the Corran Ban Bridge (at the mouth of the Winter River) during the summer months. Three of the four interviewees stated that they would like to see the causeway removed. The fish harvesters believed that poor water flow was created from the construction of the causeway and the sediment from tertiary streams was falling out in the slower water around the causeway creating a smaller opening for water flow.

Three of the interviewees expressed interest in dealing with the biomass (sea lettuce, *Ulva Lactucus*) problem that they felt had been increasing in the Winter River estuary. All four interviewees stated that the anaerobic conditions occurring in the estuary of the Winter River have been increasing in duration (extending further into the summer months) as well as recognizing increases in the total area affected within the estuary.

The interviewees believe that the anoxic conditions are due to numerous factors, but are not exactly sure where to start with regards to remediation of the problem. The interviewees feel that the causeway is causing a decrease in the water flow and speed in the section of the estuary above the bridge, causing the river to become shallower due to the fall out of sediment in the slower moving current.

The fish harvesters believe that the shallow waters and poor flushing among other factors are increasing the local water temperature. The water temperature may be rising in the Winter River considering that the water volume entering the estuary is smaller than normal. The cause of this decrease in water volume is because the Winter River Watershed is the sole watershed used to supply the city of Charlottetown with drinking water. Currently there are three separate City of Charlottetown well fields located in the Winter River Watershed.

One interviewee (TC02) stated that mussels growing in a bay that has an increased water temperature will migrate to a more beneficial habitat or reduce their amount of feeding. In turn, this will decrease the overall commercial value of the lease, considering that the growth time is longer and the yields are smaller.

In addition, aesthetic value would be increased by removing the causeway. The increase in local aesthetic value would have a positive impact on the local eco-tourism.

Three of the four interviewees stated that the upper estuary does not have the biodiversity it once had with regards to many types of fish species that used the area as a spawning ground. The fish harvesters would like to see enhancement that would deal with the reduction in fish species that currently no longer use the upper estuaries. Interviewee LH07 stated that the quahogs and clams in the bay no longer grow to a commercially harvestable size.

Another theme that was mentioned by 2 of the 4 interviewees dealt with the pollution levels in and around the harbour due to the on-site mussel plant. This plant has been in existence for approximately 20 years with additions over the last 12 years. The fishermen believe that the effluent discharge from the plant must be cleaned up.

Two of the four interviews would like to see some type of enhancement with regards to quahogs in the bay. They believe that the bay has the proper type of substrate for growing quahogs on a commercial level, but is less suitable for soft-shell clams. According to interviewees LH07 and QL08, the majority of the benthos in Tracadie and Winter Bays is sandy or muddy sand rather than mud. Quahogs prefer sandy or muddy sand, whereas soft shelled clams are usually found on muddier bottoms than quahogs (Gosner, 1978).

LH07 and QL08 also believed that if enhancement work was conducted around Tracadie Bay, the increasing amount of quahogs would provide the greatest socio-economic benefit to the area. In contrast, interviewee TC02 thought it was a good idea to enhance quahogs in the area but also believed that there would be a major problem considering the amount of mussel aquaculture that is currently in the bay. This interviewee thought that too many types of species in the bay will help decrease the average growout times considering the increase in species vs. lack of nutrients. A good example of this would be the decision by the local fish harvesters, enforced by the fish harvesters management plan, which only allows a maximum limit of 500 sock/acre (Neil McNair, PEIAFA, personal communication and CEAA 2002a). Prior to 2002 in Tracadie Bay, it was possible to have as many as 1000 mussels per sock, but the local fish harvesters set the lower limit in an effort to increase growth rates over time.

Some other ideas that were brought forward by one interviewee dealt with constructing salt marshes in the bay due to the biodiversity and productive capacity generated from a salt marsh. The same interviewee thought that some experimental work with mussel sets above the Winter River estuary might have a positive effect with regards to decreasing the amount of available nutrients for the sea lettuce further down the estuary.

A lobster harvester came forward with the idea to build a lobster reef in an area offshore. This location has been in-filled with sand over the past ten years and is no longer a viable fishing ground for lobster.

One idea shared by 2 of the interviewees was to dredge the southern channel that runs from the Tracadie Harbour into Tracadie Bay to increase the water flow. The dredge material that is removed from the channels should be placed in a different location than normal or used in the building of some type of enhancement project in the future. Currently the dredge material is side cast between the channel entrance and the approach road to Tracadie Harbour during the spring and summer months and over the fall and winter it moves back into the channel. The fishermen are not sure where the material should be placed, but they feel that it could be more beneficial in a different location.

Overall, the ideas and concerns expressed by the fish harvesters in Tracadie dealt mostly with the environmental health of the upper estuary. They focused mostly on mechanical/engineering methods such as removing the bridge in an effort to alleviate the biological issues plaguing the upper estuary. They also looked at mechanical and engineering solutions for the channel entrance and the area surrounding the mussel plant. All the fish harvesters felt that the biological loss occurring in the Bays and estuaries need to be addressed via experimental ideas and engineering. The fish harvesters of Tracadie feel that the biological health of the estuary and bay is the most important parameter that needs to be addressed.

4.2 Fish harvesters of North Port

The five fish harvesters that were interviewed in North Port included those harvesting lobster, shellfish, and ground fish. There are no mussel leases or mussel fish harvesters in North Port. The four main themes raised by the fish harvesters from North Port harbour were (1) poor water quality in Mill River and the surrounding area emptying into Cascumpec Bay, (2) the erosion of the barrier dune system that currently protects Cascumpec Bay, (3) the dredging of two channels, North Port Harbour entrance and Palmers Inlet (located east of the main estuary entrance), and (4) the reduction of sediment in the estuary.

With regards to the water quality issue, the interviewees believe that the poor water quality is the major cause of the anaerobic conditions that are increasing every year in the river systems. They feel that the water quality has resulted in the loss of fish species in the bay and rivers, including smelt, herring, Atlantic salmon, and trout. The interviewees believe that a reduction in sea lettuce, the removal of causeways in the upper estuary of the Mill River, and reduction in pollution and reduction in nutrient loading from the surrounding agricultural lands will help reduce the local anaerobic conditions. In addition, four of the five interviewees felt that excess run off from agricultural fields was major concern, but aside from the implementation of buffer zone regulations and education, they did not present a solution to abate the problem.

Three of the five fish harvesters believed that a reduction of pollution and nutrient loading would be most beneficial in dealing with the amount of biomass that is collecting with in the estuaries throughout the bay. It is normally the dying biomass that causes oxygen depletion in the rivers and the increase in anaerobic conditions. Most of the interviewees believe that removing the causeways in the tertiary regions of the Mill River will have a positive effect on the water quality of the Bay, and almost all would like to see a reduction in sediment collecting in the bay. None had any ideas as to how best abate the influx of sediment into the bay, caused by run off from agriculture land located with in the watershed.

Three of the five raised the idea of placing some type of material along the barrier dune system in order to decrease the amount of sand that moves into the bay during high winds and as of late, the increasing storms. The ideas that were suggested dealt with emplacing large objects (e.g. a former floating breakwater from North Port Harbour, which is no longer in use and being stored in a local farmer's field, old lobster traps and/or used Christmas trees). The idea behind all of these suggestions is to artificially create obstructions that would collect drifting sand. As well, the sand mounds could be seeded with marram grass to prevent erosion. The fish harvesters realize the importance of the barrier dune system and want to try and slow the process of the movement of the system into the bay.

One interviewee raised two interesting issues that were very site specific. The interviewee mentioned that if any enhancement work was to be conducted it should (1) have a positive effect with regards to ecotourism in the area (i.e., considering the amount of summer residences with in the watershed and the influx of tourists during the summer months), and (2) take into account the increased storm occurrences along the north shore particularly storm surges, and the increasing water level due to climate change.

The Cascumpec area fish harvesters are more united in their ideas for enhancement. Overall, they would prefer to see work conducted on the barrier dunes and outer coastline to help reduce erosion over the upper estuaries and rivers. They would like to have the eastern entrance to Cascumpec dredged, but dredging is not as major an issue as in Tracadie. In comparison to Tracadie, the Cascmpec fish harvesters would like to see changes in practices along the rivers and estuaries, especially practices and regulations that would help promote better water quality.

4.3 Non-Government Organizations

The Non-Government Organizations (NGOs) interviewed were made up of local environmental groups that have been working throughout PEI for a number of years. Almost all the groups represent a specific watershed on PEI. Table 4.1 lists the NGOs that participated in the interview process.

Of the groups listed in Table 4.1, PEIFA represented the provincial fisheries organization, and PEISA represented the provincial shellfish harvesters. Two other NGOs represented groups that dealt with environmental issues throughout PEI (DU and INT). SEA represented the eastern end of PEI. Four groups represented different watersheds throughout PEI. WREC representing the Winter River watershed, and two environmental groups represented two separate tributaries of Cascumpec Bay, Trout River (OWF) and Mill River (MRWIC), respectively. TREC represented the Trout River Watershed part of New London Bay.

Table 4.1 – NGO's Interviewed

Non Government Organizations (NGO's) Interviewed
Prince Edward Island Fishermen's Association (PEIFA)
Winter River Environmental Committee (WREC)
Prince Edward Island Shellfish Association (PEISA)
Island Nature Trust (INT)
Ducks Unlimited (DU)
Trout River Environmental Committee (TREC)
Southeast Environmental Association (SEA)
Mill River Watershed Improvement Committee (MRWIC)
O'Leary Wildlife Federation (OWF)

As four of the NGOs interviewed represented watershed groups, the themes and ideas were centered around enhancement work conducted in the freshwater regions of the watershed, although not exclusively. Some interviewees mentioned that enhancement work needed to be conducted in order to reduce the amount of biomass (sea lettuce) located within the estuaries. WREC and MRWIC believe that the causeways need to be removed in order to increase water quality in the surrounding area. DU, TREC and SEA all expressed the importance of enhancement with regards to salt marsh creation especially in the estuaries of watersheds that have large tidal flats. All the NGOs agreed that the majority of the problem related to water quality in the estuaries comes from issues related to the upper portions of the river systems (i.e., lack of buffer zones, nutrient loading, shallow streams, erosion from agricultural land, water temperature and oxygen levels). The representative from TREC explained an innovative and inexpensive way of creating the building blocks for a salt marsh by trapping sediment in the upper estuaries using brush mats and discarded Christmas trees. TREC is currently trying to turn very wide shallow estuaries into narrow fast moving water by placing Christmas trees and brushmats adjacent to the channel, which is supposedly trapping silt and building the banks creating a faster defined channel through the estuary. TREC's innovation is creating defined fast moving channels with mudflats on both sides.

In contrast to most NGOs and fish harvesters, one interviewee from OWF indicated the importance of not removing any existing bridge structures if they allowed for proper water flow during low tide. This interviewee stated that Goff's bridge, crossing the Trout River watershed (a tributary of Cascumpec Bay), had been there for almost 100 years, and that the problem with the anoxic conditions only started to occur in the last 30 years. He believed that the removal of the bridge structure would create a mass movement of sediment into the estuary and possible destruction of viable marine habitat that has existed for years. The interviewee stressed the importance of buffer zones and education with regards to the proper land management for both agricultural and wood lot owners. The interviewee also believed that the main problem with biomass in the estuaries cannot be addressed prior to better land management. The interviewee suggested that other NGOs and fish harvesters want to see some environmental enhancement with regards to biomass reduction, but unless they looked at the cause, they would be unsuccessful in resolving the problem.

Most groups believed that education and awareness is the major struggle when dealing with the watersheds. If enhancement work is to be successful the education of the local community needs to be a major role. They stressed the importance of educating local farmers with regards to buffer zones and proper land management. The groups also talked about keeping the river systems clean and free from garbage and pollution (e.g. from septic systems).

The interviewee from the PEISA wanted to see an increase in the amount of shell bed cultivation throughout PEI, with an increase in deep and shallow water relays, spat collection and shell mining. Another idea that was expressed by both SEA and MRWIC was to conduct research with regards to invasive species migrating throughout the PEI estuaries.

4.4 Provincial and Federal Governments

The provincial government representatives interviewed included three members of two different sections of the Prince Edward Island Department of Agriculture, Fisheries and Aquaculture (PEIDAFA). All three representatives interviewed from the federal government were members of the DFO-HMB from PEI and New Brunswick.

The PEIDAFA representatives as a group thought that more enhancement work needed to be conducted within the estuaries but were not exactly sure what should be done. They stated that, over their numerous years of working for the province, many types of enhancement have been conducted (as discussed in section 2.2 above), but that the work was either unsuccessful, with great expense and limited return, or no follow-up monitoring had occurred to see the results of the enhancement projects.

Some representatives of the PEIDAFA believed that more research is needed to be done to find additional cost effective commercial fisheries, especially within the shellfishing industry (via new markets or new native species to be harvested). One representative believed that additional work with regards to salt marsh restoration would have positive effects on local water quality. A phone conversation with Rose MacFarlane (PEIDEEF), outside of the interview process, indicated that the Winter River no longer supported Atlantic salmon.

The federal government representatives stated that there has been substantial enhancement work conducted over the last 5 years. However, nothing has been studied in depth or the work is so new that there is very little data to work from. The Fisheries and Oceans interviewees stated that they are looking at habitat enhancement for the purposes of overall ecosystem enhancement as well as compensation for loss a of fish habitat, as per the *Fisheries Act*. The representative from DFO-HMB on PEI believed that the most socio-economic and cost effect types of enhancement/compensation projects are ones that deal with oysters, quahogs, and soft-shelled clams. The representative expressed the importance of maintaining the existing shellfishing industry throughout PEI, and any type of enhancement should be conducted with that goal in mind. He mentioned artificial reef creation, research looking at water quality and invasive species, and eelgrass transplantation, but considered these ideas, with the exception of research based enhancement, to be both expensive and requiring too much time (i.e., many years) to see an overall positive effect considering the time required up front.

Although the DFO-HMB representatives from NB believed that enhancement towards shellfish is important, they had some additional marine habitat enhancement/compensation ideas. Reclamation of marine habitat by removing old wharves or causeways was mentioned. One of the interviewees thought that if a marine species could not be enhanced directly than enhancement should be conducted that would affect the species indirectly (i.e., looking at enhancing marine species at a lower trophic level).

Another idea cited was constructing underwater fingers that radiate out from a structure, such as a breakwater. This would increase the amount of interstitial spaces, in turn increase habitat for particular species. Performing beach nourishment was also suggested to help restore spawning grounds.

Other ideas that were mentioned during the interview dealt with conducting research, including research on predator control, fish production; and monitoring performance of artificial reefs. One DFO-HMB representatives talked about compensation with regards to recovery plans for species listed under the *Species at Risk Act (SARA),* as well as looking at compensation in dollar values instead of habitat enhancement.

4.5 Discussion

The most apparent difference among the five groups interviewed is that the fish harvesters expressed ideas resulting in a direct impact to the commercial fishery, although most of the fish harvesters were looking at the near or immediate future. In contrast, the NGOs and Provincial government representatives mainly focused on maintaining the health of the estuaries and the surrounding environment over the longer term. The members of DFO-HMB expressed both ideas that directly impacted the local commercial fisheries and the surrounding environment for both the immediate and longer-term future of the fisheries, if possible. The reasons DFO-HMB focused mainly on the commercial fisheries are due to the laws they govern (i.e., *Federal Fisheries Act*) and the net effect for the commercial users in the area. All groups felt that major work needed to be conducted to address the water quality issues that have been increasing in recent years.

The fish harvesters and DFO-HMB interviewees mostly looked at the immediate ecological unit (e.g., by considering impacts on individual species in particular, in the estuary), whereas the NGOs and Provincial Government representatives were looking at the entire watershed and beyond. The DFO-HMB also mentioned the importance of the commercial fishery through indirect methods, including enhancing lower trophic levels, research into invasive species and fish production, although they are currently bound by their interpretation of the *Fisheries Act* to only allow projects of enhancement for the purpose of compensation to be conducted in the area of the loss of habitat (i.e., marine habitat loss – marine enhancement and freshwater habitat loss – freshwater enhancement).

The enhancement ideas suggested by most fish harvesters were site-specific. The government organizations and NGOs suggested ideas that could be applied locally to particular sites, but which were also applicable for addressing regional enhancement over longer periods. The main reason for that difference is because the local fish harvesters, with the exception of two individuals, did not talk about creating new habitat. The NGOs and Government organizations mentioned numerous ideas with regards to habitat creation (i.e., salt marshes and shellfish beds).

Most of the NGOs and the majority of fish harvesters suggested modification or removal of the bridges across estuary tributaries. However, opinion was not unanimous. For instance, in Cascumpec the majority of the fish harvesters focused on the sedimentation issue in the bay and how they thought it could be reduced through abating the movement/erosion of the Barrier dune system, which was not mentioned by the fish harvesters in Tracadie. Few of the fish harvesters in Cascumpec talked about the upper estuaries and bridge modifications. In contrast, the Miller River NGO group expressed major concerns with the causeways and water quality.

In contrast, all the fish harvesters and the NGO group for the Winter Bay expressed the importance of water circulation and the modification of the Corran Ban Bridge. Other site specific differences were that the fish harvesters in Tracadie mentioned habitat enhancements of particular species (shellfish) as well as marsh enhancement, whereas the fish harvesters for Cascumpec did not mention any specific habitat enhancement ideas.

The majority of the NGO's can be classified as strictly mentioning ideas that address their mandate or the area they work in. Neither Provincial nor Federal Government personnel mentioned any regulatory issues or suggested regulatory changes or amendments.

Most of the ideas mentioned dealt with issues that are seen on a day to day basis within the watersheds. For instance, the water quality issues pertaining to the upper estuaries are reoccurring and very visual to residents. Eutrophication in the estuaries plays a major role in reducing potential ecotourism and the aesthetics of the surrounding coast. Hence the reason that all the local watershed groups and the majority of fish harvesters mutually support any work that is related to addressing water quality issues in their areas.

Most interviews showed mutual support towards the province-wide issue of water quality. Exclusive support was shown in Casumpec with regards to reducing sedimentation of the bay and in Tracadie with regards to specific enhancement measures. Some fish harvesters in both areas showed support for dredging channels to increase water quality.

5. Site Specific Investigations

Investigations in Cascumpec and Tracadie Bays, combined with discussions with interviewees, have suggested some potential courses of action for habitat enhancement. Although research and habitat enhancement efforts in estuaries in Maritime Canada have not been extensively conducted, examples of investigations and successful applications in other locations with similar climates, oceanographic conditions, and geomorphology exist. The data and results from these studies could be considered for Cascumpec and Tracadie Bays. In addition to shellfish enhancement and artificial reef creation, three suggested methods of habitat enhancement are beach nourishment, salt marsh creation and reduction in sea lettuce concentrations.

The following chapter looks at the above mentioned enhancement ideas, paying particular attention to how each concept impacts components of the fisheries and communities in both Tracadie and Cascumpec. The section on shellfish evaluates historic enhancements conducted in each area as well as information from the interviews, to examine the effectiveness, if any, of implementing specific types of shellfish enhancement in each area. Lobster enhancement in both areas is evaluated since it was mentioned in one interview. Beach nourishment is evaluated, because of the amount of interviewees, especially from the Cascumpec area, that were interested in reducing erosion of the barrier dunes, in turn protecting the inner bays. Salt marsh enhancement was evaluated for both areas, since this approach is an up and coming enhancement method in the Maritime Provinces with extremely beneficial effects.

The last enhancement idea evaluated in this chapter examines water quality and the possible ways to improve the diminishing water quality currently plaguing many rivers and estuaries of PEI. The final section of this chapter evaluates the impact of the enhancement concepts on the local communities taking into consideration economic, environmental, and aesthetic impacts.

5.1 Shellfish Enhancement

5.1.1 Introduction

The most common type of shellfish enhancement on PEI has been oyster enhancement, which has been conducted for many years (see section 2.2). Oyster enhancement on PEI has many benefits as a type of marine habitat enhancement method. In addition to the obvious shell fishery enhancement the newly created beds can help increase the overall biodiversity of the surrounding ecological unit and help create a healthier fishery for years to come.

The watersheds of PEI are inundated with different types of commercial shellfish fisheries. The majority of the western bays, including Cascumpec, along the north shore are catering to the oyster fishery with many public beds. These public beds are havens for the main types of oyster enhancement projects that were mentioned in the previous chapter. The majority of the eastern bays along the north shore cater to mussel aquaculture, including Tracadie. The bays are sheltered along the north by barrier dune systems, making the estuaries viable growing areas for commercial shellfish.

5.1.2 Cascumpec Bay

During interviews, there was no mention or indication for the need to perform shellfish enhancement in the Cascumpec area. This does not imply that enhancement would not be beneficial, however, or that none has been conducted in the area. PEISA (2003a, 2003b) has conducted oyster enhancement at public beds in the Mill and Kildare rivers and Cascumpec Bay (Fig. 5.1). Tubs of spat were relayed from the Bidford River to seven locations in the Mill and Hill River (a tributary of the Mill River), five locations in Cascumpec Bay, and three locations in the Kildare River in 2002. In total, 56 tubs were relayed to the upper reaches of the Kildare, 460 to the Mill and Hill Rivers, and 243 to the Cascumpec Bay area (PEISA 2003a). In 2003, the PEISA placed tubs of spat in one new location in the Hill River as well as placing tubs in three of the 2002 locations (PEISA 2003b).. In total, 98 tubs of spat were spread in 2003 (PEISA 2003b).

These efforts demonstrate that there are numerous locations in the Cascumpec area where additional shellfish enhancement could be conducted, although the areas are not as numerous as in several other PEI bays and spat spreading is not guaranteed to be a successful enhancement measure every year. Currently, the Foxley River is one of the most heavily utilized rivers with private oyster leases on PEI (DFO 2001). Private oyster leases limit the available area for public enhancement efforts. For enhancement efforts to benefit the local public fishery, it is necessary to enhance public beds. This is the reason why local NGOs have not completed any significant projects in the Foxley River, although private lease owners do conduct their own relays and spat releases.

Figure 5.1 Digitized 2000 aerial photo of the Mill, Hill and Kildare Rivers and Cascumpec Bay showing the locations the PEISA spread oyster spat in 2002 and 2003 (PEISA, 2003a and 2003b) (photo courtesy of the PEIDEEF, Ortho Photo Nos. 017, 018, 030, 031, 032 and 033).

The type of shellfish enhancement that would work very well in the Cascumpec area has historically involved relaying and spat spreading (Frank Hansen, PEISA, personal communication). Currently, any shellfish enhancement that is conducted on PEI, is done either by the private lease owners, government agencies and NGOs. Future beneficial enhancement work in Cascumpec would involve relaying or spat spreading in the upper estuaries of the Mill or Hill Rivers (Frank Hansen, PEISA, personnel communication). Potentially, any of the locations illustrated on Fig. 5.1 where spat was spread previously could benefit from additional spat release. As well, relays could be conducted from different rivers, or from shallow water to deeper water to help create new or extend existing public beds. The continuation of spreading spat over top of existing beds has been conducted for many years in the estuaries of Cascumpec and has been very productive for the local shellfish harvesters (Frank Hansen, PEISA, personnel communication). Unfortunately, attempts to create new beds in what would appear to very hospitable shellfish habitat directly in Cascumpec Bay have proven to be a gamble. Historic bed creation and relays have not been very successful in the bay and has been an enigma for many years due to the fact that the estuaries of Cascumpec create very good brood stock that do not create beds or settle on new beds that have been historically created in the bay (Frank Hansen, PEISA, personnel communication).

5.1.3 Tracadie Bay

Shellfish enhancement has been conducted in Tracadie Bay in the recent past. PEIDAFA tried to create soft shell clam beds at the northeastern end of the bay in the intertidal waters of southern side of the Blooming Point dune (Neil McNair, PEIDAFA, personal communication). According to Mr. McNair, the landings in Tracadie were not very high mostly due to the migrating sand, lack of recruitment, recruitment mortality, predators, and disease (i.e., *Haemic neoplasia*) and the project was not continued.

Research from the Tracadie area indicated that there is some interest among the local fish harvesters to enhance additional types of shellfish in the Bay, particularly quahogs (M*ercenaria mercenaria*). According to the local fish harvesters, only 'false' quahogs (i.e., quahogs no larger than approximately 2 cm in diameter) can be found in Tracadie Bay. The potential cause of this phenomenon may be that the bay has reached a threshold/saturation point with available nutrients and required nutrients and there is not enough nutrients to grow out the quahogs. Unfortunately, establishment of this suggestion would need extensive research. One fish harvester does believe that the bay is currently inundated with a sufficient commercial shellfishery (see section 4.1) and that any additional types of commercial fisheries in the bay would increase grow out times and reduce overall yields of existing mussel aquaculture farms. Therefore, enhancing quahog or soft clam habitats in Tracadie is a very large gamble, considering that the time, energy and funding may be wasted on a negative result. If the enhancement was successful, and quahogs and soft shell clams did start to flourish, it could have a negative effect on the bay as a whole and reduce the yields and increase grow out times for the very viable mussel industry in the bay. Consequently, enhancement efforts directed exclusively at quahogs in the Tracadie Bay area should not be considered.

5.2 Lobster Enhancement

There are many historic and present lobster enhancement projects existing in the southern Gulf of St. Lawrence. Surprisingly, none of the projects have been conducted along the north shore of PEI. As noted in the findings above, only one fish harvester mentioned lobster enhancement (i.e., constructing lobster habitat near Blooming Point) as the interviewee indicated that there is a small area off shore that has been infilling with sand for the last number of years. Unfortunately, locating a suitable place for conducting lobster enhancement along the north shore would be very difficult because of the amount of suitable habitat that currently exists. The main reason behind the lack of enhancement is that the north shore lobster fishery is a viable and continuously productive fishing industry (i.e., if it is not broken, do not try and fix it; Michel Comeau, DFO-Science, personnel communication). In addition, Michel Comeau also stated that the coastal waters along the north shore of PEI do not lack viable lobster habitat. Therefore, lobster enhancement along the north shore would not be the most beneficial enhancement work in the area considering the amount of good habitat that exists as well, if an area is not good lobster habitat there is probably a reason (sand transport; excessive silt; no rocky substrate is exposed).

5.3 Barrier Migration and Beach Nourishment

5.3.1 Introduction

Beach nourishment is a common practice along many sand-dominated, dune-backed coastlines where coastal erosion is significant. In parts of the southern Gulf of St. Lawrence, particularly in northern New Brunswick, it has been conducted in the past by DFO-SCH as a short-term erosion prevention measure for neighboring properties, rather than as a method of marine enhancement, particularly in areas where the natural littoral drift has been impeded by a coastal structure and sand by-pass is conducted from one side of the structure to the other (Normand Arsenault, PWGSC and Guy Robichaud, DFO-HMB, personal communication).

Along the north shore of PEI, several barrier sand dunes protecting the inner bays and estuaries from the Gulf of St. Lawrence could benefit from beach nourishment. In the last 50 years, the barrier dunes have been breached by storm waves, subjected to wind erosion, and have retreated, the result of numerous stresses but most notably due to weather, ice and anthropogenic effects (McCulloch *et. al.* 2002).

For many years the barrier dunes on PEI have been an attraction due to the attractive environment and picturesque landscape, but in order to find the real beauty of the barrier dune systems it is necessary to look at their many functions. One critical function impacting the economy of PEI is the protection provided to the inner bays and estuaries from the Gulf of St. Lawrence, vital to the local fishing economy and fish habitat. The barrier dunes protect the shellfish beds and valuable nursery and spawning grounds for many commercial fisheries from intrusion of storm surges and sediment influx. They are critical for the maintenance of estuarine ecology.

Maintenance of the barrier dune systems also can act to reduce landward migration, in response to rising sea level (ASMFC 2002). As the sea level rises and storm frequency potentially increases it is becoming increasingly more important to protect the barrier sand dunes. The effects of climate change on barrier sand dunes can be devastating if the dunes are left to fend for themselves against the increasing storm events and sea level rise. There will be an increase in wind blowouts and washovers, which inevitably compromise the stability of the dune system causing faster migration of the barrier bars into the estuaries, reducing the overall socio-economic productive capacity of the estuaries (i.e., both from a commercial and ecotourism standpoint).

Rising sea levels and climate change will have great ecological consequences that may cause the degradation of important marine, dune, tidal pool, salt marsh and estuary habitats along the coasts of the National Parks in the Southern Gulf of St. Lawrence (Scott and Suffling 2000). Since 2000, major storms have caused extensive damage to the dunes of the north shore of PEI, most notably in January 2000 and in December 2004 (McCulloch *et. al.* 2002; CBC 2006). The storm in December 2004 caused a major blowout in the dune system at Crowbush Cove, PEI allowing sea water to flood two holes of the Crowbush golf course (CBC 2006).

In addition, the presence of the dune system along the north shore protects the sandstone cliffs, which are particularly vulnerable to erosive processes (McCulloch *et. al.* 2002). The presence of the sand dune system is the most important land-conservation tool currently available, and its absence could lead to accelerated rates of erosion in vulnerable areas. This increase in erosion may cause silt to accumulate in spawning and nursery areas, causing infilling of the estuaries and bays. This would have drastic consequences on the commercial fishery of PEI, which in 2004 had a landed valued of approximately $165 million and an overall economic value of approximately $360 million (the third most important industry behind tourism and agriculture) (PEIDAFA 2004).

5.3.2 Cascumpec Bay

Cascumpec Bay is protected by the Kildare Point sand spit at the western end, and the Cascumpec Sand Hills Island in the middle. The barrier is split by the Conway Narrows at the eastern end. The barrier dune system of Cascumpec Bay is low-lying, with maximum elevations ranging from 1 m asl near the middle of the Barrier dune system to areas 4-5 m asl near the entrance of Alberton Channel Harbour. The barrier islands range in width from approximately 50 to 500 m. The dunes are low due to the direction and distance of sediment transport, as well as low rates of sediment retention. Longshore sediment transport trends from west to east, from North Cape to Malpeque Bay (Owens 1979). Sediment arriving at the north end of Cascumpec Bay is eroded predominantly from Cape Kildare, where rates of coastal retreat are approximately 70-90 cm/a (Genest and Joseph 1989). Lesser contributions of sediment are delivered to the barrier island system from rivers entering Cascumpec Bay. However, the majority of the sediment provided from erosion of the glacial diamicton and bedrock at Cape Kildare, and along the river banks, is silt and clay, and hence is transported in suspension and not deposited on the barrier island system.

Sand derived from glacial sediments and Permian bedrock is transported southeast to Cascumpec Bay, but the configuration of the shoreline limits the accumulation of sand. The absence of a transverse bathymetric obstruction, due to the alignment of the bedrock strata parallel to the shore, does not provide a locus for sand accumulation. In combination with strong winds propelling the current along the Gulf of St. Lawrence, the result is that sand from Cape Kildare is swept along the outer margin of Cascumpec Bay to the southeast, effectively limiting supply to the dune systems and preventing construction of large features.

An additional problem is the local absence or scarcity of vegetation on the Cascumpec barrier dunes. In combination with patches of moist sand, vegetation is critical in trapping windblown sand on dune surfaces, allowing the dunes to accumulate and grow vertically. Removal of vegetation results in dune migration, blowouts, and lowering of the crests (e.g. Catto *et al.* 2002). Winds blowing across a low, unvegetated sand surface act to further erode the exposed sediment, weakening the system and rendering it more vulnerable to storm surge overwash and breaching. Low barrier dunes tend to be less vegetated, as they are more exposed to storm wave and wind activity, resulting in a feedback relationship that progressively weakens the dunes over time.

Damage to vegetation resulting from anthropogenic disturbance also results in reduction of sediment retention and increased erosion. In local areas, compaction of the sand resulting from ATV use creates linear blowout paths which are areas of increased erosion, and can form routes for storm surge breaching (Catto *et al.* 2002).

Study of aerial photos of the Cascumpec Bay barrier islands indicates that they are unstable and moving landward. A comparison of aerial photos from 1974, 1990, and 2000 shows that the seaward flank of the system has moved approximately 100 m inland with the landward side moving approximately 50 m inland at the western end at Savage Island.

The eastern side of the entrance channel, along the western flank of the Cascumpec Sand Hills, has become smaller over the last 30 years by approximately 250 m. Aerial photos from 1974 show the original lighthouse, built in the late 1800s, and a square skeleton tower that was constructed in the early 1970's. In the 1974 photo (Fig. 5.2) the tower is approximately 100 m from the edge of the beach where the vegetation cover starts.

The 2000 aerial photo (Fig. 5.3) shows the skeleton light tower to be approximately 45 m from the edge of the vegetated area. Figure 5.4, a photo taken by the Canadian Coast Guard in 2004, shows the skeleton tower in the intertidal zone with the vegetated edge approximately 15 m landward of the light tower. The light tower was decommissioned in 2004 due to a major storm event

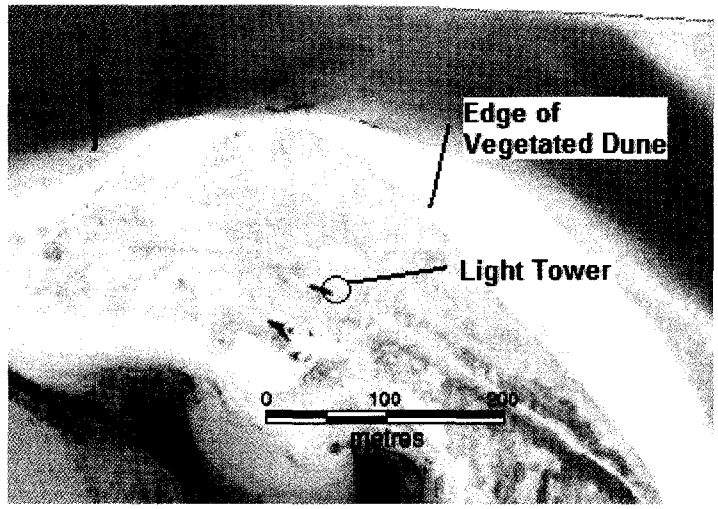

Figure 5.2 - Digitized 1974 aerial photo of the northwestern end of Cascumpec Barrier Island showing the light tower and the existing vegetative dune (photo courtesy of the PEIDEEF, Photo No. 74110-53-L63).

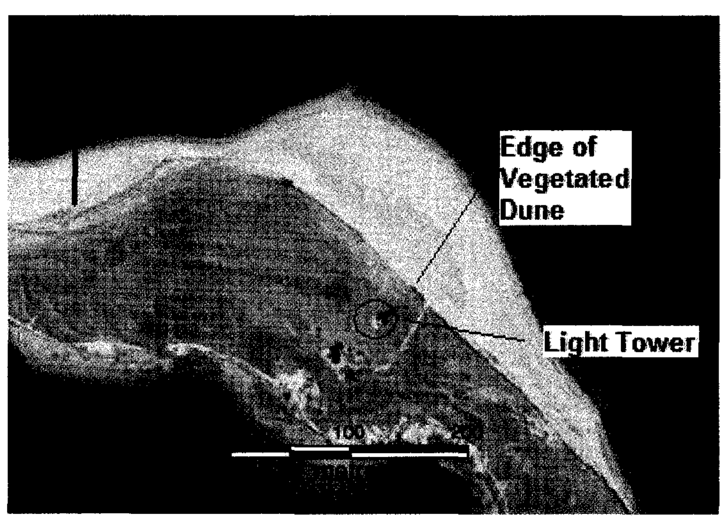

Figure 5.3 - Digitized 2000 ortho-rectified aerial photo of the northwestern end of Cascumpec Barrier Island showing the light tower and the existing vegetative dune (photo courtesy of the PEIDEEF, Orthomap 032).

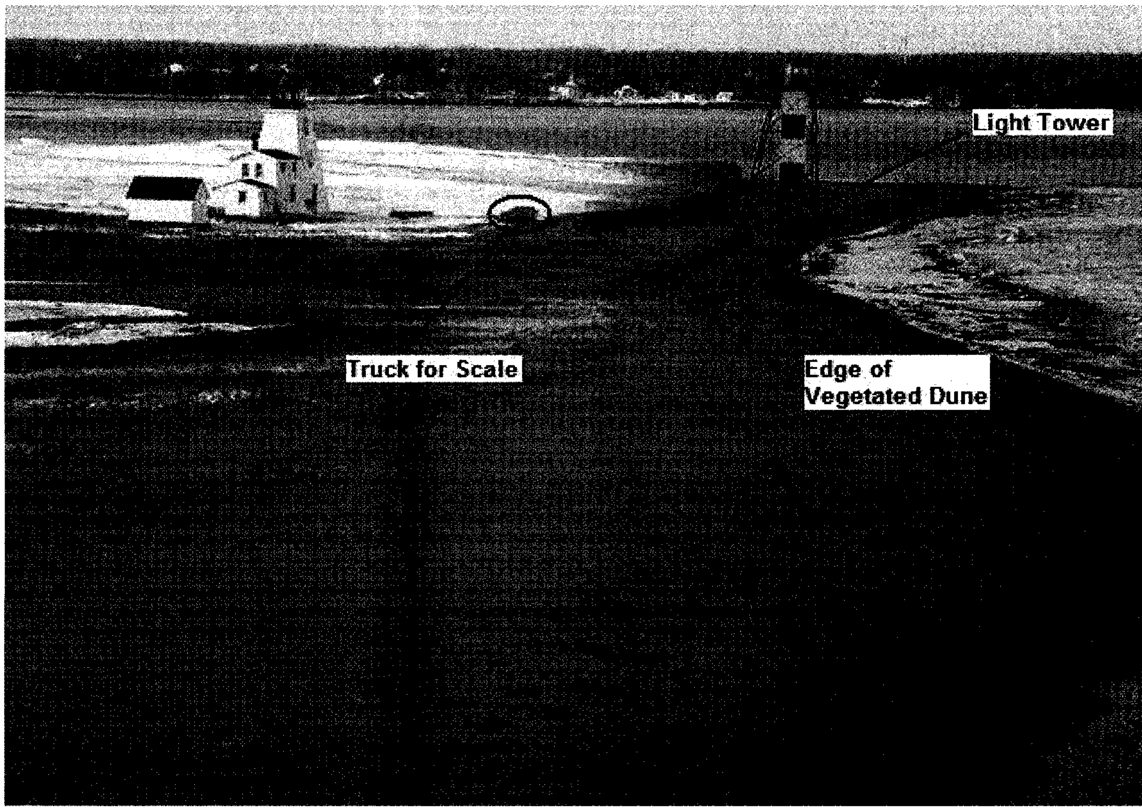

Figure 5.4 – Overall of view of the Light Tower on Cascumpec Sand Hills taken in 2004 after a major storm event in December 2003 Courtesy of the Department of Fisheries and Oceans – Canadian Coast Guard.

in the winter of 2003 that completely destroyed the structural integrity of the structure (Bob MacMillan, Canadian Coast Guard, personal communication). Therefore over the course of the last 30 years the dune has eroded approximately 115 m or 380 cm/a, which is higher than the average erosion rate.

Review of the aerial photos (Fig. 5.5, 5.6) also shows change in the eastern channel (Palmers Inlet) entrance. The minimum width of the channel has decreased from approximately 400 m in 1974, to 250 m in 1990, and to only 50 m in 2000.

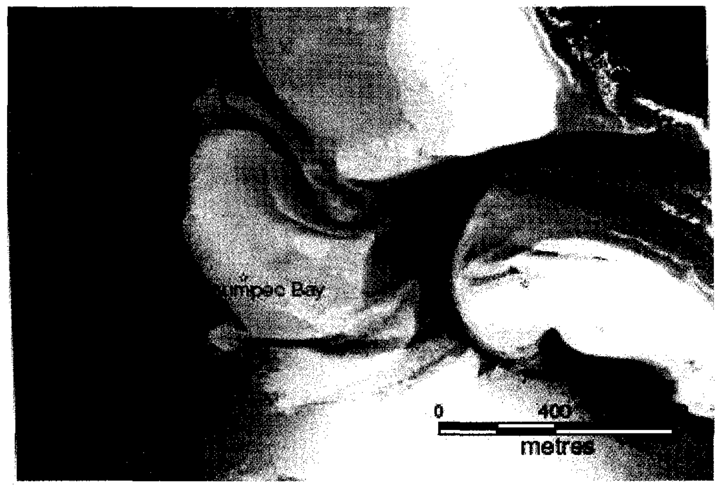

Figure 5.5 - Digitized 1974 aerial photo of Palmers Inlet at the southeastern end of Cascumpec Barrier Island (photo courtesy of the PEIDEEF, Photo No. 74112-031-L60).

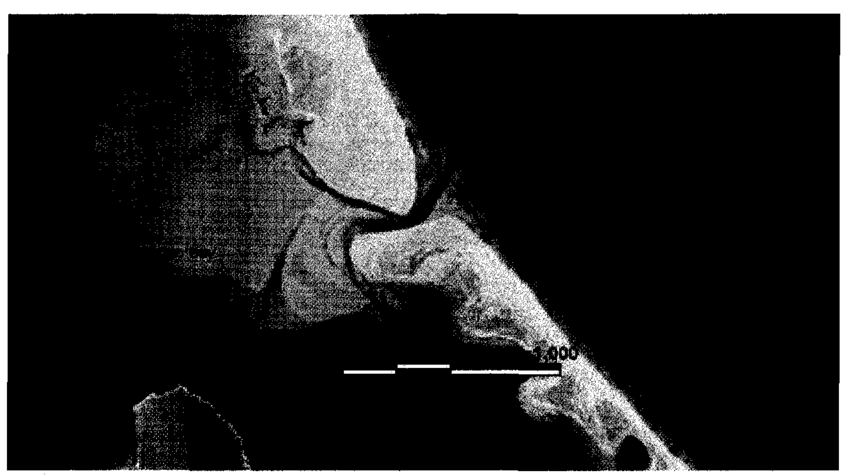

Figure 5.6 - Digitized 2000 ortho-rectified aerial photo of Palmers Inlet at the southeastern end of Cascumpec Barrier Island (photo courtesy of the PEIDAAF, Orthomap Nos. 032 and 043).

In August 2005, an aerial survey of the area was performed. Two areas along the main barrier dune appeared to have been breached in the recent past: one centrally in the sand hills (approximately 2800 m from lighthouse, marked with an A in Fig. 5.7), and the second further east toward the eastern channel

(4300 m from lighthouse, marked with a B in Fig. 5.7). Examination of the 1974 aerial photographs indicated that the two recent breaches occupied positions which had been subject to failure at some time prior to 1974, indicating re-use of these zones of weakness by storm surges.

An approximately 2000 m^2 area located approximately 100 m east of the lighthouse and extending for an additional 200 m, is marked by the absence of vegetation (Location C on Fig. 5.7). This area was subject to washover on at least one occasion since 2000. The northeaster of December 2003 lasted for multiple days with wind speeds that reached 102 km/hour for at least three days. During December 2003, there were only 5 days all month when the wind was below 31 km/hour (EC, 2004; Robert Delong, Lighthouse Owner, personal communication). The washover was facilitated by the disappearance of offshore sand bars (Peter Curley, PWGSC; Robert Delong, Lighthouse Owner, personal communication). Figure 5.8 shows an eastern aerial view of the breach in the spring of 2004 in relation to the lighthouse. The erosion of the offshore bars, resulting from prolonged/increased storm activity, decreased sediment supply and intrusive clam harvesting equipment, exposed the dune face to storm surge activity, resulting in overwash.

Further comparison of the aerial photos in the Cascumpec area over the last 30 years shows that the vegetation along the barrier dune has diminished between 1974 and 2000. The vegetation band in the area seaward of the lighthouse has been over washed and has lost approximately 115 m over the last 30 years (Fig. 5.2, 5.3, 5.4). In addition, the 550 m^2 forested area and salt marsh

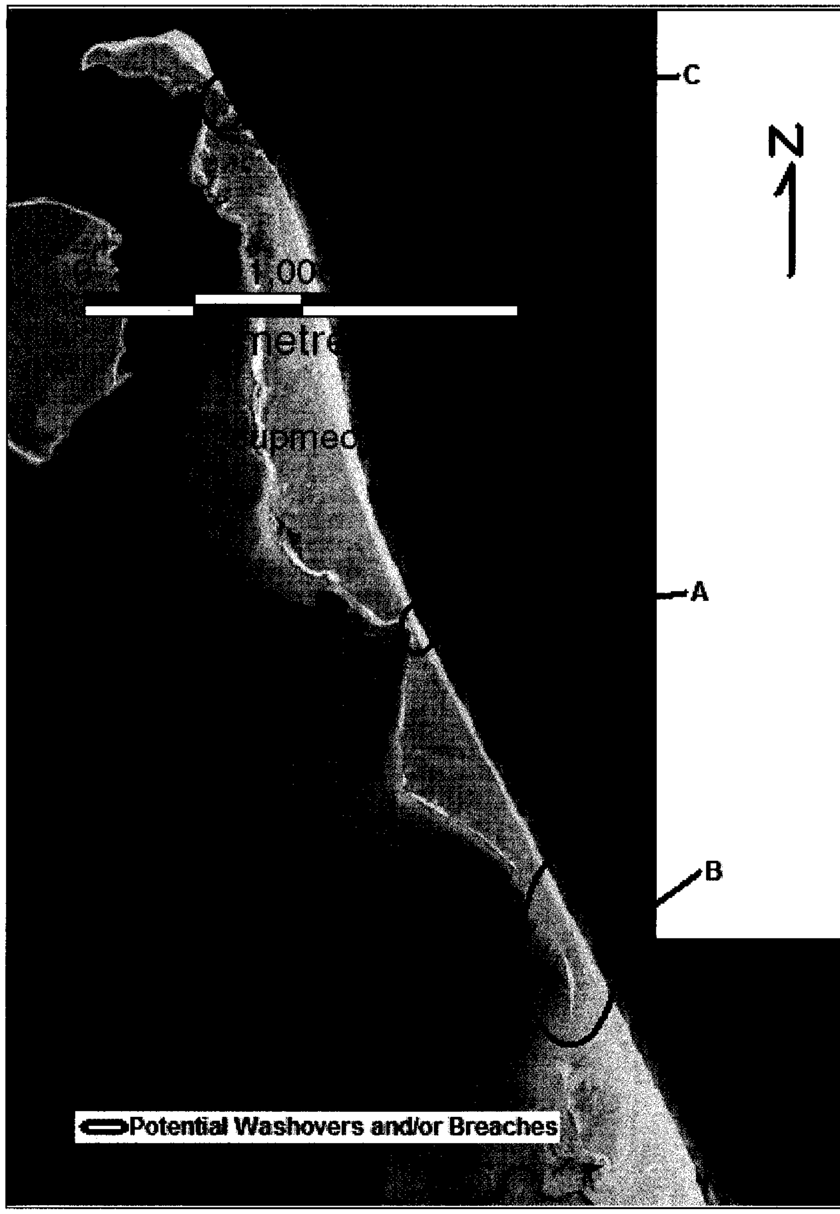

Figure 5.7 - Digitized 2000 ortho-rectified aerial photo of the Cascumpec Barrier Island showing areas of potential breaches and/or washovers (Photo courtesy of the PEIDEEF Orthomap No. 032).

area approximately 300 m east of the lighthouse was lost and filled in during the storm of December 2003 (Robert Delong, Lighthouse Owner, personal communication) Fig. 5.9 shows the forested and salt marsh area lost in the last 3 years.

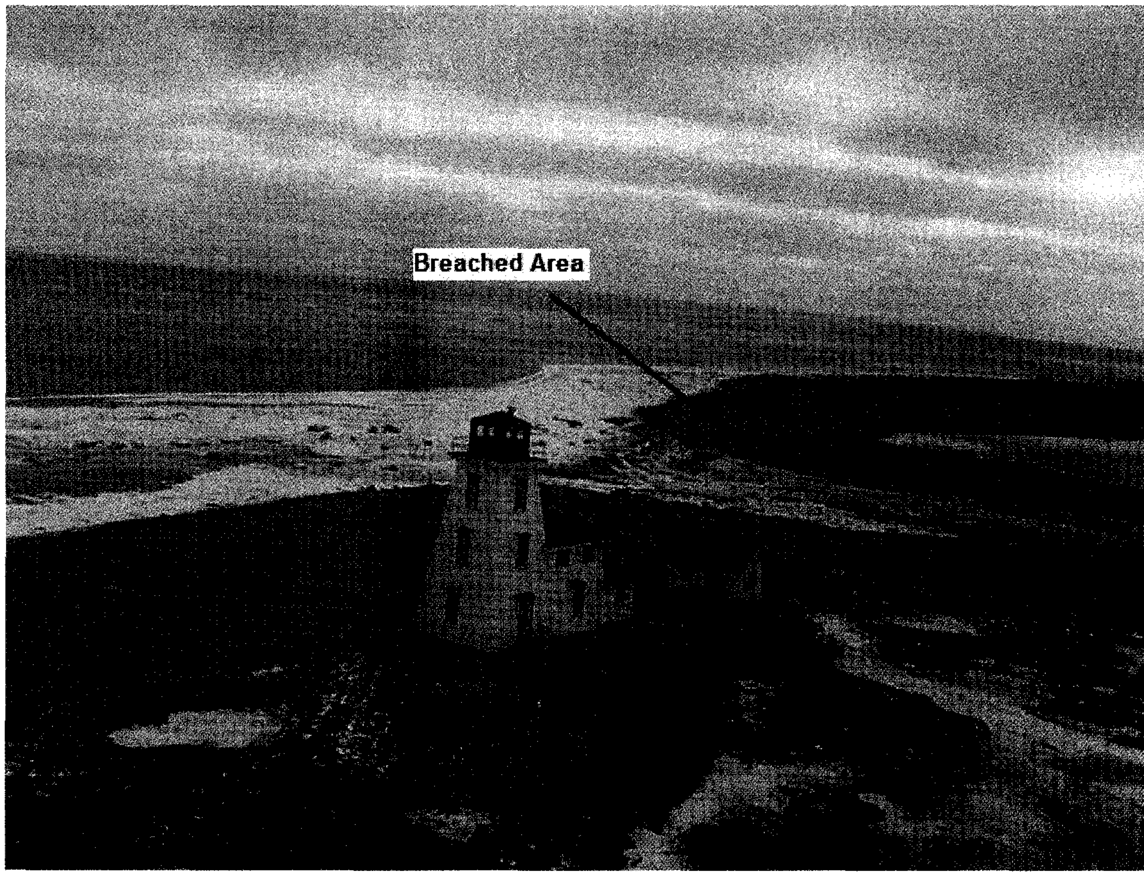

Figure 5.8 – Breach from the December 2003 storm. (Photo courtesy of Transport Canada).

The majority of the loss has been occurring on the seaward side of the dunes. The barrier dune at the western end has been moving landward with a modal rate of approximately 4 m/year from 1974 to 2000 depositing approximately 2000 m^2 of sand mobilized from the blowouts and washouts on the backside of the dunes. The majority of the sand that is lost from the western end of the barrier dune has been accumulating in the estuary directly south of the lighthouse between the barrier dune and Savage Island and on the western side of the Alberton Channel at the mouth of the Kildare River (Robert Delong, Lighthouse Owner, personal communication). Fig. 5.10 shows the locations of the accumulated sand.

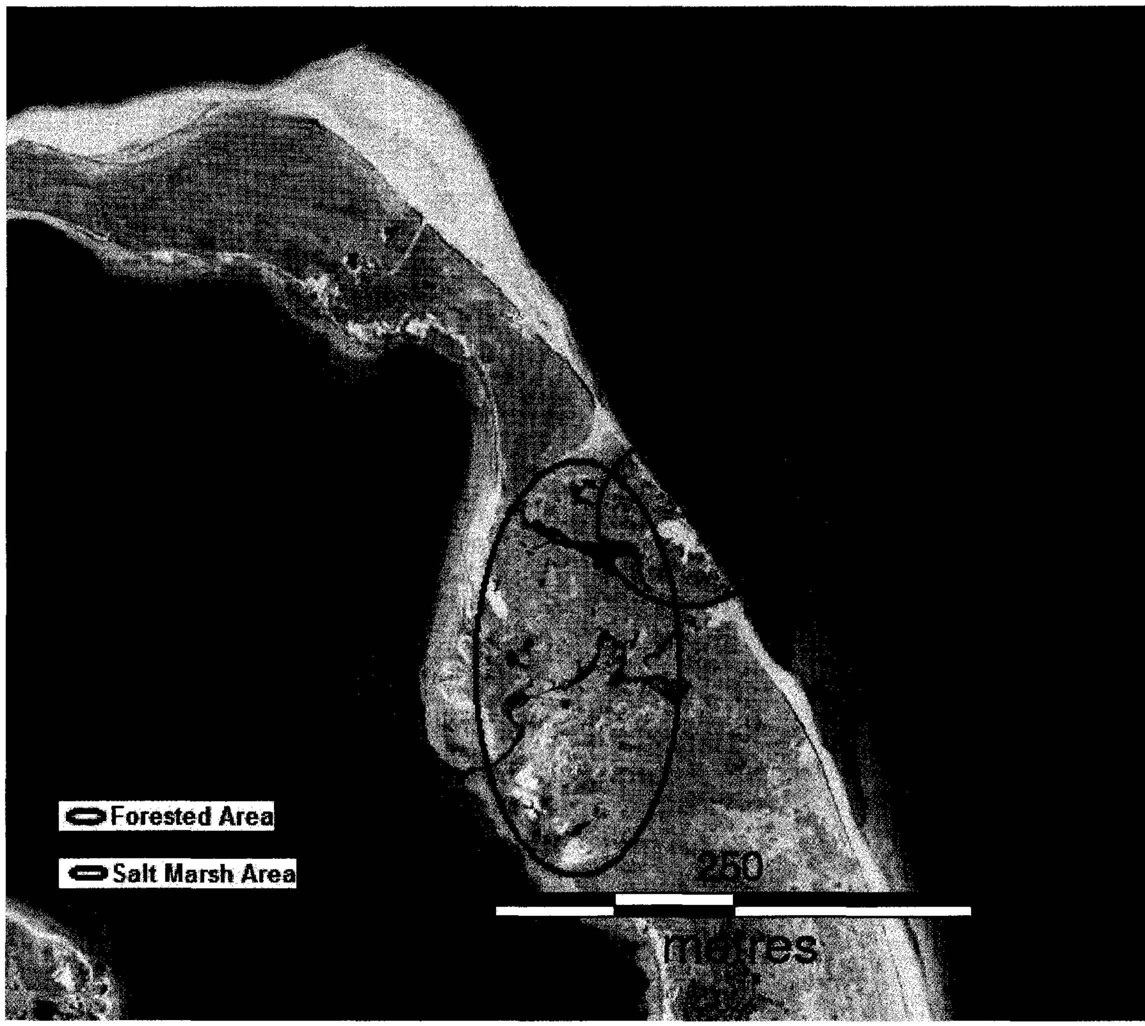

Figure 5.9 – 2000 ortho-rectified aerial photo show location of forested and salt marsh areas lost/infilled during the December 2003 storm event (Photo courtesy of the PEIDEEF Orthomap No. 032).

Previous washout sites are subject to reactivation, as indicated by the persistence of washout sites identified on the 1974 aerial photographs. With rising sea level along the north coast of PEI (McCulloch *et al.* 2002), and the possible increase in storm surge intensity worldwide (Van Vuren *et. al.* 2004), the stability of the barrier dune system in Cascumpec Bay could be compromised.

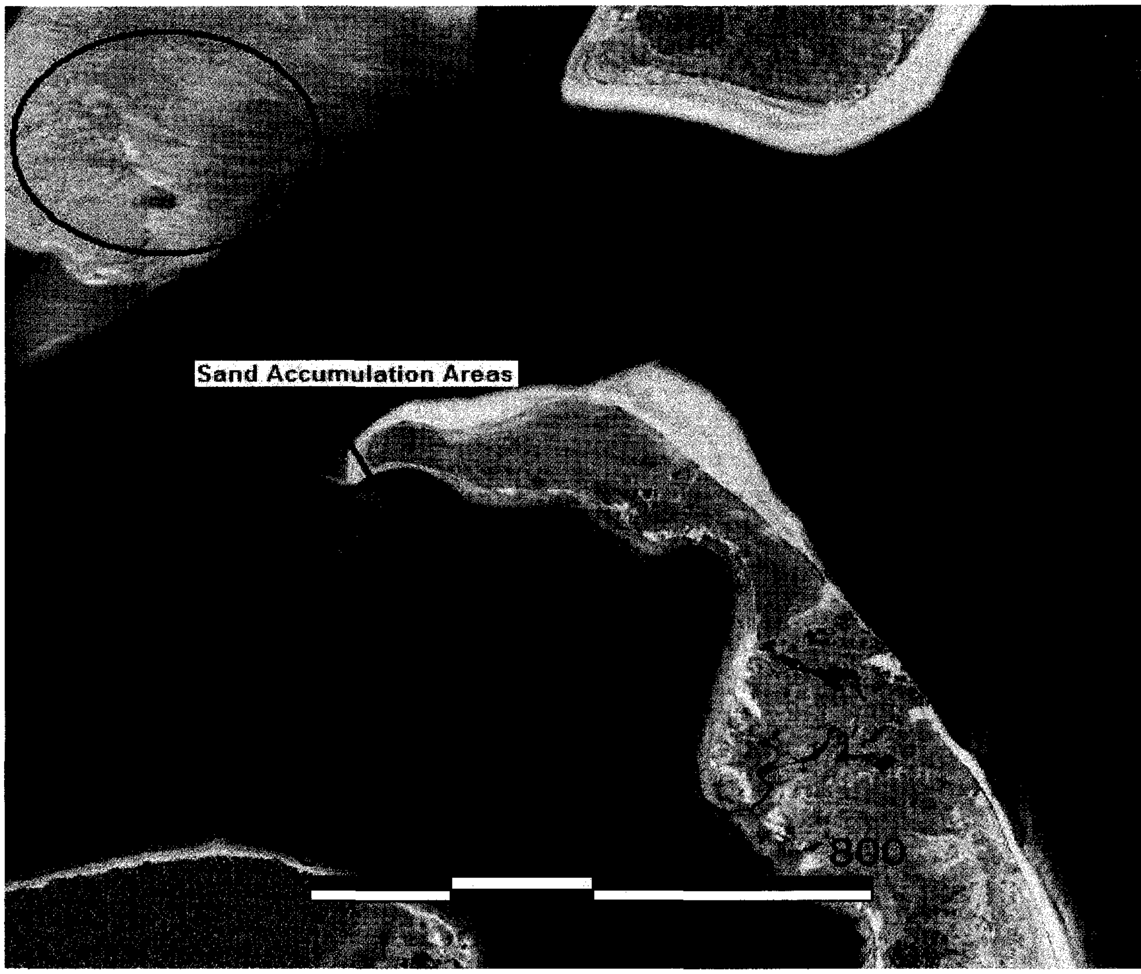

Figure 5.10 – 2000 ortho-rectified aerial photo showing the sand accumulation locations (Photo courtesy of the PEIDEEF Orthomap Nos. 032 and 031).

5.3.3 Tracadie Bay

Aerial photograph and visual evaluation of the barrier dune system in the Tracadie area showed that the Blooming Point barrier dune is more stable then the Cascumpec dune system. A comparison of the 1974, 1990 and 2000 aerial photos showed that the dune migrated marginally landward with an approximate movement of 20 m over the last 30 years (Fig. 5.11). Observations in August 2005 showed that the barrier dune was higher and more vegetated than the

Cascumpec system. Dune crest elevations ranged from approximately 5 to 7 m, with the maximum width ranging from 150 to 500 m.

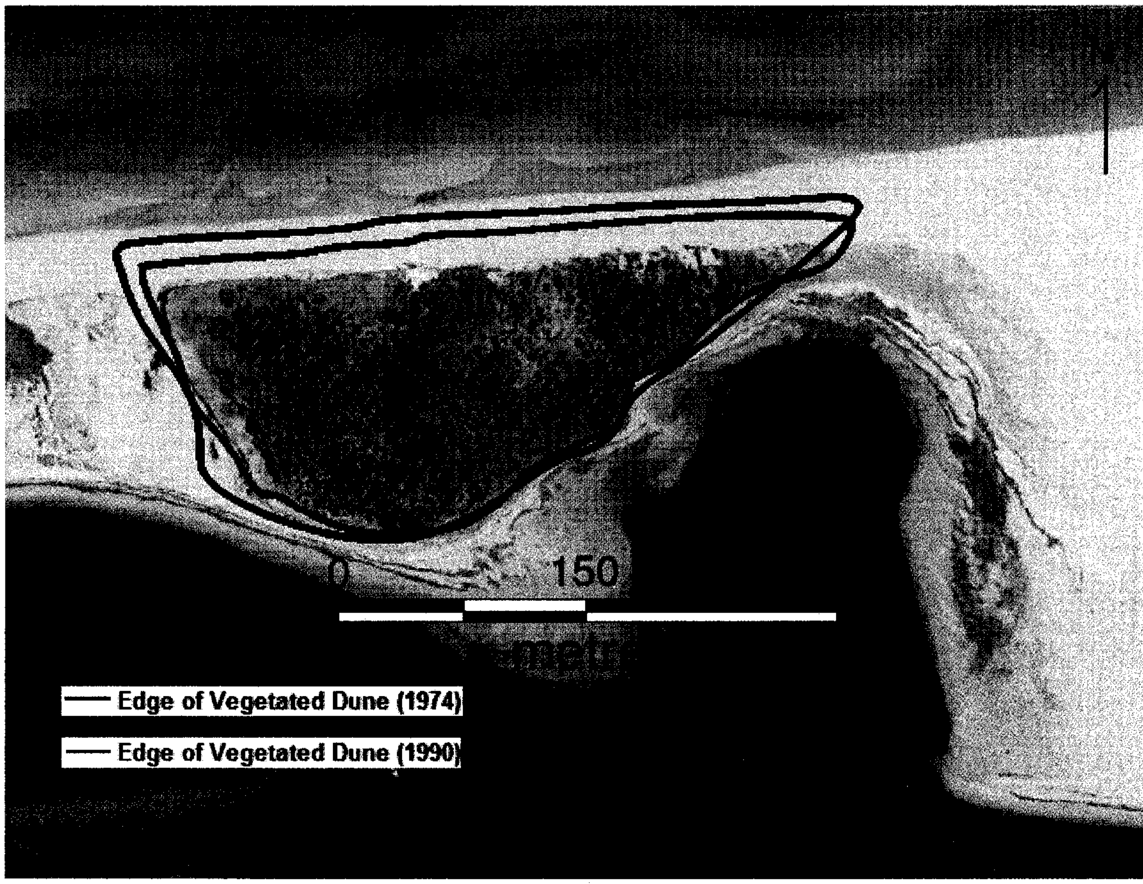

Figure 5.11 – Ortho-rectified aerial photo taken in 2000 showing the loss of seaward vegetation from 1974, 1990 and 2000. (Photo courtesy of the PEIDEEF Orthomap No. 118).

The variation in percent vegetation of the dunes between the two areas was substantial. Overall, approximately 36% of the Blooming Point spit was vegetated and approximately 80-85% of the Cascumpec Barrier Dune was vegetated in 2000. Approximately 7% of terrain of the 1600 m^2 Blooming Point barrier dune is occupied by mixed Acadian forest, whereas only 1% of the 1300 m^2 Cascumpec Dune is vegetated with mixed Acadian forest, reduced due to the 2003 storms (Robert Delong, Lighthouse Owner, personal communication).

Comparison of the 1974 and 2000 aerial photographs from Blooming Point indicated that the vegetation had increased substantially at the eastern end of the dune system, extending westward from the Deroches Pond area (Fig. 5.12).

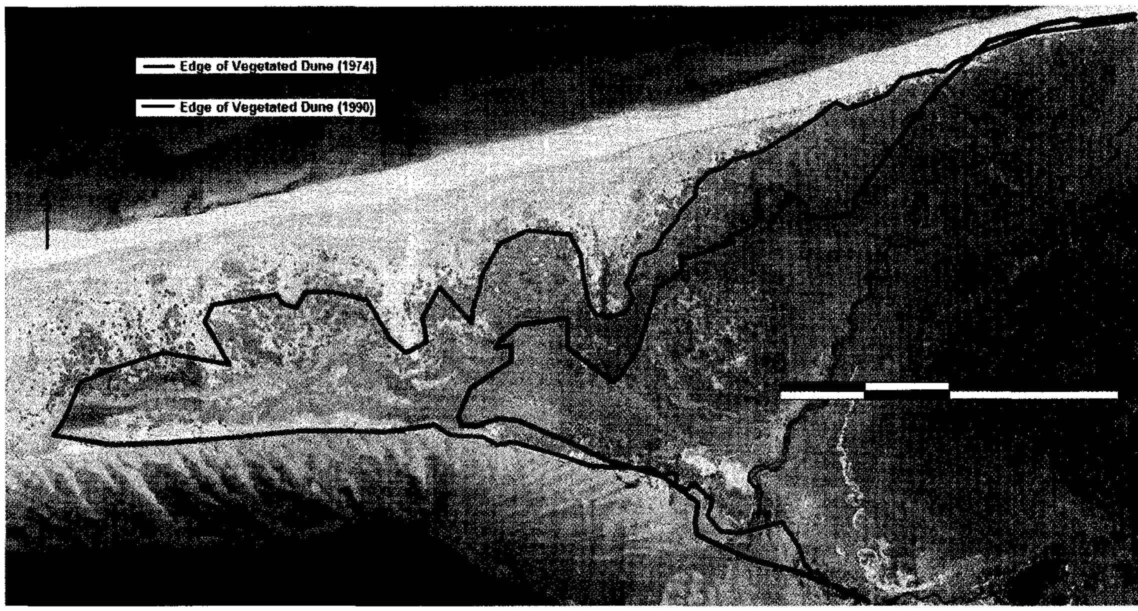

Figure 5.12 – Digitized ortho-rectified aerial photo taken in 2000 showing the migration of vegetation from 1974, 1990 and 2000. (Photo courtesy of the PEIDEEF Orthomap No. 118).

The dune system is relatively stable in the Tracadie area because sand transport is predominantly westward, originating in the Greenwich Peninsula area. Sediment arriving at Blooming Point is eroded from the entire length of coastline eastward to St. Peters Bay. The diamicton and bedrock exposed along the coastline generally contains more sand than that exposed at Cape Kildare. In addition, coastal dunes on the Greenwich Peninsula and in the Lakeside-Crowbush Cove area also contribute sand to longshore transport. Thus, the sand supply to Blooming Point is greater than that provided to the Cascumpec Bay system. In addition, the length of the Blooming Point spit is less (approximately 5 km) than that of the Cascumpec Bay barrier island system (approximately 6.3

km), and hence the sand delivered to Blooming point is concentrated in a smaller area, allowing dunes to build upwards. Maintenance of the dredged channel into Tracadie Bay also tends to interfere with longshore drift, causing sand transport around the tip of Blooming Point spit into the bay and resulting in increased sand accumulation on the point. The east-to-west direction of longshore drift is also opposed to the prevailing westerly winds, resulting in occasional reversals of transport direction. All of these factors result in greater stability for the Tracadie bay dune system in comparison to that protecting Cascumpec Bay.

Even though Blooming Point has greater stability than the Cascumpec Bay system, aerial photographic evaluation shows that the system is moving landward. There has been a reduction in the seaward vegetation by approximately 20 m from 1974 to 2000 (Fig 5.11). Although the presence of mature wooded areas and high dunes indicate that Blooming Point is less susceptible to deflation and storm surge overwash, the system remains at some risk of erosion as sea level rises in the Gulf of St. Lawrence (Forbes *et al.* 2002).

5.3.4 Discussion

Comparing the two areas, the Cascumpec Barrier dune system would benefit more from beach nourishment than the Tracadie area. This is due to the difference in stability, width, vegetation coverage and type, and the elevation of the two barrier bars.

The major problem with potential beach nourishment at Cascumpec is the same reason it is so unstable. The long, uninterrupted coastline creates a greater potential for the material to migrate southeast in the normal sand transport regime. If beach nourishment was conducted along the dune, the recent reduction of land and the increasing overwash at the western end of the Cascumpec barrier dune would seem to be the best location to concentrate enhancement effort. This area could benefit from both sub-tidal bar creation and direct beach nourishment above high water. The underwater berms (Fig. 5.13) should be created first and if possible, maintained with material from future dredging projects in the area which currently occur very infrequently. The disposal area should be located more than 300 m southeast of the existing channel, reducing the loss of suspended material from the disposal into the fast moving channel current. Placing dredge material further south of the channel could also allow the material to migrate in a different direction than the channel entrance and may help create a larger barrier bar along the gulf side of the barrier island. The underwater berms will protect the shoreline and also will have potential fishery benefits (Clarke *et al.* 1988). Stable berms have been found to provide refuge and feeding habitats for juvenile and adult life stages of a variety of finfish and crustaceans, many of which are of recreational and commercial significance (Clarke and Kasul 1994).

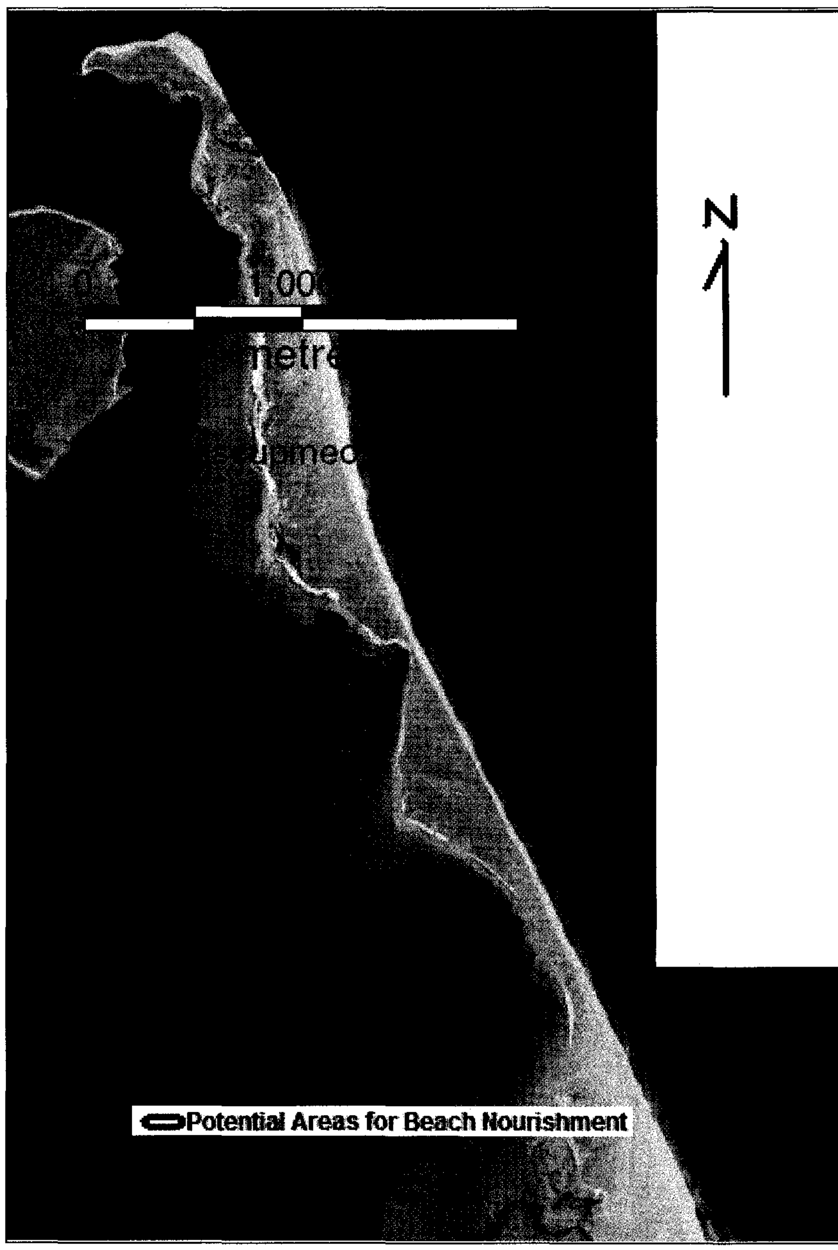

Figure 5.13 – Potential areas for underwater berms seaward of Cascumpec Barrier Island to help reduce dune erosion and washover. (Photo courtesy of the PEIDEEF Orthomap No. 032)

Potential areas where material could be placed directly on the dune system would be in relation to the areas that have had the most washover or loss of vegetation in recent years (Fig. 5.7). Of the three areas, area C would be preferred site to create an artificial dune as it no longer has any vegetation due to a recent wash over in December 2003. As well, there is existing vegetation on either side of the breach to help facilitate floral migration.

Is the area stable enough to allow an artificial dune time to develop? Probably not, considering the currently very unstable dune system, and the large amount of sand bypass. However, factors that may help stabilize the dune system could include: 1) if there are multiple mild falls and winters, reducing the amount of storm events and allowing the dune the opportunity to develop over multiple summers; and 2) if the area is artificially propagated with marram grass to help promote dune stability. Unfortunately, conducting the work in that area would still be a very large gamble considering it would only take one major storm to create a barren area of no vegetation during any given fall or winter.

Beach nourishment options are limited for the Blooming Point spit area as it is within PEI National Park. In consequence, nourishment would have to be placed below the high water mark, in order to comply with the *National Parks Act*. Therefore, the only option is underwater berms to help reduce over wash events. Along the seaward side of the spit there are two potential locations that would help reduce wave erosion along the shore by placing underwater berms (Fig. 5.14). Both upland areas are devoid of vegetation and have been affected by over wash in the past although considering the stability of the dune system and the fact that those two particular areas have been devoid of vegetation prior to the 1958 aerial photos the improvement most likely would be minimal.

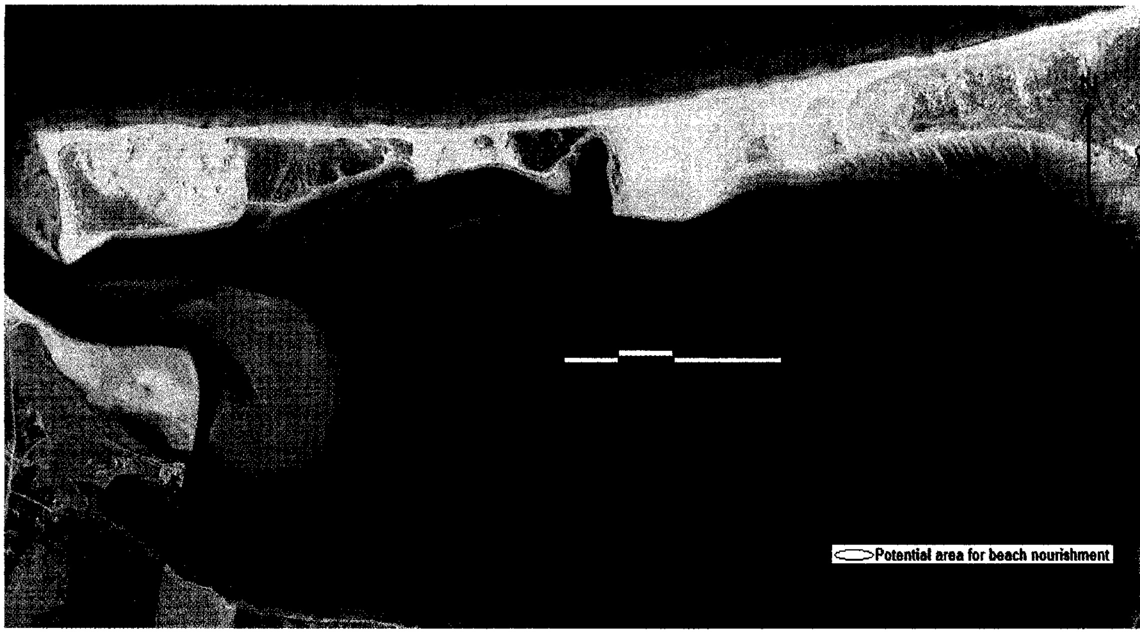

Figure 5.14 – Potential areas for underwater berms seaward of Blooming Point to help reduce dune erosion and washovers. (Photos courtesy of the PEIDEEF Orthomap Nos. 118, 119 and 120).

Any material used for a beach nourishment program must be compatible with the local environment, both biophysically and aesthetically, and must be of appropriate texture. As the barrier systems in both Cascumpec Bay and Tracadie Bay are composed predominantly of medium to fine-grained quartz sand, this material would be the most suitable for beach nourishment. Beach nourishment using silts and clays could cause turbidity levels to increase in both the source and target areas. This suggests that dredging should be confined to material that is lower in silts and clays and higher in sand content, which is often the case with the material being dredged from the channel entrances along the coast of PEI.

According to ASMFC (2002), material that has high shell content can pose long term problems, aesthetically for beaches that are used for tourism. Along the US coast shell remains on the beach essentially forever and large accumulations of dredged shells would not be good for tourist beaches. Along the north shore of PEI, shell accumulation would most likely be a minimal problem considering the dynamic climate and constant wave action. In addition, the amount of shell that would be found in clean littoral drift sand dredged from the channel mouths would be very minimal.

Although, at Cascumpec, where there is limited human usage due to the remoteness of the barrier island, shell material, if found in any large quantity, could be beneficial. If the shell from dredge material could withstand the climate and constant wave action, it could aid in the creation/stabilization of sand dunes, by accumulating sand and creating a dune, which is highly unlikely but potentially possible. Most dredge material from the bays and estuaries of PEI has low quantities of shell, lowering the risk of aesthetically displeasing deposits in tourist areas. As Blooming Point is within PEI National Park, dredged material cannot be added to the site.

The sand supply for beach nourishment programs could come from dredging of the inner bays or channels. As the barrier dunes are slowly moving landward, former dune sand is being deposited into the bays, reducing bathymetric depths and changing water circulation patterns in the embayments. Removing the material from the bays and returning it to the seaward limits would help stabilize the dunes, abate the movement landward and help restore the bathymetry of the embayments. Deeper bays have better water circulation, possibly allowing terrestrial sediment to move more rapidly through the estuaries to aid in replenishment of the barrier islands.

Target areas should have minimal vegetation, as is the case at Cascumpec. The destruction of existing dune plants should be avoided as much as possible as they help stabilize the dunes and they can very easily be destroyed. Placing the material adjacent to a heavily vegetated area could promote migration of the vegetated plants onto the newly created dune, which would help create a stable environment. Conducting the project in an area that is not regularly visited by people will also give the beach nourished area time to re-vegetate.

Possible ideas for abating the migration of the newly formed dunes on the barrier bars would be to implement erosion abatement measures including snow fencing, planting dune grasses or using brush or old discarded Christmas trees to slow down the sand transport helping create artificial dunes. Of these abatement measures, the most cost-effective and practical would be either snow fences or old trees buried in the sand to catch migrating sand. Unfortunately, snow fencing has been tried in several locations along the Gulf of St. Lawrence and has been unsuccessful, especially in areas of dynamic wind activity (e.g. Pittman 1998; Pittman and Catto 2001). Burying old trees along the barrier dune system would be very similar to snow fencing unless the trees were deeply buried, which would potentially cause disturbance. In addition, there is potential for the trees to decompose and create a very unattractive eyesore along the barrier dune system. The costs of transplanting dune grasses or trees (such as Japanese Pines) is expensive and time consuming but would be the more preferable options. The most optimal choice would be marram grass, as it is a native plant to the dune system and would migrate very easily in the very exposed environment. Japanese Pines would probably not survive the exposed location of the north shore of PEI. In fact, if the system is severely unstable, with storm activity that commonly occurs during most fall and winter seasons along the north shore, would anything work? Conducting work along the Cascumpec barrier dune area would still be a very large gamble and potentially very expensive considering it would only take one major storm to create a barren area of no vegetation during any given fall or winter.

The time of the dune enhancement also has to take into consideration the Piping Plover breeding season. The project must be conducted outside the May to August breeding time, which largely corresponds to the peak tourism season. The most beneficial time to conduct the work would probably be early spring as it would allow time for consolidation of the newly formed dunes and promote growth of vegetation during the growing season prior to the winter wind and ice.

Future compensation or enhancement work in the Cascumpec Bay area could involve nourishment of the intertidal zone on the seaward side of the dunes. Doing this may create new sand bars that could protect the dunes and possibly allow for re-growth of the vegetation which could help stabilize the dune system and reduce speed at which the dunes travel landward. Sand could be obtained from the large inner bay and placed in the sub tidal zone (Fig. 5.13).

One of the major drawbacks of a beach nourishment project in the Cascumpec area is that it would probably require multiple years of dredging and disposal, considering the open area and the potential for sand migration further south along the barrier island. In contrast to most harbour entrances along the north shore, the Alberton channel does not require regular maintenance dredging due to the fast water currents (Peter Curley, PWGSC, personal communication). Sand would have to be obtained from other areas like the inner basin or adjacent to the navigable channel in Cascumpec and would not be considered a viable option for the Cascumpec Dune system due to the expense of transporting sediment from farther distances especially if the dredging is not being conducted for the purpose of maintaining existing channels. In Tracadie, it would not be a problem considering the channel is regularly maintained for navigation purposes.

5.4 Salt Marshes: Trends and Enhancement Mechanisms

5.4.1 Introduction

Salt Marsh enhancement is becoming more common in recent years. During the last twenty years, understanding of the importance of salt marshes and the role they play in maintaining an ecosystem has grown substantially. Mitsch and Gosselink (1986) defined a salt marsh as a coastal or tidal wetland where low lying grassland expanses surround a bay or estuary. A salt marsh is covered by shallow tidal water during high tide events and is marginally above the water line at low tide events. The coastal wetland ecosystem is dominated by *Spartina* grasses in the low intertidal and *Juncus* rushes in the upper intertidal.

Salt marshes enhance water quality, protect the coastal environment from flooding, reduce erosion, and create food, habitat and temporary shelter for fish, mammals, birds, and invertebrates (McCay *et al.* 2003; Osmond *et al.* 1995).

Commonly, salt marshes are found flanking low energy coastlines. Salt marshes are commonly found in areas of net sediment accumulation, and they grow both vertically and horizontally (Davidson-Arnott *et al.* 2002). In Atlantic Canada, salt marshes develop in lagoonal areas created by barrier islands, or along the margins of estuaries marked by low wave energy. Protection of these areas promotes vegetation growth. Deposition and accumulation of sediments creates gently sloping (<0.1°) substrates, an important factor for long term stability of salt marshes.

Roman *et al.* (1997) looked at the importance of sediment accretion and the role it plays in maintaining and sustaining salt marshes subjected to sea level rise. Sea level rise is currently changing the coastal environment by covering areas of salt marshes that were formerly dry during low tide. Roman *et al.* (1997) thought that sedimentation from storms was an important mechanism allowing accumulation in salt marshes to keep pace with sea level rise, especially to compensate for periods of lesser sedimentation. When rates of accumulation are less than the rate of sea level rise, marshes will become inundated and will evolve to tidal mud flats, lacking vascular plants on their surfaces.

The deposition in salt marshes can range from organogenic (i.e., primarily from below surface organic accumulation), producing thick beds of peat, to minerogenic (i.e., accumulation of fine sediments deposited on the marsh surface (Davidson-Arnott *et. al.* 2002; Allen 2000). The rate at which mudflat-marshes build up in high intertidal zones is theoretically a function of the rate of the minerogenic and organogenic sedimentation, the rate and change of relative sea-level and the rate of long-range sediment compaction (Allen 1990). The rate at which a minerogenic salt marsh grows vertically has been shown to be asymptotic, with rapid growth in the early phase slowing to low growth rates once a mature marsh surface is established near or above the mean high tide (Davidson-Arnott *et al.* 2002). However, under rising sea-level, thick deposits can accumulate as long as the vertical growth of the salt marsh can keep pace with the rate of sea level rise (Allen 1990). In contrast, under stable sea level conditions, the vertical growth of a salt marsh is limited by the tidal range (Davidson-Arnott *et al.* 2002).

The north shore of PEI has numerous bays and estuaries emptying into the Gulf of St. Lawrence. Salt marshes have developed along several of these bays and estuaries, separating the shorelines from marine water. Along the north shore of PEI, productive salt marshes are mostly found in bays or estuaries protected from northerly winds and the waves they generate.

In recent years, salt marshes have been disappearing along the coastlines of North America due to sea level rise, erosion and anthropogenic effects. Coastal development, driven both by expanding cities and the market for vacation coastal vistas, is a significant factor. PEI is a prime example of coastal development, both in towns and along the formerly relatively remote coasts.

Assessment of the rate of change in salt marshes along the north shore of PEI is necessary to determine the combined effects of sea level rise, erosion and increased human population near the coastal environment. Declining surface area renders the remaining salt marsh areas less productive and exposes them to erosion.

Salt marsh creation has mostly been conducted in the past as a means of compensating for the destruction of similar habitat, especially in Canada according to the Federal Wetland Policy and the “no net loss of wetlands” policy. Regulatory agencies have increasingly required mitigation for the loss of valuable marshes (Havens *et al.* 2000). Currently, in the Maritime Provinces, federal regulators require salt marsh creation on a 3 to 1 ratio when a salt marsh is destroyed or disrupted, although the ratio required can be higher or lower depending on the reason for destruction/disruption (Al Hansen, Canadian Wildlife Service, personal communication). Higher compensation ratios would occur when destruction/disruption of salt marshes is proposed for structures that are built to create tourist attractions or when a construction project is conducted prior to the compensation (i.e., destruction occurs prior to an enhancement agreement). On the other end of the spectrum, lesser amounts of compensation maybe required if the compensation project is conducted well in advance of the destruction.

5.4.2 Trends in Salt Marsh Response 1974-2000

5.4.2.1 Tracadie Bay

Tracadie Bay has approximately 20 salt marshes listed in the salt marsh GIS inventory of PEIDEEF (www.agripei.isn.net), totaling approximately 130 ha. These salt marshes occupy approximately 15 km of coastline (Fig. 5.15). The

East Tracadie Barrier Marsh, the largest marsh in the area ("TB" in Fig. 5.15, No. 118363) is located on the northeast margin of Tracadie Bay, sheltered by the Tracadie Barrier Bar. It covers a total geographical area of approximately 25.50 ha. This salt marsh extends along approximately 1.34 km of coastline, and varies in width from 67 to 475 m.

The MacDonald's Cove salt marsh occupies the largest lateral expanse of coastline in Tracadie Bay ("MD", No. 112898), extending approximately 3.1 km of coastline and occupying approximately 19 ha. The widest expanse is approximately 180 m, and the narrowest is approximately 20 m. The smallest salt marsh in the Tracadie Bay area according to the salt marsh inventory is the MacDougall's Cove salt marsh ("MC", No. 112426). The total area of this salt marsh is approximately 0.2 ha, with coastal fringe coverage of approximately 70 m.

The interpretation of the aerial photos shows the coastal fringe of the salt marsh has moved as much as approximately 15 m landward over the last 30 years in some areas, most notably at the head of MacDonald's Cove. This change is contradictory to the general trend of reduction of salt marsh area around the western margin of the North Atlantic Ocean. Along Tracadie Bay, the gently sloping topography directly inland from the shore is subject to the development of fringing salt marshes as sea level rises. If the salt marshes are not restricted on the landward side by agricultural or residential development, they are able to expand landward, resulting in a net increase in salt marsh area. This pattern is thus the result of the local pre-existing topography in the Tracadie

Bay area. In areas where the topography inland slopes at higher angles, the inland expansion of the salt marshes is curtailed.

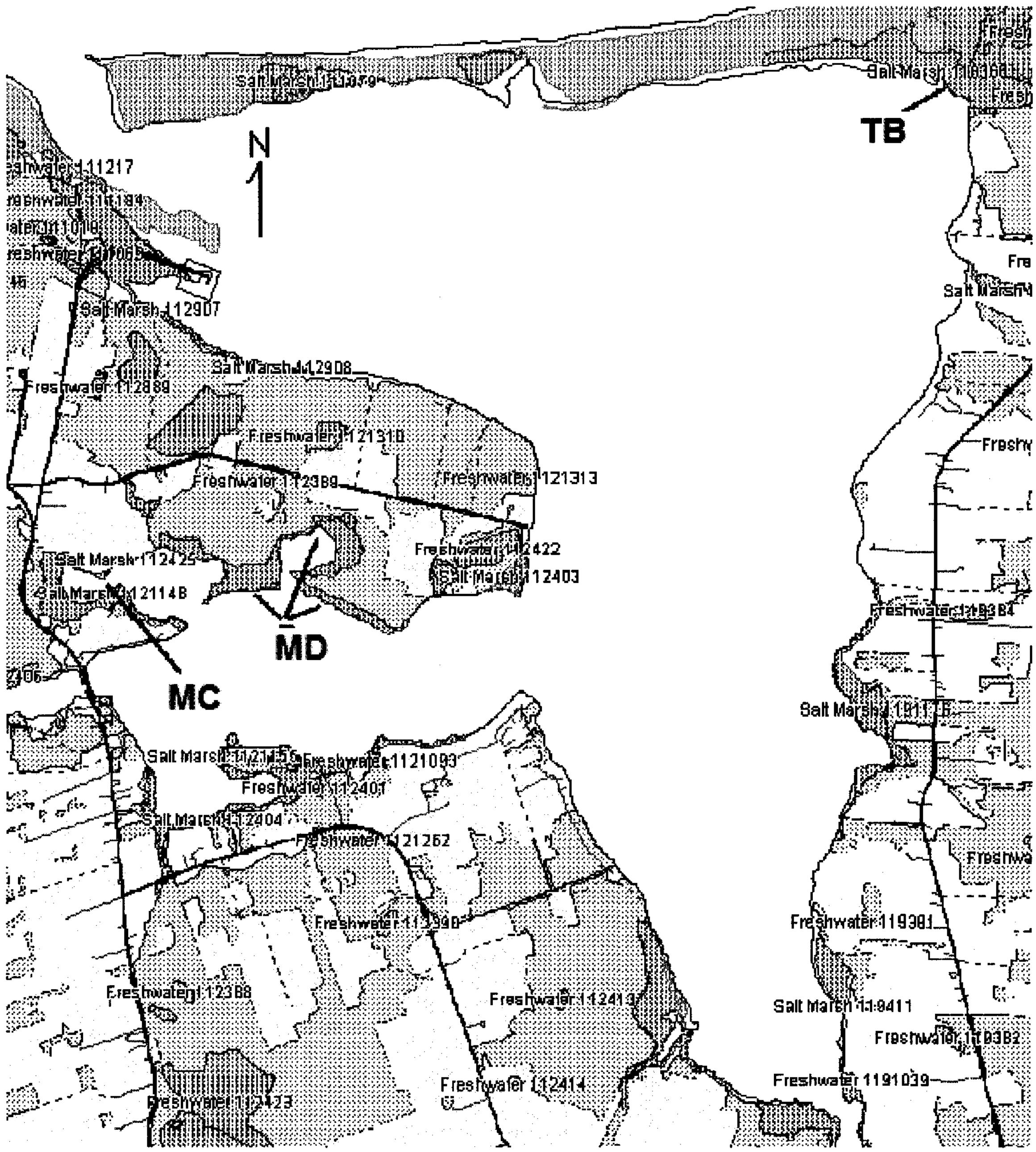

Figure 5.15 – Map of Tracadie Bay showing the PEI inventory of salt (pink) and freshwater (dark green) marshes compared to dune (brown), forested (light green) and agricultural (light brown) areas in the Tracadie Watershed (MC=MacDougall's Cove; MD=MacDonald's Cove; and TB=Tracadie Barrier). Map produced by PEI Land On-Line (PEIDEEF) Scale 1:31531.

Under rising sea level, most salt marshes along the north Atlantic coast have moved landward. Salt marshes can be permanently lost when the landward migration is restricted or prevented by coastal development (McCulloch *et al.* 2002; Mitsch and Gosselink 1986). McCulloch *et al.* (2002) measured the rate of sea-level rise at Charlottetown as 32 cm/100 years for the last century. Rising sea level, reduction in ice cover and an increase in wave energy will result in increased erosion damage and changes to coastal geomorphology in some areas, particularly along dune-backed coastlines. In the areas of Savage Harbour and Tracadie, the dollar value benefit from salt marsh retention was estimated at $21,200 ha/year for a total of $188,000 (McCulloch *et. al.* 2002).

Figure 5.16 shows the digitized outline determined through aerial interpretation of the salt marsh in 1974, 1990, and 2000 around MacDonald's Cove. Analysis shows that the area of salt marsh in 1974 was smaller than the salt marsh in 1990 and 2000. The marsh area at the northeast portion of Macdonald's Cove has widened from approximately 125 m in 1974 to approximately 180 m at the widest point in 1990 and 2000. Similar trends can be seen for salt marsh MC, located along the eastern portion of MacDougall's Cove west of MacDonald's Cove. The 1974 digital coastline and salt marsh zone shows the coastline to be approximately 6 m seaward of the 1990 and 12 m seaward of the 2000 position, but the total marsh area has increased as the landward margin of the salt marsh has moved further inland, as much as approximately 30 m at the widest area (Fig. 5.17). The Deroches Pond marsh (DP) (Fig. 5.18) located in the northeastern corner of Tracadie Bay has in some

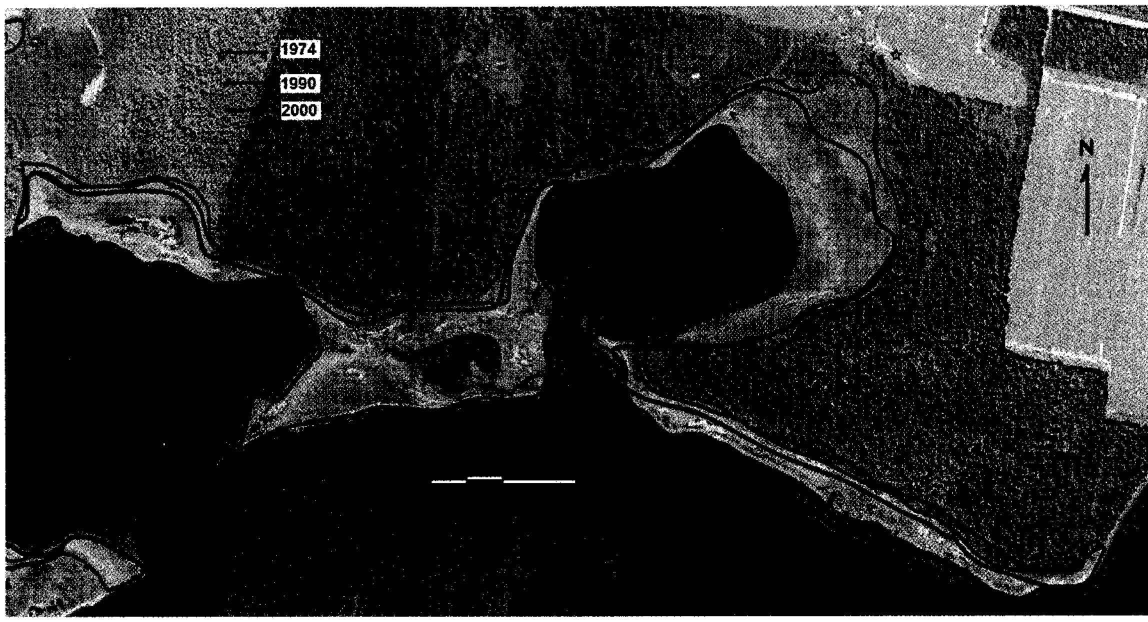

Figure 5.16 – Digitized ortho-rectified 2000 aerial photos of MacDonalds Cove, part of Winter Bay, comparing the 1974 coastline and salt marsh outline represented by the green line,1990 salt marsh represented by the red line and the 2000 salt marsh interpretation represented by the blue line (2000 layer courtesy of the PEIDEEF Orthomap No. 112).

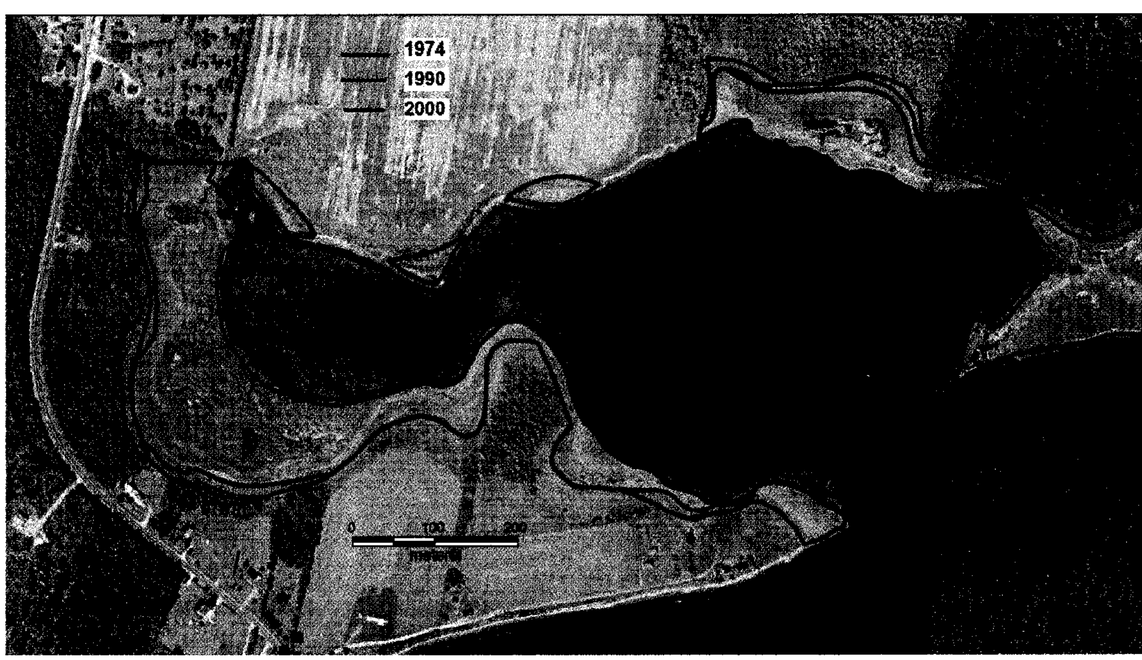

Figure 5.17 – Digitized ortho-rectified 2000 aerial photos of MacDougalls Cove, part of the Winter Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, 1990 salt marsh represented by the red line and the 2000 salt marsh interpretation represented by the blue line (2000 layer courtesy of the PEIDEEF Orthomap No. 112).

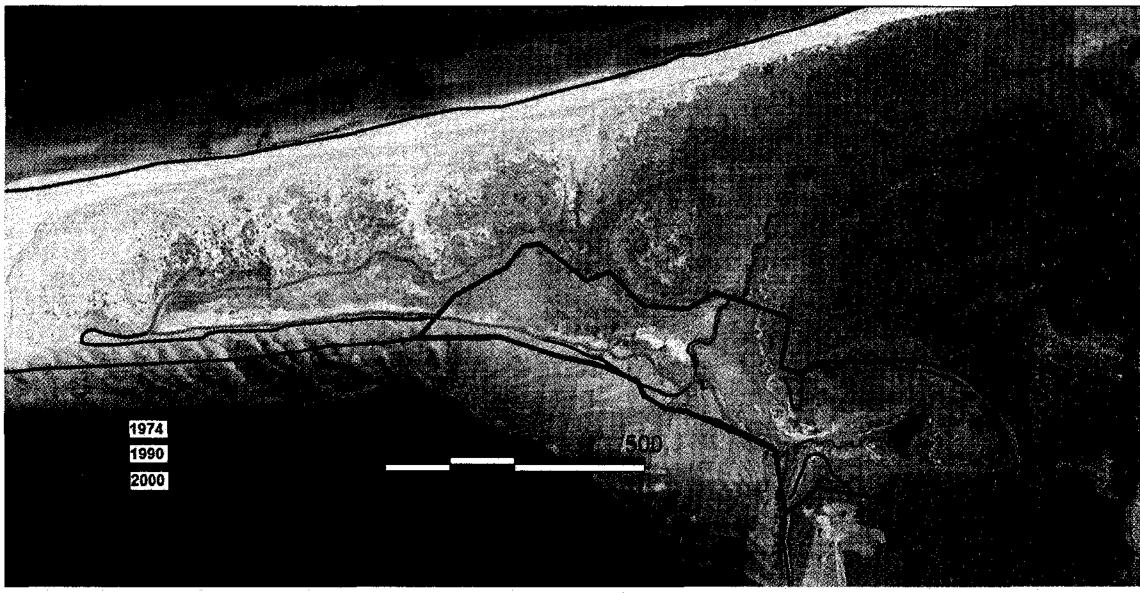

Figure 5.18 – Digitized ortho-rectified 2000 aerial photos of Deroches Pond, part of the Winter Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, 1990 salt marsh represented by the red line and the 2000 salt marsh interpretation represented by the blue line (2000 layer courtesy of the PEIDEEF Orthomap No. 118).

areas moved landward, but has also migrated westward along the barrier dune and diminished in area on the eastern side from 1974 through 1990 and 2000. This area is affected by the freshwater creek flowing from Deroches Pond and sand transport from the barrier dune. The area west of the creek shows that the marsh has migrated approximately 50 m from 1974 through 1990 and 2000, with the largest change of approximately 25 m from 1990 to 2000. A review of the western end of the marsh appears to show that the marsh has migrated approximately 500 m westward from 1974 to 1990, and seems to have possibly diminished approximately 25 m from 1990 to 2000. Infilling of the marsh (along the western end) can result from dune migration from the barrier towards the south.

The rate of movement of the MacDougalls' and MacDonald's pond salt marshes is very consistent from 1974 through 1990 to 2000 at between 3-5 mm/a, consistent with the average rate of sea level rise of 3 mm/a. The DP saltmarsh seems to be changing faster than MC and MP, mostly likely due to the instability of the area resulting from dune migration across the large barrier bar that is located to the west of the marsh.

5.4.2.2 Cascumpec Bay

Cascumpec watershed has approximately 128 salt marshes in the salt marsh GIS inventory of PEIDEEF (www.agripei.isn.net). Within Cascumpec Bay there are approximately 26 salt marshes, occupying approximately 10 km of coastline (Fig. 5.19). The Hardy Point Barrier Marsh, the largest marsh in the area ("HP" in Fig. 5.19, No. 033309) is located in the south of Cascumpec Bay east of the Foxley River. Forming a point, the HP marsh has saltwater lapping on two sides and covers a total area of approximately 37 ha. This salt marsh occupies approximately 1 km of coastline on the eastern side and approximately 0.5 km on the western side, and varies in width from 60 to 800 m. The Stephen's Cove salt marsh ("SC" No. 033226) which is located southeast of the HP marsh extends approximately 0.5 km along the coast and occupies approximately 7 ha. The widest expanse is approximately 250 m, and the narrowest is approximately 50 m. The Cascumpec salt marshes showed very different trends than the marshes at Tracadie. The Foxley Island marsh (Fig. 5.20) showed very little loss of marsh seaward and showed an overall decrease in the amount of saltmarsh landward. Between 1974 and 1990, salt marsh width along the southern side of the Foxley Island marsh decreased by as much as 100 m. Limited or no movement was detected between 1990 and 2000. The Hardy Point (HP) marsh

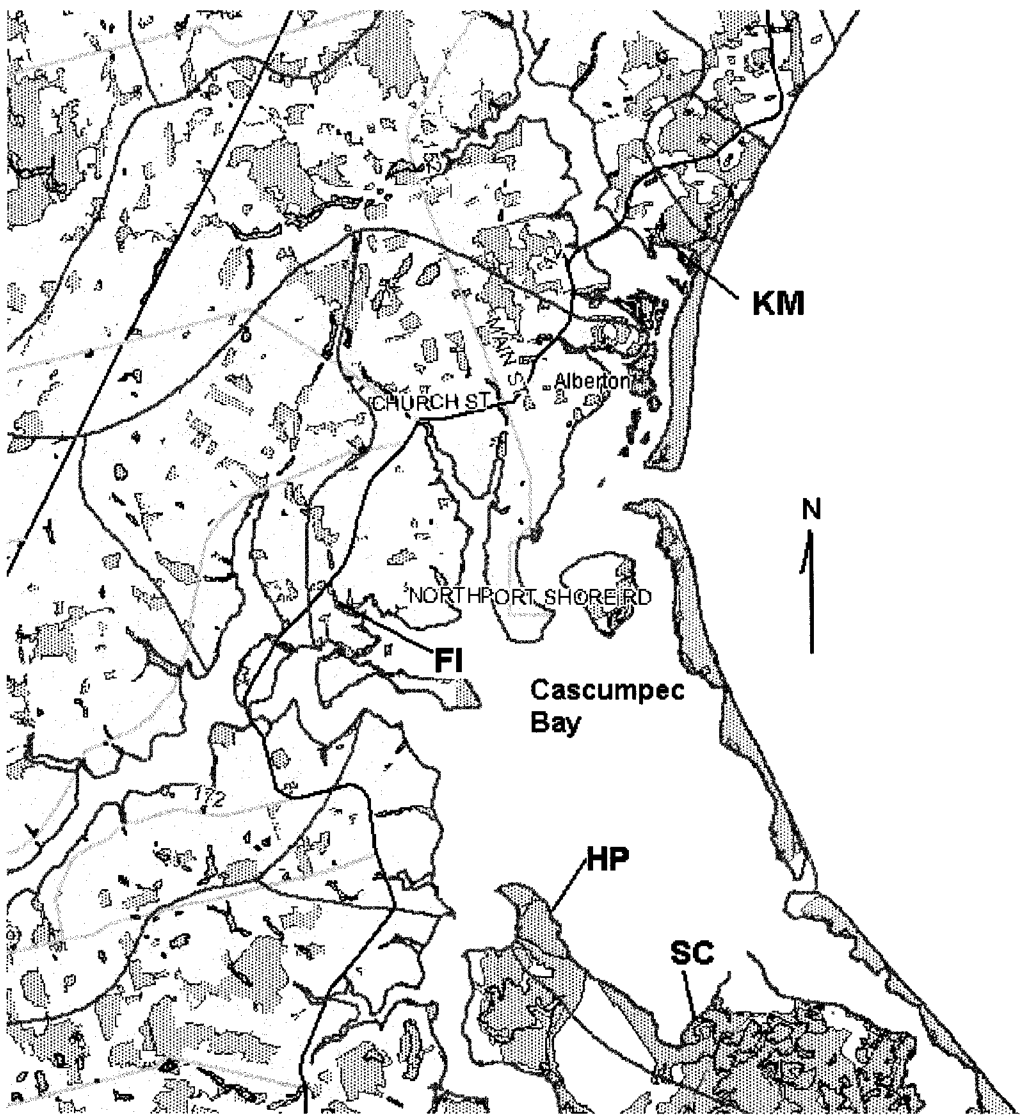

Figure 5.19 – Map of Cascumpec Bay showing the PEI inventory of salt (pink) and freshwater (dark green) marshes compared to dune (brown), forested (light green) and agricultural (light brown) areas in around Cascumpec Bay (KM=Kildare Marsh; FI=Foxley Island; HP=Hardy Point; and SC=Stephens Cove). Map produced by PEI Land On-Line (PEIDEEF) Scale 1:97000.

(Fig. 5.21) showed a loss of marsh on both seaward sides and a loss of marsh in the upland. The east margin migrated landward approximately 35 m between1974 and 2000 with almost 20 m of the migration occurring over the last 10 years, while the west side appears to have only migrated approximately 10 m landward with minimal migration between 1990 and 2000. The northeast end of the marsh moved approximately 150 m between 1974 and 1990. The marsh gained area between 1990 and 2000 with an upland migration of approximately 50 m. The southern end diminished in size between approximately 30 to 80 m seaward between 1974 and 1990 with minimal change appearing to occur

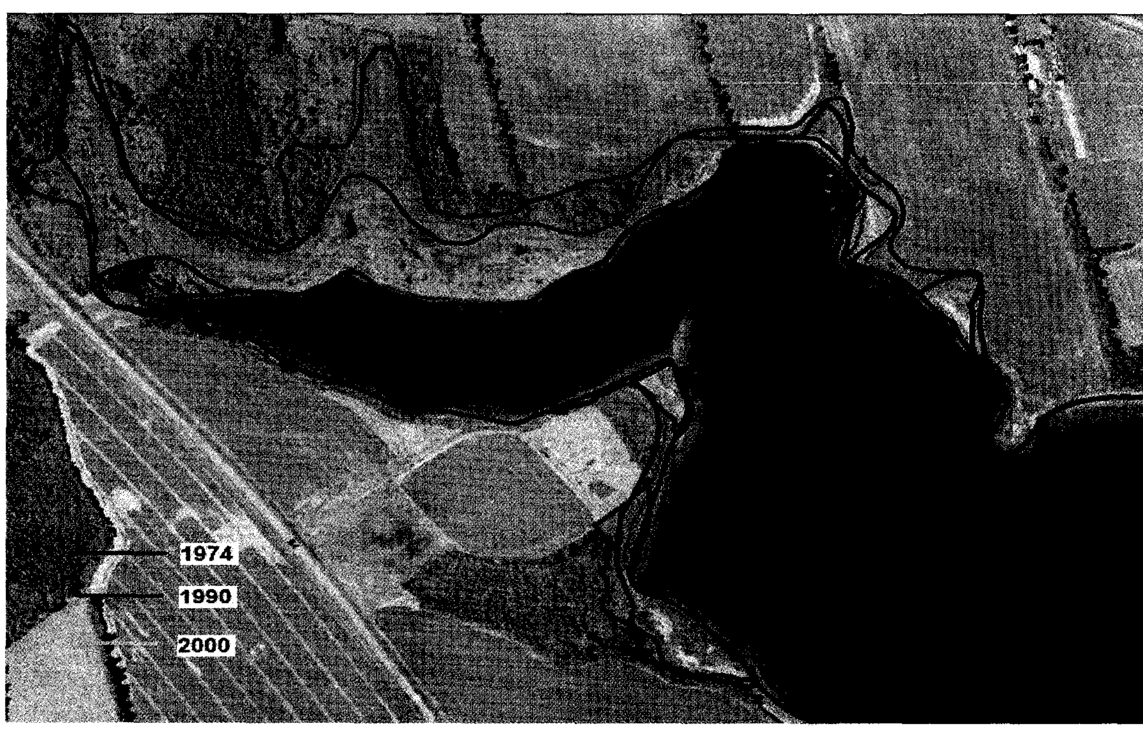

Figure 5.20 – Digitized ortho-rectified 2000 aerial photos of a cove north of Foxley Island in Cascumpec Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, with the 1990 and 2000 interpretation represented by the red and blue line, respectively (2000 layer courtesy of the PEIDEEF Orthomap No. 032).

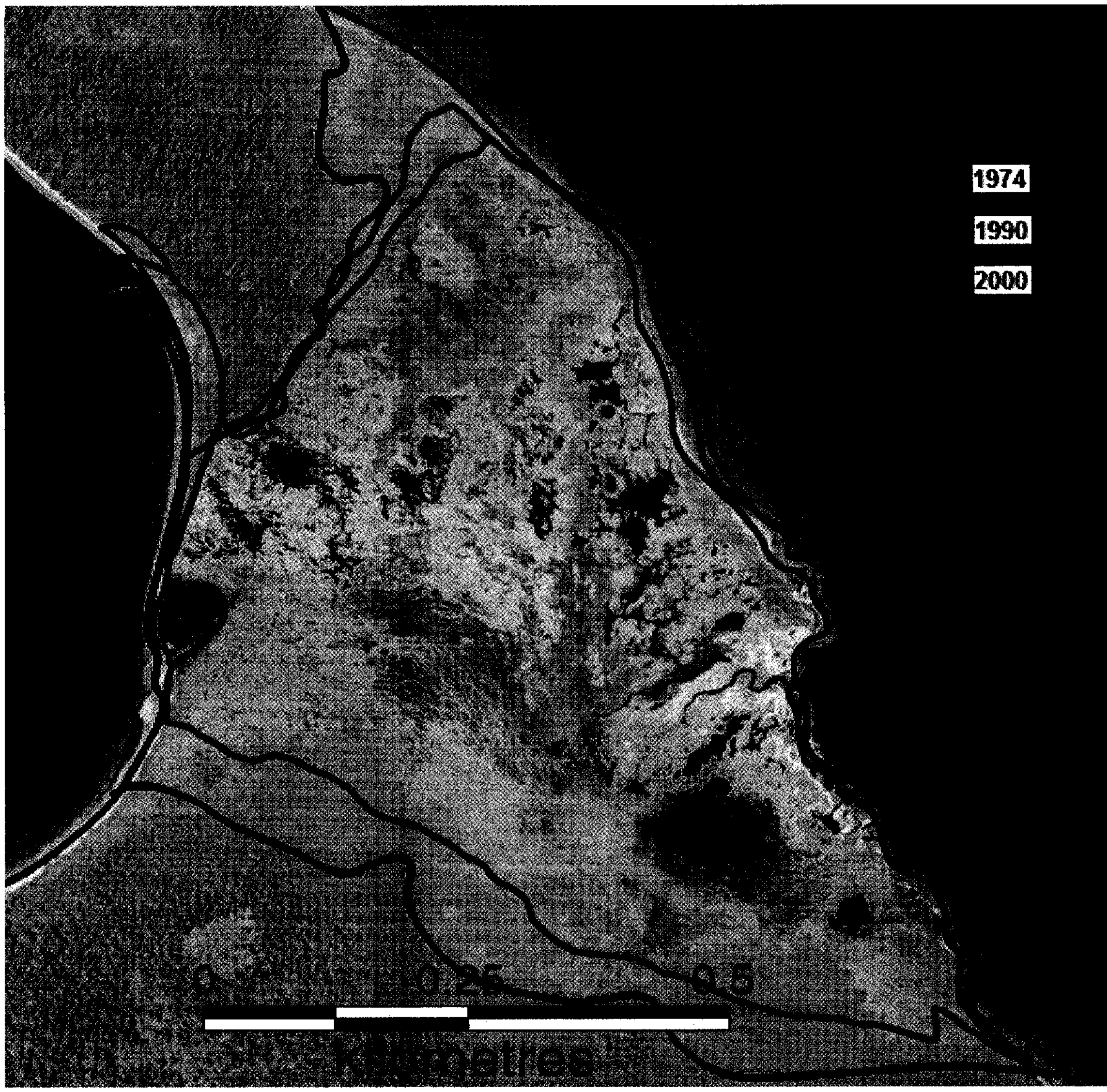

Figure 5.21 – Digitized ortho-rectified 2000 aerial photos of Hardy Point in Cascumpec Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, with the 1990 and 2000 interpretation represented by the red and blue line, respectively (2000 layer courtesy of the PEIDEEF Orthomap No. 033).

between 1990 and 2000. A similar pattern was evident in Stephens Cove (Fig. 5.22), where the loss of saltmarsh on the landward side was as high as approximately 150 m. The marsh at Stephens Cove appears to have moved approximately 10 to 25 m landward since 1974, with the largest migration between 1974 and 1990 (i.e., approximately 15 m) and a smaller landward migration from 1990 to 2000 (i.e., 10 m). The Kildare saltmarsh (Fig. 5.23) showed similar trends to the Tracadie systems, with a landward migration along the coast of approximately 10 m between 1974 and 2000, with the majority of movement occurring between 1974 and 1990. The coastline appears to have been in approximately the same location in 1990 and 2000, with a few exceptions of approximately 5 m distance.

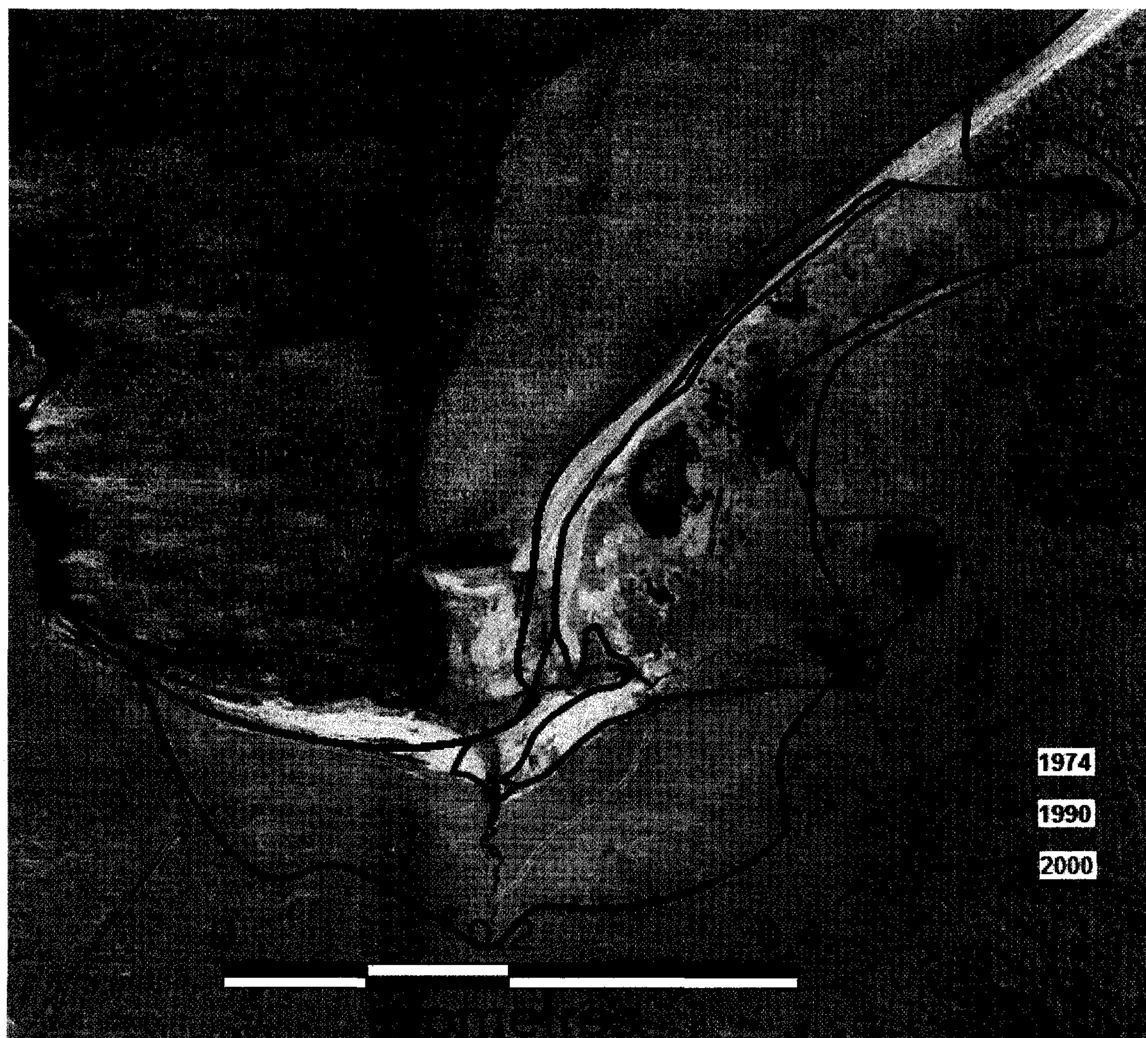

Figure 5.22 – Digitized ortho-rectified 2000 aerial photos of Stephens cove part of the Cascumpec Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, with the 1990 and 2000 interpretation represented by the red and blue line, respectively (2000 layer courtesy of the PEIDEEF Orthomap No. 033).

5.4.2.3 *Discussion*

From these examples of salt marshes in both Tracadie and Cascumpec, there does not appear to be an overall trend of either reduction or increase in salt marsh area across northern PEI. Local factors appear to be dominant in the areas that were investigated. In order to recognize an overall regional trend, all salt marshes on the PEI North Shore would have to be considered.

In Cascumpec, with the exception of the Kildare Marsh there appears to have been an overall loss of salt marsh area. In contrast, Tracadie Bay had an overall gain of salt marsh area. The marshes in Tracadie and the one in Kildare are typical examples of fringe salt marshes, where rising sea level generally causes the marsh along the upland border to transgress towards the upland, thereby potentially increasing the areal extent (Schwimmer and Pizzuto 2000).

The overall loss of area for the Cascumpec marshes could be due to the following reasons:

1) the Cascumpec area has more agriculture, especially in the Mill River watershed, which could hinder the migration of marshes landward because the farmers in the area continuously transform the upland area into farm land abating the migration of the marshes;
2) the marshes at Hardy's Point and Stephens Cove are adjacent to upland peat bogs that are farmed for peat, and the farming practices and drainage techniques could have affected the drainage of the marshes and removed the potential for landward migration.

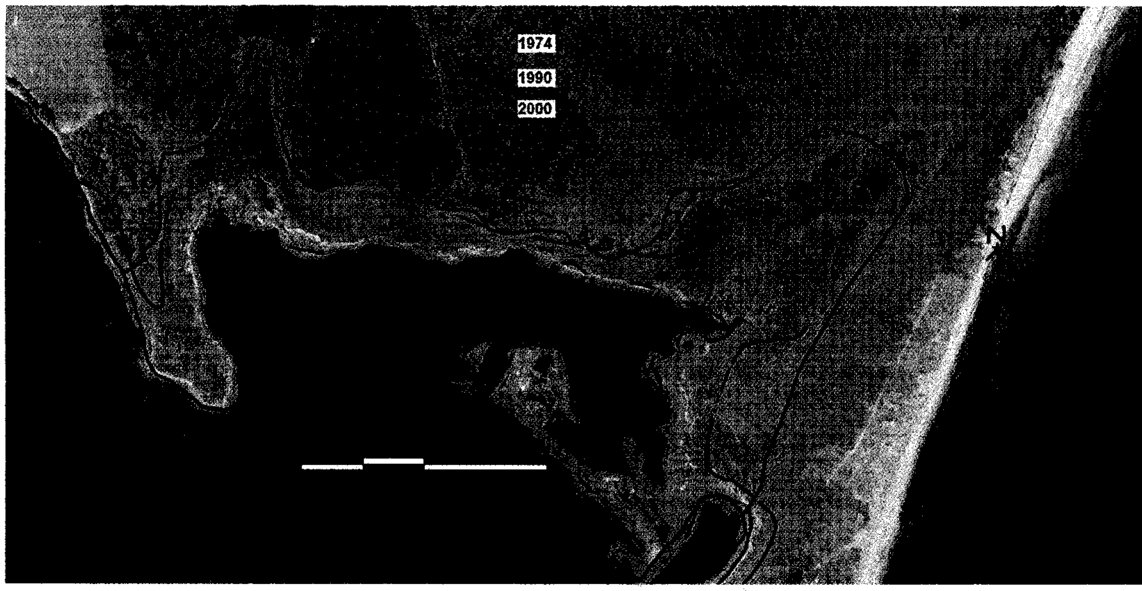

Figure 5.23 – Digitized ortho-rectified 2000 aerial photos of Kildare Salt Marsh in Cascumpec Bay, comparing the 1974 coastline and salt marsh outline represented by the green line, with the 1990 and 2000 interpretation represented by the red and blue line, respectively (2000 layer courtesy of the PEIDEEF Orthomap No. 031).

5.4.3 Salt Marsh Enhancement

Marsh creation is a relatively young science, and the complete establishment of a constructed marsh is fraught with many difficulties, variables and unknowns (Havens *et al.* 2000). Salt marshes are critical for protecting upland areas from storms and storm surges. A recent example is the devastating effects of Hurricane Katrina, which was augmented by the loss of the coastal wetlands and fringes along the Gulf of Mexico that have been diminishing since the 1930s (Bourne 2004). Moller and Spencer (2002) stated that well vegetated saltmarsh surfaces are very efficient dissipaters of wind-wave and tidal energy. Moller and Spencer (2002) monitored a 310 m wide mudflat to saltmarsh transition and showed that wave height attenuation averaged 92% over the monitoring period of 10 months. The most rapid reduction in wave heights occurred over the most seaward point of the salt marsh vegetation, with wave height attenuation over shallow sloping and cliffed coast sites averaging 2.1% and 1.1% per m, respectively. The wave height attenuation over mudflats and the remainder of the marsh area were significantly lower, with an average of 0.1% and 0.5% per m, respectively. This research shows that having mudflats/salt marshes extending out into the marine environment will diminish the effects of the storm events on upland areas, which will potentially reduce the erosion rates of the coastal fringe along the north shore of PEI.

Most work historically involved construction of salt marshes in coastal freshwater marsh areas formed by infilling, damming, or diking for agricultural purposes. In Canada, the most common types of salt marsh enhancement involves culvert and/or dam removal allowing salt water infiltration into historic flood plains, combined with inland excavation along the coastal fringe to provide the necessary width (Al Hansen, Canadian Wildlife Service, personal communication). Most of the marshes flanking Cascumpec Bay have shown decreases in salt marsh habitat since 1974, whereas most along Tracadie Bay are showing increases. Unfortunately, the increases around Tracadie Bay may not be sustainable considering the increase in coastal development (i.e., summer cottages and permanent residences since 1974) with the predicted increase in storm events and sea level rise. Salt marshes are very important coastal habitats that have a major effect on helping maintain the local biological environment as primary trophic level producers and as ecological buffers. Salt marshes are also very important on PEI as they help abate the erosion problem by acting as buffers from storm events. The physical protection and the biological role salt marshes play help maintain food fisheries in the bays and protect upland farms from losing valuable land through coastal erosion.

Another possible way to create new salt marshes, especially in the inner bays of PEI, is by constructing berms from dredge material that is removed from inner harbour basins or channel entrances. Although this would be a new technique in PEI, it has been conducted in other areas of North America. Yozzo *et al.* (2004) stated that dredge material has been used to create tidal marshes since the 1970s on United States coastlines. The idea of placing dredge material from channels along the shore to create salt marsh berms could be very easily adopted in the inner bays and estuaries of PEI. Dredged material used for salt marsh creation must be uncontaminated and of the proper grain size in order to provide an ideal substrate for tidal marshes (CATTR 1996). When constructing tidal salt marshes with dredge material, attention needs to be given to proper elevation, as intertidal marsh vegetation is extremely sensitive to elevational changes, species composition, and the physical and chemical nature of the sediments to be used.

The easiest way to create the proper elevations for a salt marsh would be to place the material adjacent to an existing salt marsh and mirror the elevation of the existing salt marsh. Unfortunately, periodic additional placement of material will be required due to the consolidation of dredge material over time. This could possibly be compensated by depositing material to an initial height greater than the designed level, with the intent being that within a year of consolidation the elevation will be at the same level as the existing salt marsh. In addition, if supplementary placement is required for certain areas, the material from the formation of salt marsh channels can be used or the outer fringe of the new area can be reduced to create the optimal elevation.

Many PEI rivers and estuaries are overloaded with soft sediment due to agriculture, road construction and coastal development (http://www.gov.pe.ca/infopei). The soft sediment is made up of red brown sand, silt, and clay, and travels downstream until the sediments drop from suspension, which normally does not occur until the sediment laden water reaches tidal waters. In the Maritime Provinces, salt marshes have been constructed in sheltered areas and anchored by species of saltwater cord-grass (DFO 1996).

When constructing a salt marsh in an estuary of PEI, it is very important to place it in an area that will receive sediment from upland and from upstream. Salt marshes with adequate sediment supply will adjust to a moderate acceleration in the rate of sea-level rise in meso- and macro-tidal areas, but sediment deficits have been noticed within some micro-tidal environments (French and Burningham 2003). Although Cascumpec and Tracadie are micro-tidal environments, the sandstone cliffs and red brown silty sand soil create an abundance of sediment, potentially helping the coastal salt marshes to receive an abundance of sediment which helps maintain the outer fringe of the salt marshes against sea-level rise.

In order to create salt marshes using dredge material, it is necessary to place the material behind a barrier system to allow time for the material to solidify and become stable in order to allow marsh plants to colonize promoting further stabilization (CATTR 1996). Additional factors that affect the stability of salt marsh soils derived from marine sediment are salinity, acidity, moisture and nutrients (CATTR 1996). Soil salinity is affected by flood waters, marsh elevation, soil texture, climatic factors (i.e., temperature, evaporation and rainfall) and vegetation composition. Where the acidity of the soil affects plant establishment and growth, increased moisture content in the material affects stability and nutrients are normally higher in finer sands and silts as apposed to coarser grained material. In Tracadie, material adjacent to the fishing harbour has been determined to be fine grained, with moderate moisture content and high in total organic content, making it very suitable for potential marsh creation (JWL 2005).

The area with the most potential for salt marsh creation would be adjacent to Tracadie Harbour, considering that the dredge material would not have to be transported very far and thus reducing the cost of transportation and handling. The southern part of Winter Bay and the Winter River upstream of the Coranban Bridge will require special equipment, and potentially double or triple the handling requirements of the dredge material in order to transport the material to the final destination. These two options are not as favourable as is the salt marsh adjacent to the harbour.

Constructing salt marshes with dredge material requires careful placement of the material, involving, creating the proper elevation and slope into the sub-tidal zone, and allowing channel development. According to Broome (1989), the slope should be as gentle as possible (ranging from 1 to 3 percent) while still maintaining good surface runoff at low tide. Although this is probably a good indicator for areas where there are no existing salt marshes, in the case of Tracadie it would be most beneficial to try and create a slope that is similar to the slope in the adjacent salt marshes. In order to achieve this slope it might be necessary to re-visit the site after the material has settled depending on the grain size of the material being used, as silty material will have to consolidate before it can be manipulated.

Some alternatives that are more economical and have been considered to be more biologically suitable would be to construct a successional precursor to the desired wetland, (a tidal mudflat) allowing the desired wetland system to develop naturally (CATTR 1996). It could be even more beneficial to construct a tidal mudflat adjacent to an existing salt marsh which would help promote flora migration towards the newly sloped intertidal area. The idea of creating a successional precursor in the estuaries of PEI would mostly likely be the most cost-effective and practical method, especially in sediment-laden areas.

A difficulty with large salt marsh creation in the intertidal zone, noted by Yozzo *et al.* (2004), is the issue of habitat trade-off. Most shallow estuarine habitats support diverse and abundant benthic invertebrate and finfish populations. This concern with destroying current benthic habitat to create tidal marshes is an issue that has been mentioned by two Federal Regulators in the Maritimes (Guy Robichaud, DFO-HMB and Al Hanson, Canadian Wildlife Service, personal communications). Hanson, a salt marsh ecologist, has noted that viable eel grass habitat or shellfish beds are currently the best existing habitats, and thus should not be altered for the purpose of expanding salt marshes. Therefore, when conducting salt marsh terracing in Tracadie or Cascumpec, it is necessary to select areas that are not viable eel grass beds or shellfish beds. Figure 5.24 shows potential areas within Tracadie Bay where salt marsh creation could be possible with dredged material from Tracadie Harbour.

Salt marsh terracing thus must be carefully considered when working in Tracadie or Cascumpec. Salt marshes could be created in areas that have an overall low productive capacity (i.e., areas that are anoxic and/or hypoxic due to extreme growth of *Ulva sp.*).

5.5 Water Quality

5.5.1 Eutrophification and Salt Marsh Terracing

Since 1970, algae productivity has been greatly increased by nutrient loading from increased fertilizer use, discharge of animal and human wastes, conversion and destruction of riparian wetlands and increased atmospheric deposition (Peterson *et al.* 2000). On PEI, eutrophication first appeared in the late 1970s in estuaries where natural tidal exchange was hindered by anthropogenic impediments (bridges and causeways). In some areas (e.g. North River, Vernon River), this problem has been addressed and the impediments removed, which reduced the euthrophication in the upper estuaries considering

Figure 5.24 – Areas in red represent potential areas within Tracadie, Winter Bay and Winter River for potential saltmarsh creation using dredge material (2000 Ortho-rectified layer courtesy of the PEIDEEF Orthomap Nos. 111, 112 and 119).

the tidal flow was returned as much as possible to the original state (pre-causeways).

On PEI, estuary eutrophication due to non-point sources in nature was not a major reoccurring issue until the late 1990s (Cindy Crane, PEIDEEF and Clair Murphy, EC, personal communications). The first of the major estuaries to experience a significant anoxic event from eutrophication was the Mill River in 1997 (Cindy Crane, PEIDEEF, personal communication). Since 1997 the province has classified 20 estuaries throughout PEI that have reoccurring anoxic conditions, including Winter Bay/River, Mill River, Kildar Bay/Huntley and Montrose and the Foxley River. Many factors have lead to the recent reoccurrences of eutrophication. The estuaries of PEI are well suited for algae growth as they have small tidal ranges resulting in slow flushing, suitable water temperatures during the summer months and high nutrient supplies.

Agriculture is one of the main industries on PEI, with potato production being the largest. Through fertilizer use, agriculture has been known to increase the amount of nitrogen and phosphorus in watersheds, leading to the deterioration of water quality. In addition, livestock produces approximately 323,000 kg of waste nitrogen and 240,000 kg of waste phosphorus per year (Cairns 2002). Approximately 60-70 % of water flow in the rivers comes from groundwater on PEI, and almost 100 % of water flow from July to September is sourced from the groundwater (Clair Murphy, EC, personal communication).

Clair Murphy also believes that the level of nutrients in the estuaries is not directly related to the amount of fertilizer used by agriculture farmers in recent years but to the accumulation of the nutrients in the groundwater over longer periods. This suggests that there is a major misconception among the fish harvesters interviewed. Most of the interviewees discussed the water quality issues in the estuaries on the premise that recent agricultural practices have resulted in increased use of fertilizers. Paul MacPhail, Potato Development Officer with the PEIAFA, stated (personal communication on July 9, 2006) that the use of fertilizers by farmers has decreased from 2000 to 2006, for the following three reasons:

- Farmers have realized that too much fertilizer reduces the overall quality of the crop. Reducing the amount of fertilizer lowers the overall yield but increases the quality;
- Farmers have discovered that nutrients remain in the soil from the previous year. They are considering that the amount of nutrients in the fields before administering additional fertilizer (i.e., have realized the benefit of manure); and,
- The cost of fertilizer is a deterrent.

These observations support Clair Murphy's analysis that existing high nitrate concentrations in groundwater are due to previous fertilizer usage, rather than recent applications of fertilizer. Nitrate currently found in the PEI groundwater is probably one of the main variables resulting in increased algae productivity and overall water quality, as groundwater is the largest water source for the rivers and estuaries on PEI. Currently, Savard *et al.* are undertaking a study on PEI relating to the nitrate levels in groundwater to climate change, although unfortunately no results were available as of August 2006.

According to the interviewees in Tracadie and Cascumpec, the issue of sea lettuce and poor water quality is becoming a significant problem. Unfortunately, there are no studies or records of the amount or biomass of sea lettuce in any estuary on PEI (Cindy Crane, PEIDEEF, personal communication). The only records are for estuaries that have been recognized as reoccurring anoxic areas.

The construction of tidal marshes in highly vegetated sea lettuce areas and/or anoxic areas could help reduce the amount of biomass in an area, which in turn will reduce the overall anoxic conditions. Anoxic conditions or eutrophication occurs in the estuaries of PEI in the late summer and early fall when warm temperatures increase the rates of microbial activity. The warm temperatures, low tidal range and freshwater input from the rivers creates a stratification of freshwater on the surface and salt water at a depth that hypoxia and anoxia can occur in the bottom water of estuaries (Clair Murphy, EC, personal communication). Anoxic conditions occur as the abundant sea lettuce in the estuary dies and decomposes, resulting in the death of benthic shellfish and finfish that migrate through the anoxic areas (Cairns 2002).

An oyster enhancement project conducted along the Neuse River, USA (Peterson *et al.* 2000) showed that oyster reefs above the anoxic bottom were not affected by the low amounts of dissolved oxygen because the oysters were above the area being affected by the anoxic conditions. This observation led to the idea of salt marsh terracing into the sub-tidal zone. By creating terraces extending into the sub-tidal zone, making areas with re-occurring anoxic events or high sea lettuce biomass intertidal, the sub-tidal zone could be converted into a viable salt marsh that would no longer be prone to sea lettuce growth or anoxic conditions.

The terraces can be constructed using many different methods. The best method would be to attach a durable silt fence (i.e., Type II Geotextile Silt Fence) created to retain sediment. The type II silt fence, which is constructed of geotextile fabric, would be held in place by wooden stakes and in some instances a wire mesh to help with stability, can withstand small storm events and freeze in place during the winter months. The Type II silt fence would be constructed along the outer fringe of the terrace in order to help keep the sediment in place throughout the year until the material has had a chance to settle and be colonized by marsh plants. A typical section of a Type II Geotextile Silt Fence is illustrated in Fig. 5.25.

Creating a salt marsh adjacent to an existing salt marsh helps promote colonization, which in turn would shorten the time the salt marsh would take to reach maturity, if there are areas adjacent to salt marshes that are currently inundated with sea lettuce.

In Winter Bay, there are many places where salt marsh terracing could be conducted which would have an overall positive effect on the water quality and help maintain the bay as a viable aquaculture area. The preferable areas for salt marsh terracing would be in McDougall and McDonald Coves. These embayments are well protected from waves and storm events, and the currently

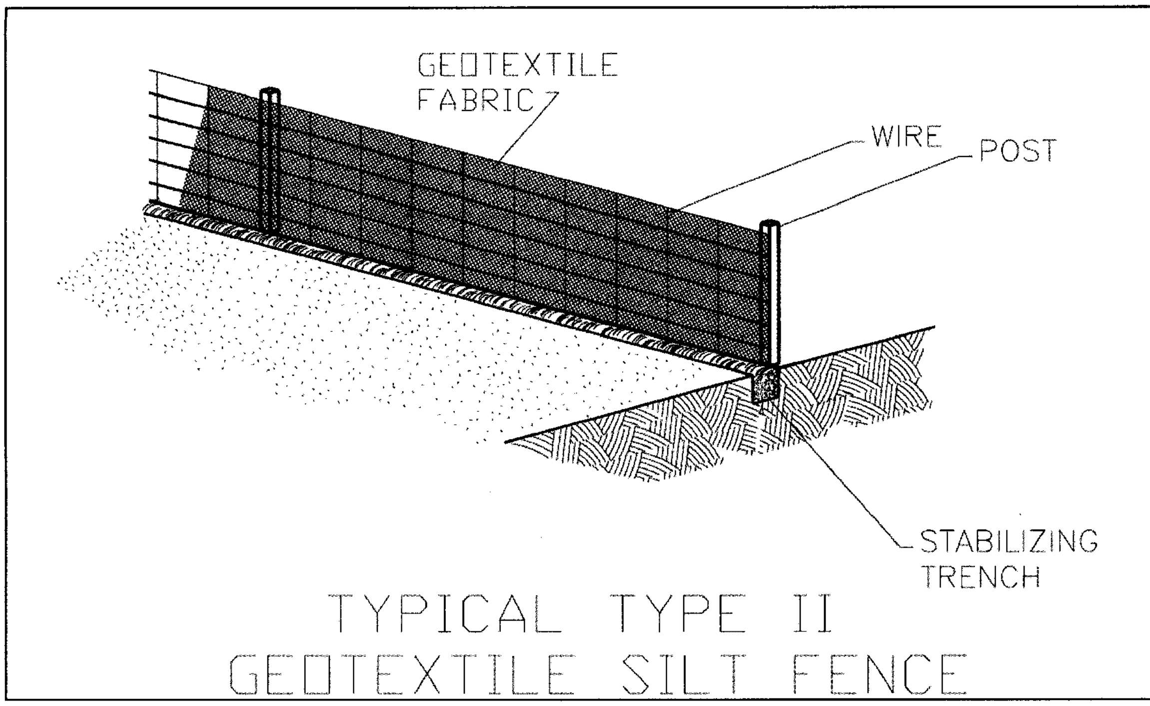

Figure 5.25 – A Figure showing a typical section of a Type II Geotextile silt fence. Courtesy of Jacques Whitford Limited, Charlottetown, PE.

existing salt marshes could help in colonizing the expanded areas. Winter Bay and Winter River are currently experiencing major algae blooms in the summer months, continuously increasing spatially and temporally. The development of salt marshes in areas that are presently anoxic could reduce the extent of the sea lettuce problem and help increase the overall water quality, as well as creating viable habitat for lower trophic levels. The potential increase in the lower tropic levels would help the local aquaculture industry as well as potentially aid the recruitment of finfish into the upper estuaries (including trout, salmon, gasperaux, and smelts) increasing tourism in the area.

The area adjacent to the south side of Tracadie harbour is another good area for salt marsh enhancement, as it is currently inundated with sea lettuce during the summer months. Forthcoming dredging for local harbour improvements could potentially provide the material to build the terraces and berms. The proposed dredge material has been tested and was found to be below the *Canadian Environmental Protection Act* (*CEPA*) Ocean Disposal guidelines. The material is high in total organic content, making it suitable for use (JWL 2005). The placement of material to create terraces would have to promote tidal inundation and settling of suspended sediments.

In promoting salt marsh creation in and around Tracadie Bay there is the potential for public outcry. Local residents like their view of the bay and river, and creating salt marshes could reduce that aesthetically pleasing view. However, the salt marshes will help reduce the odour from anoxic waters and promote new areas for wildlife to live and migrate through. As well, the proposed salt marsh enhancement would be created adjacent to existing salt marshes making the obstruction of the view a minimal issue considering the benefits. According to Simas *et al.* (2001) and Davidson-Arnott *et al.* (2002), salt marshes have high primary productivity and species diversity, representing habitat for migratory waterfowl, transient fish species and indigenous flora and fauna. In addition, salt marshes provide important resources for commercial fisheries as nursery grounds for several fish and crustacean fisheries.

5.5.2 Bridge Modification

As mentioned in section 4, local NGO groups and some fish harvesters felt that the majority of the water quality problems could be due to poor circulation in the upper estuaries due to poorly constructed bridges and causeways. In the past on PEI causeways have caused significant water quality issues by reducing the water flow and flushing times of the estuaries. Three prime examples of this would be the North River, West River and Vernon River causeways. Prior to the removal of the causeways at the three above locations between the 1980s and 1990s, major eutrophic events were occurring each year from the lack of flushing due to the restricted openings.

The local communities near Cascumpec and Tracadie watersheds feel that the bridges are aiding in the eutrophication and water quality issues in the upper estuaries and they would like to see something done. Unfortunately, the bridges that span rivers in both estuaries have been in place as early as the 1950s (see section 1) and the water quality issues did not start until the late 1980's (Cindy Crane, PEIDEEF, personal communication). Would conducting bridge modifications in either area abate the local water quality issues? Possibly, but unfortunately the cost associated with bridge modifications are extremely high and are only conducted if absolutely necessary for health and safety or possibly water quality. In 2002 the local community of Miller River and the province commissioned an oceanographic company to conduct modeling of the Mill River to see what if anything could be done to abate the water quality issues in the upper estuary. The oceanographic company looked at different scenarios that could be conducted to see if they would have any effect on the water quality. The modeling looked at bridge removal, selective channel dredging in different locations on the Mill River and Goose Harbour and the major sources of nutrient loading (Martec Limited 2002). Interestingly enough the Martec (2002) report showed that the modification of the bridges on the Mill River would have a negligible effect on water quality. In fact the report stated that removing the Cascumpec bridge would have a negative effect on the nutrient levels in the river (Martec Limited 2002).

5.5.3 Manual Removal of Ulva sp.

Another potential method to improve water quality and reduce anoxic conditions in the estuaries is to remove the sea lettuce manually using rakes and boats. Once the sea lettuce has been raked out of the estuaries it can be left on the shore to dry or be processed and washed to remove the high salt content. Once the material has been dried it can be reused as fertilizer for fields or sold as fodder for livestock. Sea lettuce has been used as fodder in the past and is still used in other countries throughout the world. Each year Japan harvests approximately 1500 tonnes of *Ulva* (dry weight) from natural populations where it is used as food and food additives (Pacheco-Ruiz *et al.* 2002). In addition, there has been an increased demand to use *Ulva* as fodder for fish and albalone in Mexico (Pacheco-Ruiz *et al.* 2002). Ventura and Castanon (1997) conducted research on the nutritive value of *Ulva lactuca*, and found that sea lettuce is a medium quality forage for goats, with a high protein content. The sea lettuce that is removed from the estuaries for either fodder for livestock or fertilizer for the fields would reduce the amount of nutrients in the estuaries. Use of lettuce would reduce the necessity for fertilizer applications and hence further contribute to alleviating the anoxic conditions considering that a majority of the sea lettuce that flourishes in the estuaries is aided by the fertilizer that reaches the estuaries through runoff.

The placement of shellfish spat in grow-out bags in the upper estuaries above the area influenced by sea lettuce blooms was suggested during interviews. Once in place the spat would feed off the nutrients moving down stream and reduce the amount of nutrients available for the growth of sea lettuce. Unfortunately, this is not a common practice and research is only being started in northern Europe and the idea in Europe is not for habitat enhancement (Jens Peterson, Senior Scientist, National Environmental Research Institute, Denmark, personal communication) and could be tried on PEI. Another reason why Tracadie would be a good bay to try mussel spat collectors in the upper estuary is because there is only one main tributary to Tracadie Bay, and hence one main source of nutrients.

5.6 Impacts on local communities

5.6.1 Economic Impacts

All the ideas mentioned above would have beneficial impacts economically for the local communities in both bays, although some would have more direct and/or greater socio-economic impact. For instance the shellfish enhancement or the creation of shellfish reefs, if successful, would have a direct impact on the local fishery within one to two years.

The reduction of dune migration over the long term would aid in the economy of areas such as Tracadie considering the large mussel fishery in the bay that could be affected from infilling bay and dune migration. Fortunately, dune migration in Tracadie is minimal. As well, beach nourishment for the purpose of abating sediment transport into the bays would protect the inner bays and help maintain protected nursery grounds and breeding grounds for many commercial fisheries. As well, the creation of salt marshes in the estuaries would help create viable habitat for primary and secondary trophic levels, as well as the possible reduction in nutrients that would be removed from the new salt marshes, potentially reducing sea lettuce growth in the upper estuaries.

In addition, abating the water quality issues in the bays and estuaries would be economically beneficial for the local community for both the commercial and recreational fisheries. Maintaining good water quality would hopefully reduce sea lettuce and eutrophic events, helping increase the health of the estuaries and rivers. Healthier rivers would promote increased fish migration and ecotourism into the area.

5.6.2 Environmental and Aesthetic Impacts

Environmentally, most types of enhancement projects are beneficial although some types of enhancement could be considered more environmentally beneficial than others. Fortunately, the ideas mentioned above are all very environmentally beneficial considering that they are ideas that have been mentioned or requested to be researched by local fish harvesters, NGOs and government agencies.

The creation of most types of marine habitats would be beneficial to the surrounding ecological unit especially if they are biodiverse and support multiple species of different tropic levels (such as salt marshes and shellfish beds). Looking at ways to fix the local water quality issues would be very beneficial especially if the enhancement was successful. Abating the nutrient levels in the estuaries and removing the sea lettuce would not only help the local water quality and environment but would be very beneficial to the local aesthetics of the many rivers and estuaries associated with both Tracadie and Cascumpec. The reduction in sea lettuce could potentially abate the eutrophic conditions in the upper estuaries and help promote the areas as more aesthetically pleasing environments.

The creation of salt marshes in areas where sea lettuce has historically grown will reduce the biomass in the estuary, promote the area as habitable for marine species and increase the amount of terrestrial species in the local area by creating a new food source. The increase in both marine and terrestrial species will encourage recreation in the area and enhance tourism in the surrounding communities.

No matter what type of enhancement is conducted it will have positive effects on the surrounding environment, by creating a healthier ecosystem that would be more sustainable. Habitat enhancement in the bays and estuaries will increase the local aesthetics making the area a more desirable and enjoyable environment to live, visit and/or vacation.

6. Discussion and Conclusions

6.1 Discussion

In assessing potential marine enhancement projects for PEI, collecting ideas and information from local fish harvesters and NGOs seemed to be a useful method of determining the best type of enhancement that could be conducted. The rationale was that the local groups and fish harvesters would have the most knowledge of the surrounding areas, and that their historical and working knowledge of the watersheds would be able to produce viable enhancement options specific to their areas. By using the interviewees' information, it was possible to determine the issues that are of significance in the coastal zones and upper estuaries helping indicate the optional types of enhancement to be integrated in the areas. The following is a list of the main ideas that were suggested by the interviewees:

- Enhancement;
- Barrier Dune Migration;
- Wetland Creation; and
- Water Quality enhancement.

Historically, most enhancement work that has been conducted on PEI deals with enhancing shellfish habitat (specifically for oysters). For Cascumpec Bay, it is very probable that shellfish enhancement (spat release and relaying) would be beneficial in the upper estuaries of Mill and Hill Rivers and more of gamble in Cascumpec Bay proper. Shellfish enhancement in Tracadie would not be a suitable idea considering the amount of mussel aquaculture currently in the bay. Shellfish harvesters in Tracadie stated that they would like to see some type of enhancement directed towards quahogs and/or soft shelled clam, but the issue of increasing the amount of biomass that requires nutrients could possibly affect the mussel farming industry, which would be economically and environmentally deleterious.

Lobster habitat enhancement was only mentioned by one fish harvester, and was not researched in depth for either area. Lobster enhancement along the north shore would not be as beneficial as other types of enhancement, as the commercial lobster fishery along the north shore is thriving and there is currently no lack of viable lobster habitat along the coast.

One of the biggest concerns raised in the interview process dealt with water quality of the bays and estuaries. Most enhancement ideas focused on maintaining or enhancing water quality on PEI.

The majority of harbours along the north shore require dredging of the channel entrance either yearly or on a five to ten year cycle, with the exception of a few, including Alberton Harbour. Dredged material is normally placed on the opposite side of the channel continuing with the coastal sand transport regime. Therefore, if dredging and disposal of dredge material is already being conducted it would be much easier to create sub-tidal berms to protect barrier beaches or to place the material in sub-aerial or inter-tidal areas potentially reducing the barrier dune migration into the inner estuaries.

The first idea of creating berms would help reduce the erosion rates of the barrier dunes by minimizing the wave action which is one of the major causes of coastal erosion, barrier breaches and washovers. The sub-tidal berm locations proposed for Cascumpec have great potential for protecting the upland and abating dune migration into the inner bays. Unfortunately in Cascumpec the dredging of the harbour entrance is not a yearly endeavor and alternative sources of material may be required to maintain the berms considering the amount of sand transport in the coastal environment.

A sub-tidal berm created off Blooming Point would not be as beneficial as at Cascumpec, as Blooming Point is much more stable than the Cascumpec Barrier Dune. Placing material in the sub-tidal zone at Blooming Point would have minimal effect over the long term.

The placement of dredge material directly on the beach is another good option for reducing the migration of the barrier dunes landward. The Cascumpec dune would be a prime location for dredge material placement, if the barrier dune was more stable. The creation of new dunes would help prevent erosion of the existing dunes also helping the existing vegetation that maintains the dune structures. The recent washover area adjacent to the lighthouse at the west end of the Cascumpec Dune would be a suitable location to place dredge material for dune creation. The area is located between existing vegetated areas, which would help to promote vegetation migration and dune stability. Unfortunately, the placement of the material and installation of the necessary erosion control measures would be a very large gamble as the area is subject to northeasterly storms in the fall and winter, and the potential of the enhancement work being destroyed in one storm is very high.

Another option for dredge material in the inner bays is salt marsh enhancement. Salt marsh enhancement has been found to be very beneficial for the marine environment. Salt marshes are breeding grounds and nursery grounds for many lower trophic level species, and hunting grounds for higher trophic level species. They also protect the coastal shoreline from erosion, they are habitats for wildlife and waterfowl and they help maintain water quality. Considering the amount of coastal development that has been occurring in recent years, salt marsh habitat is becoming more and more important. It is advisable to try and maintain, enhance or create new salt marshes.

Currently the most viable option for creating a salt marsh is to remove a dike or infill to allow tidal flushing into an area that once was salt marsh habitat or to re-slope the upland area of a salt marsh to create more area for salt water inundation. Both have been conducted with great success in the Southern Gulf of St. Lawrence and could potentially be conducted in either area. Another type of salt marsh enhancement that could be conducted on the north shore is via salt marsh terracing or creation into the intertidal zone. One of the main reasons it could be very successful and inexpensive has to do with the amount of dredging that is done for the local small craft harbours in some of the bays and estuaries along the north shore. On PEI, considering the issue of sea lettuce and the reduction in water quality that is occurring from nutrient loading, the creation of a salt marsh in sea lettuce dominated areas would help reduce the amount of sea lettuce biomass accumulating in the estuaries, creating better water quality, and providing ecological benefits from the new salt marsh in future years. PEI has large amounts of marine dredge material that could be used (depending on grain size, organic content and contamination) for salt marsh creation.

In Tracadie Bay, the area located adjacent to the small craft harbour, which will need to be dredged in the near future, would be the best location considering its proximity to the potential construction material and the adjacent existing marsh. Creating mud flats with the dredge material adjacent to the existing marsh would promote plant migration, potentially making the marsh a viable habitat in future years. At the other end of the spectrum, constructing a marsh in an area that is not adjacent to an existing marsh would require transplantation of marsh plant species, and would increase the time required to become an ecologically beneficial marsh. Creating a marsh adjacent to an existing marsh and planting marsh plant species would help the maturation of the marsh faster.

Salt marsh enhancement on PEI will also help protect the vulnerable coastline by diminishing the wave action from storms, reducing the amount of coastline lost from erosion. As well, the creation of marshes in the intertidal zone will help increase the amount of salt marsh area. These new areas, as they grow horizontally with river sediment, will help maintain salt marshes as the sea level rises. The upland migration of salt marshes could potentially become a major issue in both Tracadie and Cascumpec considering (1) sea level rise, (2) areas with high embankments between the coastal area and the upland, and (3) amount of agriculture land which farmers try and maintain.

Currently, the biggest hurtle would be the amount of time before a marsh becomes as ecologically sound as a natural salt marsh. In the long run the major benefits of creating a salt marsh outweigh the maturation time, if they reach their maximum productivity. The habitat created is so important for primary and secondary producers of the food chain and the protection created against the potential increase in storm events will help reduce the amount of sediments, nutrients and hazardous material from entering the estuaries and reducing the health of the islands coastal inlets.

Eutrophication is becoming a rising concern in the estuaries of PEI. The spatial and temporal extents of the anoxic events are both increasing and are threatening the health of the estuaries. The cause is the growth of sea lettuce in the upper shallow estuaries, along with the high temperatures. In order to enhance the water quality it will be necessary to try and reduce the sea lettuce growth. Two options, farming the sea lettuce for potential land applications and/or fodder and salt marsh creation in known sea lettuce source areas, would help remove the amount of available nutrients from the water column, reducing the sea lettuce growth and the anoxic conditions created from the dying plant matter. Using sea lettuce on farmer's fields as a nutrient supplement instead of fertilizer would appear to be viable. The salt content could be removed by spreading the lettuce above high water and allowing rain water to dilute the salt.

The material can then be moved to the fields were it will decompose and return the nutrients back to the soil.

For socio-economic reasons, shellfish enhancement has been one of the main enhancement ideas practiced year after year on PEI. Socioeconomic benefits are created from low maintenance and inexpensive enhancement work. Cascumpec Bay watershed shellfish harvesters have benefited from many years of spat release in the upper estuaries. Another argument for shellfish bed enhancement is the beneficial type of habitat that is created. Not only would habitat be enhanced for oysters, but the biodiversity of the viable shellfish reef and the multiple trophic levels that would use the area would be extremely beneficial to the surrounding marine environment.

Beach nourishment as marine habitat enhancement is very new in the Maritime Provinces. FOC has not considered it as an option for marine habitat compensation, as it does not directly create marine habitat, although beach nourishment does help to maintain the existing viable inner bay habitat. On PEI, the inner bays are very important as breeding, nursery and spawning grounds for many commercial and recreational fish species and are very important to maintain for many socio-economical reasons. In addition to abating the erosion of the barrier dune systems, newly created sub-tidal berms could be potential habitat for many marine invertebrate species of the lower trophic levels helping to increase prey for the higher trophic levels (commercial species).

Unfortunately, beach nourishment is not a very good enhancement idea for Cascumpec or Tracadie. In Cascumpec the barrier island is unstable and the gamble would be rather large considering that dredge material is not readily available year after year. For the Tracadie area dredge material could be readily available but the barrier dune system is located inside the national park, so no material can be placed directly on the barrier dune. With regards to creating sub-tidal berms in Tracadie, the barrier dune system appears to be stable enough that the enhancement work would have a minimal effect.

Salt marsh enhancement would probably be one the most socio-economically beneficial types of enhancement mentioned by local fish harvesters, NGO's and government agencies. Salt marshes create viable habitat for primary and secondary trophic level species, the building blocks of the coastal commercial fish harvester. They help maintain water quality in estuaries which could directly enhance the local estuaries commercial fishery and recreational fishery, in turn increasing the eco-tourism in the area. They protect the upland agricultural land from erosion helping reduce the amount of silt and sediment in the estuary. Creation of salt marshes in existing sea lettuce habitat would also reduce the water quality issues in the estuaries by reducing the amount of biomass in the upper estuaries hopefully abating the eutrophic events that have been occurring in greater frequency in the bays and estuaries of Tracadie and Cascumpec.

Direct removal of sea lettuce is another socio-economically beneficial option for Tracadie and Cascumpec. Harvesting sea lettuce for agricultural field applications would create a new industry on PEI which would help reduce the amount of fertilizer that is used on agricultural fields and removes large amounts of nutrients that help create the anoxic events in both Tracadie and Cascumpec watersheds. The reduction of those events would increase local water quality, increasing the potential for estuary commercial fisheries and recreational fisheries, in turn promoting eco-tourism in the area.

6.2 Conclusions and Recommendations

This research paper has focused on selected marine enhancement alternatives for the coastal north shore waters of PEI. The main conclusions reached are:

- The ideas that were researched, although new for the southern Gulf of St. Lawrence, have been successfully applied elsewhere. They should be given due consideration by DFO-HMB as viable marine enhancement ideas for compensation requirements in the future.
- Beach nourishment is not practical for either Tracadie or Cascumpec.
- Salt marsh creation would probably be the most beneficial type of enhancement for both Tracadie and Cascumpec Bays
- The enhancement ideas in order of maximum socio-economic benefit, from highest to lowest, are salt marsh creation, shellfish enhancement, and sea lettuce removal. Dike removal would have negligible socio-economic and limited environmental impact.

The present policy of DFO does not easily recognize freshwater enhancement as compensation for destruction/disruption of marine habitat, although according to new information sent out by DFO in the summer of 2006 they are realizing the importance of the upper freshwater tributaries and the role they play in the health of the overall coastal environment. On PEI, the coastal environment should be defined to include the entire watershed that empties into the marine environment, every freshwater river should be considered part of the coastal environment. All the bays on PEI are fed by the freshwater rivers which are vital for helping maintain the overall health of the estuaries and bays. Conducting freshwater enhancement to help maintain water quality or fish passage will help maintain or create healthier estuaries for commercial and recreational fish species, multiple trophic levels, and salt marsh stability. Therefore, it is necessary to realize the importance of the rivers and their role in the coastal ecosystem of PEI, making freshwater enhancement a viable option for marine enhancement requirements.

In addition, increasing awareness and education to help reduce runoff from roads, construction and agriculture fields will reduce sedimentation and infilling in the breeding, nursery and spawning grounds along the rivers and in the estuaries.

Along the north shore of PEI there are numerous bays and estuaries that could be studied to determine if beach nourishment is viable option for enhancement. Luckily there are many bays and estuaries along the north shore outside the National Park that could potentially benefit from beach nourishment, considering that the majority of bays have small craft harbour that require maintenance dredging, making beach nourishment a very practical, inexpensive and social-economically beneficial marine enhancement option for helping maintain the inner estuaries.

This research did not show the need for Lobster enhancement in either Tracadie or Cascumpec areas. However, if enhancement work was being investigated along the south shore of PEI, lobster enhancement should be considered and researched.

Other types of enhancement that could be conducted along the north shore would be research based, focusing on invasive species that attack commercial shellfish, or studying new ways to maintain the local water quality in the bays. Any new type of enhancement project that is researched along the north shore should be conducted in conjunction with the local fish harvesters, community members, NGO's, provincial and federal regulators and local educational institutes. A good example would involve creating an alliance with Federal and Provincial departments, NGO's (including Ducks Unlimited and local environmental groups), fish harvesters and the local university to conduct salt marsh terracing with a long term study to determine the most appropriate methods for the north shore estuaries.

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Appendix A

Research Questionnaire

Habitat Assessment Questionnaire
Habitat Enhancement Thesis

Dale Conroy Master's Student
Memorial University

Personnel Information (Volunteer)

Identification No.:

Occupation:

Harbour/Watershed where you work:

Type of work that is conducted:

Historical Enhancement work that has been performed in the Area

When was the work conducted:

Where was the work conducted:

How was the work conducted:

Who conducted the work:

Potential Enhancement work

Potential Enhancement work that could be conduced within the vicinity of the Watershed/Harbour: