Barachois Evolution in the Bras d'Or Lakes Under Past, Present and Future Sea-level Rise: Progress to Date

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Introduction

'Barachois' is a term used in Atlantic Canada that refers to coastal ponds and lagoons that are either fully or partially separated from the open sea by a barrier beach. Approximately 12% of the Bras d'Or Lakes (BDL) shoreline in Cape Breton, Nova Scotia, is formed by barachois (Taylor and Shaw, 2002). Many of these barriers have been developed into harbours, roads and recreational areas. Under present rates of sea-level rise (36.7 cm/century, based on tide gauge data recorded in Charlottetown and North Sydney between 1970 and 2005; Shaw *et al*., 2006) and future estimates (115.1 cm/century by 2100; Shaw *et al*., 2006; Church *et al*., 2001) barrier beaches in the BDL will migrate landward and/or drown. Any increase in storm frequency and/or intensity will accelerate this process. Likewise, if shoreline development that results in hardening persists, sediment supply to coastal barriers may be cut off in some areas, increasing the likelihood of barrier erosion and drowning. As such, increased effort and expense will be necessary to maintain coastal defences and other structures, particularly those developed on barrier beaches, which are an inherently dynamic component of the coastal zone.

The value of the barachois to the health of the BDL ecosystem, including their potential role as nurseries for aquatic life, is poorly understood. The barrier beaches that define the barachois also serve as protection for the ponds themselves, whose ecosystems will be altered as the barriers become submerged and/or migrate landward. Erosion of the backshore of the barachois, where most of the BDL residential infrastructure (e.g. houses, wells and septic systems) is located, is also expected with continued sea-level rise.

Together with partners from the Geological Survey of Canada (Atlantic), the Unama'ki Institute of Natural Resources (UINR) and the BDL Collaborative Environmental Planning Initiative (CEPI), the Nova Scotia Department of Natural Resources (NSDNR) aims to develop a basic understanding of the age of the barachois, the nature of the sediments underlying them and the geodynamics of the barriers (i.e. how quickly they evolve from growing or stable phases, to landward-migrating or submerging phases; see Taylor and Shaw, 2002). This information will provide baseline data with which modern and future coastal dynamics may be compared, including barrier response to both faster and slower rates of sea-level rise (documented for the Holocene) with respect to modern rates. This paper outlines the approach to this study and progress made in 2013.

Background

Following deglaciation, which occurred locally around 14,000-15,000 years before present (years BP; Shaw *et al*., 2006; Stea *et al*., 2011), the BDL basin was isolated from the Atlantic Ocean and consisted exclusively of freshwater lakes, fluvial systems and wetlands. These freshwater environments were drowned when relative sea level rose above -25 m (the depth of the sill at Great Bras d'Or Channel) ~6350 years BP (Shaw *et al*., 2006). Relative sea level continued to rise throughout the remainder of the Holocene—rapidly at first, then slowing to modern rates and drowning coastal landforms as it rose. Spits, tombolos and barrier beaches below modern sea level in the BDL have been clearly identified from multibeam imagery and range from -7 to -25 m, with most occurring between -15 to -20 m and -20 to -25 m (Shaw *et al*., 2006). Based on a relative sea-level curve constructed for the BDL (St. Patricks Channel area; Fig. 1; Shaw *et al*., 2006), *in situ* and near *in situ* drowning of these coastal landforms took place prior to 4500 calibrated (cal) years BP, with the majority of drowning occurring between

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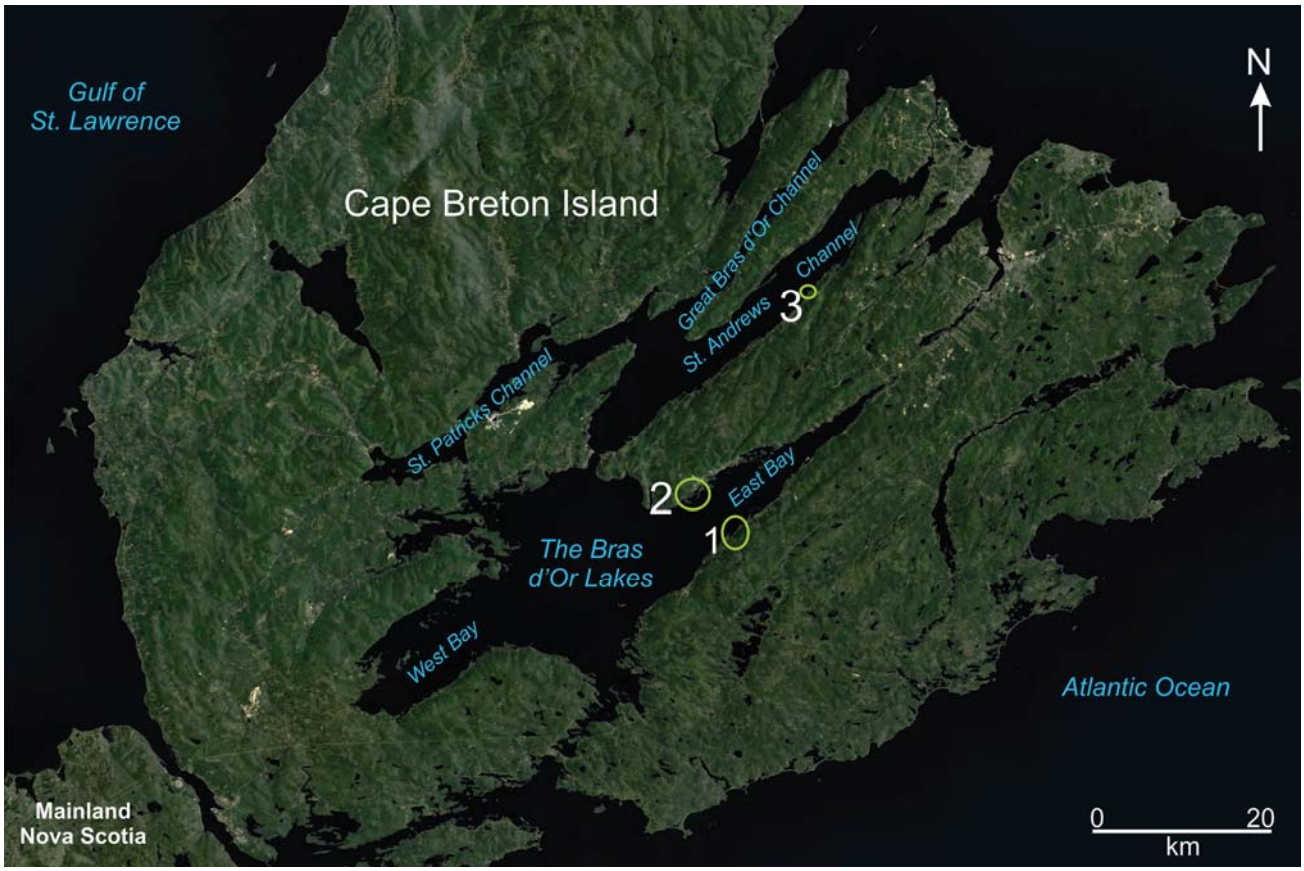

Figure 1. Location of Bras d'Or Lakes, Cape Breton Island, Nova Scotia, and barachois study sites: 1. Irish Vale Pond; 2. Amaguadees Pond; 3. Campbells Pond.

5500-6000 cal years BP. The rate of sea-level rise at 4500 years BP was 57 cm/century and 69-75 cm/century between 5500-6000 years BP. The rate at the time of the onset of marine conditions in BDL (at ~6350 cal years BP) was 79 cm/century. It follows that if future rates of sea-level rise exceed ~60 cm/century, then *in situ* drowning of modern coastal landforms in the BDL will occur. Migration of dynamic coastal landforms, including the barriers that define the barachois, will proceed inland until that time unless reductions in sediment supply occur (e.g. from shoreline hardening), which would accelerate *in situ* stranding and drowning.

The ages of the modern barachois that fringe the Bras d'Or Lakes are unknown. Taylor and Frobel (2005) attempted to core submerged backshore ridges behind several barriers in the Bras d'Or Lakes and radiocarbon date peat deposits; however, they found little evidence of older consolidated peat. Based on this and on modern rates of sea-level rise derived from tide gauge records, Taylor and Frobel (2005) concluded that to obtain a better chronology of the barrier beaches, sediment coring beneath the backshore ponds was required.

Three barachois were selected to study the age and dynamics of the modern barriers in the BDL: two in East Bay (Irish Vale and Amaguadees ponds) and one in St. Andrews Channel (Campbell Pond) (Figs 1-4). The three ponds are diverse in terms of the evolutionary phase of their enclosing barrier. Irish Vale Pond is formed by a barrier that is partially submerged due to ongoing sea-level rise and inadequate sediment supply (Fig. 2). Taylor and Shaw (2002) classified the Irish Vale Pond barrier as a Phase 5 barrier (i.e. "collapsed, stranded"). The barrier enclosing Campbell Pond, in St. Andrews Channel, is classified as a natural, cuspate, Phase 3 barrier (Fig. 3; Taylor and Shaw, 2002). The barrier here is normally closed, which keeps salinity levels low, although a channel on the

Figure 2. Oblique aerial view of Irish Vale Pond in East Bay, Bras d'Or Lakes (photo courtesy of F. Baechler). Irish Vale Pond is ~485 m N-S and has a maximum width of 145 m.

north side opens up periodically (Fig. 3). Finally, the barrier enclosing Amaguadees Pond has been anthropogenically altered with roads, a bridge (across a dredged channel) and a playground (Fig. 4). In terms of its evolutionary phase, Taylor and Shaw (2002) classified it as a Phase 3 ("establishment") artificial barrier. The pre-developed barrier is currently being assessed via aerial photograph analysis and interviews with local elders.

Methods

Aerial photograph analysis and historical research via interviews with local, long-term residents and elders will allow for the identification of major changes in the barriers of the three barachois study sites (Irish Vale, Amaguadees, and Campbell ponds). This research will establish some of the major (i.e. permanent to semi-permanent) changes in barrier dynamics that have occurred over the past ~50-80 years, which will eventually be compared with evidence for past barrier dynamics and evolution recorded in geological records.

Geological proxy data that are being collected for this study include shallow seismic and sidescan sonar data, as well as sediment cores from each of the three barachois. Sedimentological and microfossil analyses will be conducted on the sediment cores with the aim of identifying paleoenvironmental change in the pond (e.g. initial barrier development, barrier breaching during large storms and break-down of the barrier). Radiocarbon dating of organic matter sampled

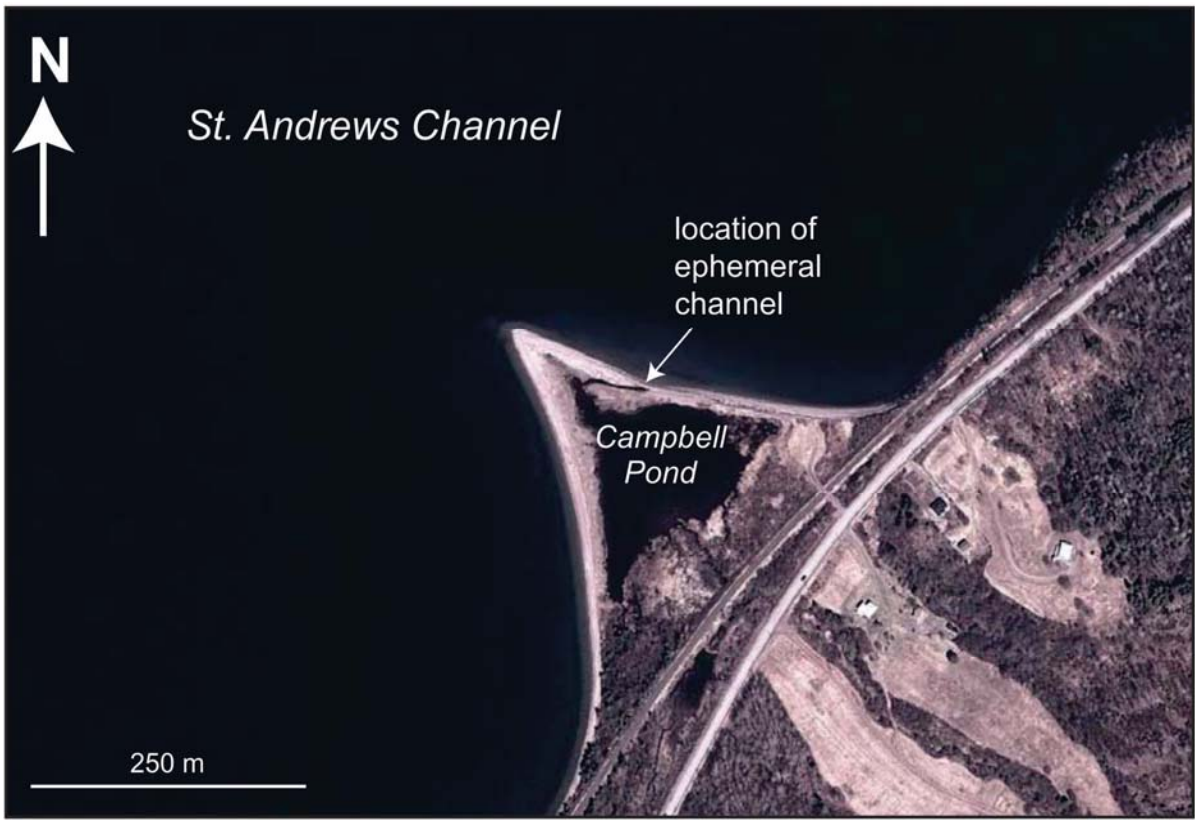

Figure 3. Satellite view of Campbells Pond, St. Andrews Channel, Bras d'Or Lakes (Google Earth, July 19, 2013).

from the sediment cores will be used to establish a temporal framework for the documented paleoenvironmental change.

2013 Work Program and Initial Results

Approximately 25 line-kilometres of sidescan and high-resolution (low penetration) echosounder profiler data were collected across Irish Vale, Amaguadees and Campbells ponds on the 5th and 6th of October, 2013 (Fig. 5). Seven sediment samples were also collected from the three ponds using a 20 cm × 20 cm rope-mounted, stainless steel van Veen-style grab. These samples will be examined for their microfaunal content and used as a modern analogue for down-core paleoenvironmental interpretation.

All of the grab samples, which were collected from central parts of the barachois, are fine-grained and organic rich. Two of the samples included broken oyster shells (from Amaguadees and Irish Vale ponds).

Initial interpretation of the acoustic data and grab samples indicate that all three ponds have centrally located, organic-rich mud fill and sandy, gravelly margins. Shallow methane gas, which masks the underlying stratigraphy, is common in all of the ponds. Amaguadees Pond has up to ~5 m of fine-grained sediments and a preserved stratigraphy that includes unconformities and buried channels (Fig. 6). Submerged overwash deposits of sand and gravel occur behind the barriers that define the ponds. Underlying the stratified sediment in Amaguadees Pond is a prominent reflective surface (unconformity), below which may be interpreted as 1) till dating to the last glacial maximum (~20,000-24,000 years BP; Stea *et al*., 2011) or to the Younger Dryas (~10,000-11,000 years BP); 2) a coarse-grained delta with steeply dipping beds; or 3) bedrock (Fig. 6). The sidescan data from Amaguadees Pond revealed numerous mounds, up to 1 m in height and 4-6 m in diameter (Fig. 7). Some of these mounds are arranged in a linear pattern, and the initial interpretation of these is that they are oyster bioherms. Attempts were made to sample the mounds with the grab sampler, but they

Figure 4. Oblique aerial view of Amaguadees Pond in East Bay, Bras d'Or Lakes (photo courtesy of F. Baechler). Line A-B (~375 m long) is seismic profile shown in Figure 6.

Figure 5. The author and two collaborators from the Geological Survey of Canada (Atlantic Division) conducting seismic and sidescan sonar surveys in Irish Vale Pond. Instruments are mounted on wooden frame across bow of NSDNR boat.

are hard and we were unsuccessful in obtaining any sediment.

All together, the information collected from the seismic and sidescan surveys provide the basis for future mapping, further interpretation, and targeted core sampling (planned for March, 2014). Interviews with local residents, aerial photographic interpretation, and sediment core analyses are also planned for 2014.

References

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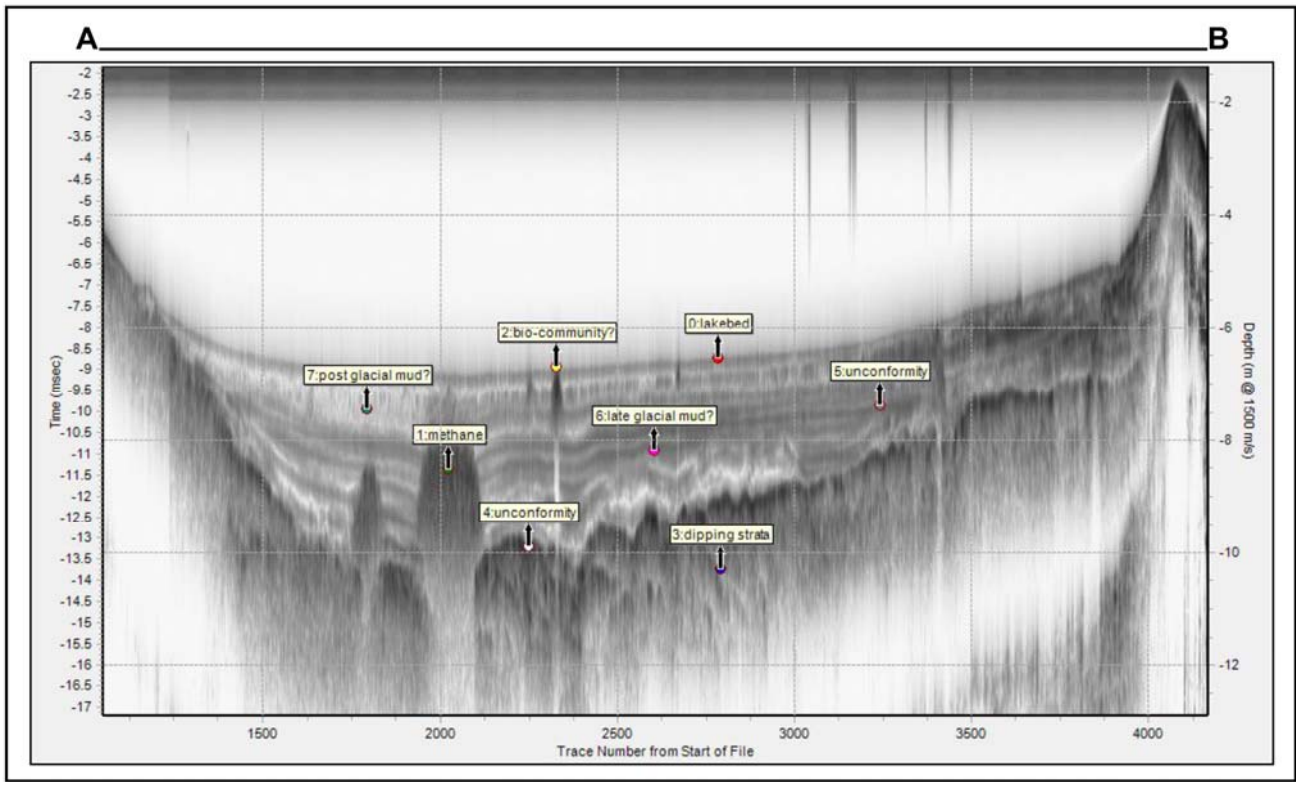

Figure 6. Initial interpretation of seismic surveying in Amaguadees Pond. Location of line A-B is shown in Figure 4. Labels on figure (initial interpretation): 0. lakebed; 1. shallow methane; 2. oyster bioherm; 3. dipping strata below lowest unconformity; 4. lowest unconformity; 5. another unconformity; 6. late glacial mud; 7. post-glacial mud.

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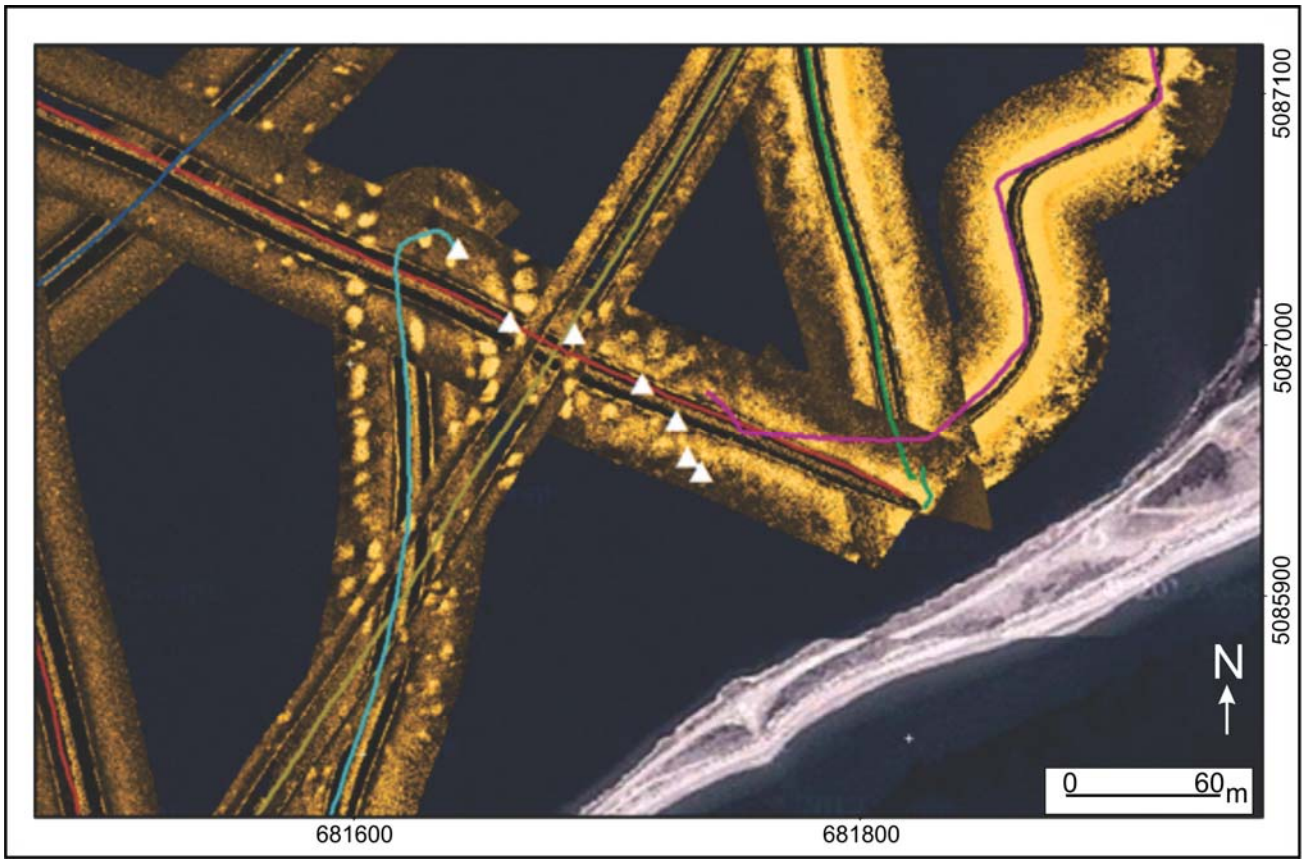

Figure 7. Example of sidescan mosaic and boat tracks (coloured lines) in Amaguadees Pond, showing what are thought to be oyster bioherms (circular features on the sea floor). Their unusual linear pattern in places may indicate anthropogenic influence (i.e. evidence of past aquaculture activities). White triangles show locations of sediment grab samples.