The Changing Bay of Fundy:
Beyond 400 Years

Proceedings of the 6th Bay of Fundy Workshop
Cornwallis, Nova Scotia
September 29th – October 2nd, 2004

Editors

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Dedication

This workshop report recognizes the continued efforts of all citizens and organizations living on or around the Bay of Fundy and Gulf of Maine, committed to the sustainable use of the region's living and non-living resources and to the protection and conservation of its many ecosystems and diverse wildlife. Such efforts, one by one and collectively, and often against great odds, offer hope to the future of this unique and irreplacable coastal region of the Canadian Maritimes and the New England States.

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Preface

The 6th Bay of Fundy Workshop was held from September 29th to October 2nd, 2004 at the Annapolis Basin Conference Centre, Cornwallis Park, Nova Scotia. The years 2004–2005 mark the 400th anniversary of the arrival of Samuel de Champlain and a small group of French colonists in the Bay of Fundy and the establishment of the first enduring European settlement in Canada. In the 400 years since, there have been profound changes in the Bay's ecosystems. On this anniversary it seemed timely to consider what has happened to the Bay during these four centuries, reflect upon its present condition, and discuss what needs be done to ensure its continued ecological integrity and productivity. Fittingly, the Workshop theme was *"The Changing Bay of Fundy—Beyond 400 Years"*.

The Workshop attracted 165 participants, including a large contingent of students. A total of 65 papers and 26 posters, record numbers for a BoFEP Workshop, were presented in ten scientific sessions. Three plenary talks pertaining to the Workshop themes were also given. Following the final plenary session, participants formed three round tables to discuss the future of the Bay of Fundy in relation to the health of the Bay, the management of the Bay and the coastal communities of the Bay. After the banquet, members of the public joined delegates in a "Fundy Festival and Showcase", at which Moira Brown, a Senior Scientist at the New England Aquarium, gave an illustrated talk entitled "*Struggling in an Urban Ocean—The Plight of the North Atlantic Right Whale*".

A number of awards were presented at the Workshop banquet. The first BoFEP "Environmental Stewardship Award" was presented to Patricia Hinch, a "Special Recognition Award" was presented to Graham Daborn, and awards were given for the best papers and posters presented by students at the Workshop.

The BoFEP Annual General Meeting was held during the Workshop. An offer by Huntsman Marine Science Centre to host the 7th BoFEP Bay of Fundy Science Workshop in St. Andrews, New Brunswick, in the autumn of 2006 was accepted. We look forward to seeing you all there.

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March 2005

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Overview of the Workshop

The 6th BoFEP Bay of Fundy Workshop was held from September 29th to October 2nd, 2004 at the Annapolis Basin Conference Centre, Cornwallis Park, Nova Scotia. The years 2004–2005 mark the 400th anniversary of the arrival of Samuel de Champlain and a small group of French colonists in the Bay of Fundy and the establishment upon its shores of their fortified Habitation at Port Royal, the first enduring European settlement in Canada. In the 400 years since, there have been profound changes in the Bay's ecosystems, in the abundance and diversity of its natural resources, and in the number and nature of the human communities along its coasts. Thus, on this significant anniversary, it seems timely to consider what has happened to the Bay over the past four centuries, reflect upon its present condition, and discuss what needs be done to ensure continued productivity and ecological integrity of this unique ecosystem during the centuries to come. Fittingly, the Workshop theme was *"The Changing Bay of Fundy—Beyond 400 Years"*. Appropriately, it convened just across the Annapolis Basin from, and within sight of, the defensive embrasures of the reconstructed Port Royal Habitation. The Workshop attracted 165 participants from around the Bay of Fundy and the northern Gulf of Maine, including a large, enthusiastic contingent of student researchers, and several overseas visitors.

Plenary Presentations

In keeping with the theme, on each of the three days of the workshop, keynote speakers were invited to give an opening plenary presentation focusing on the past, present and future, respectively, of the Bay of Fundy. The three invited presentations were:

"Early Perspectives on the Fundy Environment"
Heather MacLeod, St. Mary's University, Halifax, NS

Heather stresses the importance of the writings of some of the early explorers and colonists of the Bay of Fundy in understanding the history and natural history of this region. Their descriptive commentaries provide valuable insights into the native inhabitants, environments and natural resources of a region still relatively unsullied by European influences. Their descriptions and quantitations are especially good for the many abundant natural products deemed to be marketable commodities. The historic documents provide "important baseline data of ecosystems operating at their prime", from which we can trace Fundy's subsequent history and sketch out the changes in populations and economies over the 400 years until the present day. It is very much a history of resource exploitation, largely in an unsustainable manner, both on the land and in the sea.

Heather describes the role of the early fur traders in the initial exploration and economic development of the area. However, excessive hunting and trapping soon led to the collapse of the local fur trade and hastened its westward migration into virgin areas of New France. Nevertheless, there were still the vast, seemingly limitless, tracts of old growth Acadian forest, dense with giant hemlocks, pines, oaks, maples and birches, many 300 to 400 years old and measuring five feet or more in diameter. This was very much the landscape of Longfellow's *Evangeline*, "the forest primeval, the murmuring pines and hemlocks, bearded with moss and in garments green". Over the following centuries, a booming timber industry transformed the primeval forests and entire watersheds, first selectively removing prime softwoods for spars and sawlogs, and later clearcutting vast swaths for timber and pulp production. Sawmills and dams sprang up on virtually every river in the region, with devastating consequences for anadromous fish populations already reeling from overharvesting.

A wide variety of other wildlife and waterfowl was also available for harvest, not to mention the teeming marine life of the coastal waters. In the early days, there were almost unimaginably large schools of pelagic and demersal fish, including vast numbers of huge cod and halibut, the likes of which are seldom seen nowadays. Most rivers were choked in late spring with incredible runs of anadromous fish such as salmon, shad and striped bass. Over the centuries, unregulated harvesting reduced most of them to pitiful remnant populations, some now struggling on the verge of extirpation. Heather recounts the plight of the shad as a representative example of what has happened to so many other fish stocks. There was also extensive dyking of productive marshlands by the Acadians and subsequent generations of farmers, effectively transforming rich marine productivity into valuable agricultural production that has sustained the region's economy.

Towards the end of the 19th century came a growing appreciation of the Bay of Fundy's aesthetic and recreational values, as a promising destination for visitors. This interest has blossomed in recent years into an ecotourism boom, an important and expanding economic factor in more and more coastal communities. With this shift in attitude toward Fundy, and towards the natural world in general, has come a growing appreciation for what has been diminished or lost over past decades and centuries.

"The Bay of Fundy at a Turning Point"
Arthur Bull, Saltwater Network, Sandy Cove, NS

Arthur opened and closed his thought-provoking presentation about the Bay of Fundy in the present day with poetry. The first poem, Bliss Carman's *Low Tide at Grand Pré*, evokes stirring images of Fundy tides reaching out across mudflats and salt marshes, and the long-ago attachment of the Acadian settlers to their bountiful coastal lands. The second, *Bay of Fundy Crossing*, a vividly descriptive verse from Arthur's own pen, gives a contemporary, fleeting backward glimpse at the region's major urban centre, Saint John, New Brunswick, with its residential sprawl and industrial blight—"oil tanks like white pills lined upon the rock". Thus, he neatly frames his message about the Bay between contrasting images of a once pristine, natural ecosystem functioning at its prime and a present wounded, troubled ecosystem rendered impoverished and threadbare by modern man's thoughtless misuse.

Arthur goes on in a more positive vein to describe how man and nature have interacted, and still do interact, intimately in the Bay of Fundy region. He points out the many interweaving strands of culture, history, economics, society, and latterly, the natural sciences, which are helping us to understand what the Bay of Fundy is and how it works. Here, unlike in large urban centres, the human and natural worlds are almost always interconnected and interacting. Thus, it is vital that we think of the

Bay holistically, to view its cultures, economies, ecosystems and sciences as part of interdependent wholeness, if we are ever going to live sustainably and harmoniously upon its shores.

He cautions, however, that there are great world trends bearing inevitably upon coastal communities and threatening their well-being, as well as the natural resources they rely on. Firstly, there is corporatization, whereby profit-driven, remote, corporate entities increasingly monopolize and overexploit fisheries and other natural resources. Secondly, there is globalization, whereby powerful multinational corporations with no links to, and little or no concern for, the needs or well-being of small communities, extract local natural resources to satisfy insatiable international markets and their financial bottom line. In this connection, Arthur highlights an ongoing controversy over a proposal to develop a mega quarry on Digby Neck, Nova Scotia, to export basalt for road building in New Jersey. Thirdly, there is the problem of accessibility to information, whereby an exponentially growing stockpile of information about our natural and human worlds remains virtually inaccessible to those who need it for making informed decisions about the future of their communities and environments.

But coastal communities have always been resilient, and many are responding to these retrograde trends by finding new ways to avert or blunt their impacts. To this end, there has been a remarkable growth of diverse, community-based initiatives designed to protect and conserve the environment and resources. This has been accompanied by a steady rise in the number of grass-roots organizations ready to assume a more direct role in the stewardship of local resources and accept greater responsibility for their communities' economic and social well-being.

Arthur also speaks eloquently about the intimate, almost spiritual, connections that form between the people of Fundy and this "special place on the planet". From the time of the original native inhabitants to the present, people living here experience some measure of profound connectivity to the Bay's natural rhythms and maritime processes. Many of those who now dwell around the Bay have a special relationship with it—they have made a life on its shores and it has become a part of their very being. Because of such intimate dependence, they should have a dominant say in what happens to their community, their environment and their resources; in short, the "people in this place have a primary role in determining its future". Increasingly, coastal communities around Fundy are demonstrating a determination to assume such primacy by taking charge of their own destiny and acquiring the skills, tools and resources to do it effectively and well.

"Challenges for Ocean Science and Ocean Management"

Arthur Hanson, International Institute for Sustainable Development, Winnipeg, MB

Art was invited to help participants shift their focus from the past and present issues confronting the Bay of Fundy to what needs to be done to ensure a bright and productive future for the Bay and the coastal communities dependent on it. In his presentation, he stresses the importance of thinking long term, at least as far as the middle of this new century, rather than the present practice of devoting most time and scarce resources to responding to present or imminent crises. In looking to the future of the ocean, we must take into account the many new drivers that are influencing marine science and development such as advances in biotechnology, remediation science, information technology, nanotechnology, and remote sensing. It is also necessary to recognize that the perceptions and attitudes of most Canadians, dwelling far from the ocean in urban centers, are increasingly alienated from the natural world. The disparate groups claiming to speak for the ocean are mostly promoting their own interest rather than that of the ocean. Neither should we count on governments to be that voice for the ocean.

Art suggests that there are four legs to the sustainable ocean development stool, namely, ecology, economy, society and security, and he briefly elaborates on each of these legs. There are a number of environmental issues that will become critical within several decades such as global warming, sea level rise and loss of biodiversity. Immediate management action is required if we are to avert or adapt to these crises. Furthermore, there is an urgent need for periodic comprehensive overviews of the state of our oceans and the status of coastal communities. Marine environmental quality guidelines and standards must be developed to guide management decisions. As people extract more and more products and services from the sea, we must ensure that it is done in a sustainable, economically viable manner. To this end it is important to take full advantage of new opportunities for the sustainable use of the oceans arising from new technologies, new collaborations and new investment approaches.

As ocean development proceeds, we need to appreciate the social dimension, recognizing who will reap the benefit and who will bear the costs. It is also important to recognize the reality and scope of options foreclosure, in that the decisions made about ocean use today may preclude many future uses. It is important to make effective use of integrated coastal management and adaptive management tools, as well as such legislative implements as the new *Oceans Act* and various international marine agreements. We need to be much more efficient in acquiring and sharing ocean information widely amongst those who require it. It is also important to enhance the capacity of coastal communities to participate in ocean management and to broaden the capabilities of marine institutions in the region. We also have to recognize growing security concerns that may impact on sustainable development and on coastal communities. In concluding, Art states, "I see a clear future for BoFEP and its partners in speaking out and acting on behalf of the Bay of Fundy."

Scientific Paper and Poster Sessions

A total of 68 papers and 26 posters, a record numbers of submissions for a BoFEP Fundy Workshop, were presented in the following scientific sessions:

1. Contaminants and Ecosystem Health

While much of the Bay of Fundy marine ecosystem is considered relatively unpolluted, there are local areas where concentrations of some contaminants are higher than natural background levels, and where synthetic industrial compounds such as pesticides are detected. Additionally, a few contaminants, notably mercury, may be present at elevated concentrations through much of the region. Therefore, a dozen papers and several posters focused on the sources, distribution, fates and effects of contaminants in the Fundy marine environment.

Seafood-processing plants are found in many coastal communities in Atlantic Canada. Typically, these plants release processing wastewater containing organic matter, nutrients, and bioaccumulated toxic chemicals into the nearshore environment, raising concerns about eutrophication and other contaminant problems in shallow-water habitats. **Corkum et al.** investigated the wastewater discharged from six seafood processing plants in various parts of the Maritimes, examined the pollution prevention procedures that they use, and considered possible environmental impacts. This study is part of an ongoing Environment Canada program aimed at developing a national strategy for more effective management of wastewater from seafood processing plants. A study by **Garron and Rutherford** looks at the toxicity of this wastewater, which may contain cleaning chemicals and pesticide residues as well as the organic wastes. They carried out a suite of toxicity tests, including fish survival, sea urchin fertilization and Microtox® light inhibition tests on the effluent from several processing plants. The wastewater from the different plants varied considerably in toxicity, but most of the tests revealed that all effluents were toxic to some degree.

The water and sediments in many confined, coastal embayments of the Bay of Fundy periodically have elevated levels of coliform bacteria that trigger costly closures of clam beds to harvesting. Typically, the exact source of this contamination has been notoriously difficult to pinpoint. **Bezanson et al.** have studied the fecal contamination on a productive clamflat in Nova Scotia's Annapolis Basin and attempted to identify the source. They used DNA typing to distinguish between bacteria coming from wildlife present in brooks flowing into the cove, runoff from beef cattle pastures, influx of contaminated seawater into the cove, seepage from residential septic systems, and the excrement from flocks of gulls foraging on the flats. Preliminary results from this ongoing study do not provide sufficient evidence to clearly implicate any one particular source. In another paper dealing with the question of coliform contamination in coastal waters, **Sullivan** reviews the results of a recent workshop devoted to microbial source tracking (MST). This technique tests for specific genes in bacteria that may indicate whether they originated from an animal or a human source. Such molecular fingerprinting represents a considerable improvement over traditional fecal monitoring techniques that provide little insight into the source of the contamination.

Several papers considered the concentrations of heavy metals, particularly mercury, present in different compartments of the Bay of Fundy ecosystem and assessed some of the possible harmful biological effects. In 2002, **Yeats and Dalziel** collected samples of water, suspended particulate matter and bottom sediments from many sites in the Bay and analyzed them for 28 heavy metals. Most of the metals were at, or close to, natural background levels over much of the Bay, although elevated concentrations of a few metals occurred in localized areas. For example, there were significant concentrations of copper in Minas Basin, zinc near Passamaquoddy Bay, and iron and manganese in Saint John Harbour. The use of such data in assessing environmental quality is discussed, particularly in relation to a specific threshold, such as areas where concentrations exceed normal background levels or are higher than specified in toxicity guidelines designed to protect marine biota or human health. **Didyk et al.** assembled the available data on parasite load and body burden of mercury to determine if this combination of stresses threatens migrating shorebirds. Parasites are most prevalent during the bird's stopover in Fundy, largely because their principal food, *Corophium,* plays host to several different types. *Corophium* also accumulates mercury, likely passing it along to the shorebirds. The level of mercury measured in the birds agrees closely with an estimate derived from their consumption of *Corophium*. The neurological and physiological effects of low levels of mercury and the added stress from parasitism may be compromising bird migration, particularly as juveniles, which tend to have more parasites and a greater mercury burden.

Fundy's salt marshes are a sink for heavy metals adhering to the accumulating sediments. **Hung and Chmura** investigated the distribution of five heavy metals in sediments collected from seven salt marshes scattered along Fundy's New Brunswick coast. They analyzed sediments deposited over a five-year period at undisturbed sites that were remote from point sources of metal pollution. Concentrations of lithium, lead, zinc, copper, and arsenic varied with the characteristics of the sediments, but were mostly close to natural background levels for the Bay. Nevertheless, it was possible to detect an influence from some major contaminant sources, such as elevated lead levels in marshes near Saint John and an adjacent coal-burning power plant. Methylated mercury is a particular concern because of its greater toxicity and tendency to bioaccumulate and biomagnify in the food chain. **Harding et al.** consider the presence of methyl mercury in various compartments in the Fundy ecosystem, including rivers flowing into the Bay, sea water entering and leaving the the Bay, bottom sediments, plankton, pelagic organisms, seaweeds, benthic invertebrates, demersal and pelagic fish, and marine mammals. Their results support the concept of food chain biomagnification, with the methyl mercury concentration increasing by several orders of magnitude from sea water to tuna. **Sunderland** presents an ecosystem-scale model of mercury dynamics in Passamaquoddy Bay that illustrates the various components and linkages considered in assessing its potential impacts. These include the anthropogenic sources of mercury, its deposition in coastal habitats, its cycling within the aquatic system, and its uptake and retention by organisms. The model clearly shows the importance of already contaminated sediments as a reservoir that is continually releasing methyl mercury back into the water, and thus slowing any traces of recovery even after anthropogenic inputs are reduced or eliminated. The author outlines a methodology for assessing risks that methyl mercury pose to ecosystems and to human health.

Engel et al. studied the levels of contaminants and incidence of endocrine disruption and leukemia in mussels collected along gradients near aquaculture sites, municipal sewage outfalls, and industrial sites (pulp mill, fish plant, and ferry terminal) in Passamaquoddy Bay, New Brunswick, and Annapolis Basin, Nova Scotia. Adverse physiological effects were detectable in mussels collected close to all pollution sources, with some evidence of impaired reproductive function. The concentration of a contaminant measured in the sediment may bear little relation to the amount that is actually available to organisms, to be taken up and thereby cause adverse physiological effects. **Hellou et al.** used the burrowing amphipod *Corophium volutator* to assess the bioavailability of polycyclic aromatic hydrocarbons (PAHs) present in, and added to, sediments collected in Halifax Harbour. The study demonstrates the role of sediment characteristics and the physico-chemical nature of the chemical in influencing its bioavailability.

A recent proposal to develop a mega quarry close to the shore on Digby Neck, Nova Scotia, in order to mine basalt for export has many people concerned about adverse environmental effects of such a project. **Mahtab et al.** describe some major concerns, including the likely effects of shock waves on fish and marine mammals, increased sedimentation nearshore, release of contaminants from explosive residues, hydrological drawdown of local groundwater, as well as shipping-related threats such as the introduction of invasive marine species in ballast water and vessel collisions with, or disturbance of, endangered right whales and other marine mammals.

2. Ecology of Seabirds and Shorebirds

Several informative papers on the ecology of marine birds focused on the seabirds colonizing islands around the mouth of the Bay and the migratory shorebirds foraging on the mudflats of the upper Bay. **Black and Diamond** tracked radio-tagged Arctic and Common Terns at Machias Seal Island to determine where they feed in relation to the colony. Early results suggest that Common Terns feed widely, both near the coast as well as farther offshore. In contrast, Arctic Terns tend to feed well offshore. Additional studies in offshore areas where the foraging ranges overlap may determine if they are competing for food or using different parts of the habitat. Another study reveals that the numbers of Red-necked Phalaropes making a migratory stop-over at Deer and Campobello islands in southeastern New Brunswick declined dramatically in the late 1980s, from millions in 1986 to none observed by 1990. **Chardine** compares results from his plankton surveys in the area with ones conducted before this decline. The abundance of the Phalarope's principal food, the copepod *Calanus finmarchicus*, has also declined in the surface waters of this area of the Bay. This may explain the decline in Phalaropes, although the reason for this change in the copepod community is unknown. **Minich and Diamond** also provide evidence of changes in the availability of food for other marine birds nesting on nearby Machias Seal Island. Analysis of data on the food provided to chicks of Common Terns, Razorbills and Atlantic Puffins clearly reveal that over the past decade there has been a marked shift from herring to less nutritious crustaceans, particularly euphausiids, with adverse affects on growth, fledging success and productivity of the birds. The cause of this shift is also unknown. In an award winning presentation, **Sprague et al.** examine factors affecting the movements of sandpipers during their migratory stopover on the mudflats of the upper Bay. By radio tracking individual birds, they were able to assess the use of different roosting sites and feeding areas and thus determine the factors influencing their selection, such as food availability, presence of predators and particular landscape features. Preliminary analysis indicates that the birds' fidelity to particular mudflats varies in different areas of the Bay. In another study involving sandpipers, **Hicklin** analyzed his extensive database of banding results with respect to the frequency and timing of recaptures of banded birds. Particular groups of birds are recaptured together year after year, suggesting that the returning visitors are not simply random assemblages but rather, well-structured groups of individuals remaining together for extended periods. Genetic studies will be required to ascertain if these are, in fact, family groups.

3. Coastal Development and Sediment Flux

Sediment is a dominant feature in the upper Bay of Fundy ecosystem. Papers in this session explore the complex movements of fine sediments and the likely impacts that causeway construction or removal may have on their dynamics. **Kolstee** discusses the dynamic and cyclic nature of many Fundy mudflats, even under seemingly natural conditions, that make it extremely difficult to predict their response to man-made modifications of coastal areas. **Crewe et al.** have studied movements of bottom sediments in the Salmon River Estuary at the head of Cobequid Bay. They report a steady landward migration of sediment during the summer, gradually infilling and restricting the estuary channels. This may contribute to winter flooding, which is characteristic of this region. The presentation by **Curran et al.** describes the dramatic changes in hydrology and sediment distribution in the Petitcodiac River after causeway construction at Moncton. Examining the hydrodynamics and oceanography of the estuary below the causeway, they find that the routine opening and closing of the structure's control gates can have a significant effect on flow, temperature and salinity for a great distance downstream. **Bugden et al.** give an overview of the effects of the causeways on both the Peticodiac and Avon rivers on sediment accumulation, navigation, fish passage, fishing and municipal effluent dilution. **Kolstee** provides insights into the likely effects of removal of the causeway across the Avon River at Windsor, Nova Scotia, including loss of agricultural land, increased risk of urban and rural flooding, loss of recreational opportunities, effects on fish passage, and erosion of riverbanks. On a related topic, **Daborn et al.** consider some of the ecological implications of the further twinning of Nova Scotia's Highway 101, which could involve a widening of the existing causeway across the Avon River. This is likely to alter the adjacent, extensive and biologically productive mudflat and salt marsh complex that has formed during the 30 years since the causeway was built.

4. Sustainable Use and Management of the Bay of Fundy

The Bay of Fundy region is in the forefront of efforts to promote community-based management of natural resources and to encourage communities to play a more active stewardship role in protecting and conserving their environment. **Bigney** gives an overview of a community-based management pilot project in Scotia-Fundy that was designed to involve coastal communities in the management of groundfish stocks and the allocation of quota amongst fishermen. She describes the roles of the key players in the process and touches upon the successes as well as problems encountered. This pilot project suggests that such a shared management approach is a positive step in fostering sustainable coastal communities, provided that several changes are made in the existing regulatory regime. **McCuaig** summarizes the results of a recent project of BoFEP's Minas Basin Working Group that involved working closely with coastal communities around the Basin to identify and assign priority to issues that might be adversely affecting the health of the watershed and Basin. These initial community consultations are being followed up by efforts to engage groups and individuals in the communities to develop strategies for tackling some of the more pressing problems. The Clean Annapolis River Project (CARP) is a very successful, community-based, environmental organization that has for a decade and a half been engaged in monitoring and improving the ecological health of Nova Scotia's Annapolis River and its watershed. **Hawboldt** discusses some of the tools used in fostering effective multidisciplinary approaches to the conservation and restoration of local aquatic ecosystems. Aesop's fable of the gradual intrusion of a camel into its owner's tent serves as an analogy for the step-by-step approach needed to gain the trust, support and participation of all the stakeholders in a project. **TeKamp** surveys the role of the coastal planner and outlines what is required to ensure effective coastal planning in Nova Scotia. He explains how the role of the coastal planner differs from that of more traditional land use planners and describes the changes needed in existing management and governance structures to facilitate development of an effective coastal planning system.

5. Science, Mapping and Information Management

Minas Basin's long-held claim to having the "World's highest tides" has been periodically challenged by those who consider that Leaf Basin in Ungava Bay deserves the title. **O'Reilly et al.** attempt to resolve the controversy by comparing new results from tide gauges in Ungava Bay with those from a long-term tidal monitoring station at Burntcoat Head in Cobequid Bay. While the average amplitude for Fundy is 0.2 m greater than for Ungava, the difference is statistically insignificant, causing the authors to declare the contest a draw and affirm that both share the accolades and "bragging rights". **Parlee and McKenzie** describe the role and activities of the Canadian Climate Impacts and Adaptations Network (C-CIARN) and its ongoing efforts to understand climate change and to develop strategies to adapt to the expected consequences. They review the results of a 2003 C-CIARN workshop that considered the vulnerability of Bay of Fundy coastal areas to climate change and tried to identify gaps in our knowledge, particularly about likely effects on coastal communities, infrastructure, health and natural resources. The findings are being used to develop a research agenda on climate change that is directly relevant to the Fundy region. **Laflamme and Percy** describe the Atlantic Region Sensitivity Mapping Program for managing and mapping environmental and other information required during environmental emergencies. This Web-based geographic information system (GIS) is a flexible tool for planning and response coordination that is readily accessible to all governmental and industry groups responding to hazardous material spills. It can, among other things, track marine spills, indicate shoreline sensitivity, show video clips of shorelines, identify natural resources at risk and suggest appropriate responses. Remote sensing is another high-tech tool increasingly important in many environmental fields. **Ripley et al.** outline the use of a compact airborne spectrographic imager (CASI) for assessing seagrass beds in the shallow, dark waters of a large river in northeast Florida, thereby demonstrating its utility for use in other optically dark waters, such as the Bay of Fundy. A great deal of environmental information is stored in a wide array of digital databases and other archives and the rate of acquisition is increasing steadily. Unfortunately, this information is not always readily accessible to those who most require it. **Boxall et al.** suggest that one solution to this problem is the creation of digital geolibraries, consisting of collections of digital data with a spatial dimension, that can be readily and widely accessed. The authors examine the potential for expansion of digital geolibraries and issues to be addressed for them to reach full potential. Particular attention is paid to steps to create an effective digital geolibrary for the Bay of Fundy-Gulf of Maine region.

6. Fish, Fisheries and Aquaculture

The fishing industry has long been an economic mainstay of many coastal communities around the Bay of Fundy. During the past two to three decades, finfish aquaculture has rapidly expanded and the harvest of many wild fish stocks has declined. **Isaacman and Beazley** use historic, archaeological and anecdotal information to describe how the fish populations in the Avon River, particularly anadromous species such as salmon, have changed since European settlement of the region. Almost all have declined precipitously, particularly within the last century. The authors consider some of the likely causes of these declines and conclude that a variety of human activities contributed, the most significant being hydroelectric dam construction on tributaries during the 1920s and 1930s. Faced with such declines, there have been many attempts to rebuild anadromous fish populations in rivers around the Bay of Fundy. **Carr et al.** describe an unsuccessful effort to enhance the population of Atlantic salmon in a New Brunswick river by releasing adults reared to maturity in a local hatchery. Most of the released fish stayed in a lake close to the hatchery. Few if any migrated upriver to the spawning grounds and none of them appear to have produced any offspring. Finfish aquaculture is often reported to have adverse effects on coastal ecosystems, particularly on benthic communities. **Pohle and Wildish** surveyed benthic macrofauunal assemblages at stations in Letang Inlet in southwestern New Brunswick before and after the expansion of the aquaculture industry in the 1980s. Between 1975 and 2000 there were major alterations in the benthic community, including changes in biodiversity, dominant species, trophic structure and extirpation of some species. Identifying the cause is complicated by the fact that a pulp and paper mill built in the early 1970s initially enriched benthic habitats in the inlet. Stringent effluent controls decreased this source of organic input over ensuing decades, while aquacultural detritus increasingly enriched the benthic habitat. Whales are an important component of the Fundy ecosystem. A major portion of the North Atlantic right whale population summers near the mouth of the Bay of Fundy. Entanglement in fishing gear, both here and along the east coast migration route, is a major causes of death of these endangered animals. **Merriman and Smith** describe preliminary results of a project to develop and test different types of fishing gear that might prevent or reduce such entanglements.

7. Protecting Special Places

In recent years there has been a growing interest, and some progress, in identifying and protecting special or sensitive marine areas in and around the Fundy region. **Rangeley et al.** recount the efforts of the World Wildlife Fund (WWF) in fostering the development of a network of marine protected areas (MPAs) in the Gulf of Maine-Scotian Shelf region. They outline the criteria being used to identify marine areas that should be protected, the principles involved in the systematic planning of a protected areas network, the desired protection standards, and the indicators of effective management. The overall goal is to preserve representative examples of many different habitats within a large geographic region and use the MPAs as a tool in regional conservation planning. In a similar vein, **Sheppard** considers the possibility of creating a marine reserve in the Bay of Fundy by means of the National Marine Conservation Areas (NMCA) Program of Parks Canada. She confirmed the widespread interest in such a reserve by interviewing diverse members of the Bay of Fundy community. She outlines several of the steps needed to achieve NMCA designation, including creation of a non-governmental secretariat to provide leadership, launching of a campaign of public education and consultation, obtaining the commitment of potential partners, and securing adequate funding and other resources. Biosphere reserves may provide another, more flexible approach to environmental conservation than do traditional protected areas. **Canning** reviews the concept and goals of the biosphere reserve approach to ecosystem conservation. She discusses progress in the development of a proposed reserve in the upper Bay of Fundy and some of the problems encountered in gaining the support of communities within the area. The evolution of this project demonstrates the need to begin consultations with local communities early in the planning process, the importance of an effective education campaign, and the desirability of starting with a manageable small area and gradually expanding.

Craig describes the work of the Environmental Monitoring and Assessment Network (EMAN) in creating an effective monitoring and research network linking selected sites across the country, including ones adjacent to the Bay of Fundy. The network provides the information needed for effective, large-scale, ecosystem management and guidance in setting management priorities. The author reviews the standardized monitoring and sampling protocols that EMAN has developed, the methods of data management and interpretation, and the communication tools for monitoring ecosystem trends locally and over wide areas. Fisheries and Oceans Canada (DFO) and its partners have designated the Musquash Estuary in southwestern New Brunswick a candidate Marine Protected Area, an important first step towards full protection of the area under the new *Oceans Act*. In another award winning paper, **Ng'ang'a and Nicholls** characterize the hydrographic and bathymetric features that have been used in defining the limits of the proposed Musquash protected area, particularly its seaward boundary. They present results from multibeam bottom surveys that identified a variety of natural and man-made submarine features. Because of the dynamic nature of the flushing regime, current flow and sediment movements in the estuary, the researchers recommend establishment of a buffer zone just outside of the estuary to better protect the salt marshes and other valued features of the planned protected area.

8. Monitoring Environmental Impacts in Coastal Areas

Munkittrick et al. describe the development of an environmental monitoring program for Saint John Harbour, using two local fish species. Their study examines the applicability to marine environments of a method of assessing cumulative effects that has been successfully used with freshwater fish populations. However, this particular marine system is more complicated to assess because it involves several different stressors that affect the performance of the fish populations. **McLatchy et al.** also use a local fish, the mummichog, in a study aimed at developing protocols for the use of estuarine fish for monitoring industrial effluents. Artificial stream exposures and lab bioassays served to identify contaminants in effluents from a pulp and paper mill in Saint John, New Brunswick. Reproductive hormone endpoints are used to assess the sources and characteristics of bioactive chemicals in the effluent. Marine benthic invertebrates have also been used as sentinels in monitoring the health of the environment. **Edgell and Rochette** employ the periwinkle to assess the biological effects of industrial effluents. They measure such variables as population demographics, size at maturity and fecundity of snail populations along a gradient of industrial discharge. **Methven et al.** examine the temporal variability in the structure of fish assemblages in shallow waters around Saint John Harbour in order to understand how this might affect the design of sampling programs. Of 20 species collected, only 8 dominated the community and 11 were very rarely encountered. The assemblage was extremely dynamic, with significant short-term community variability associated with tidal and daily cycles combined with a relatively simple benthic habitat structure. **Westhead** reports on the first successful attempt to use a traditionally freshwater habitat assessment technique in the marine intertidal environment. She uses the reference condition approach to assess the state of intertidal mudflats surrounding Minas Basin, particularly in relation to the frequent, large-scale disturbance of the sediments by commercial clam and baitworm harvesting in the area. **Theriault et al.** describe a project to develop monitoring tools for detecting the environmental effects of liquid effluents released from fish processing plants around the southern Gulf of St. Lawrence. They use fish community structure and sentinel species approaches to monitor the effects of the plants. Community volunteers also participated in a related monitoring program designed to assess the health of estuarine and coastal shorelines in their areas. Similarly, volunteers play a key role in monitoring water quality in the Annapolis River in Nova Scotia. **Sharpe** describes the Clean Annapolis River Project's very successful River Guardian Program, particularly considering its strengths, successes and weaknesses. He emphasizes the importance of multi-agency partnerships and discusses how this program could serve as a model for other community-based environmental monitoring programs in the Fundy region.

9. Coastal Habitat—Eelgrass and Salt Marsh

Salt marshes are found around the Bay of Fundy, while eelgrass beds are largely restricted to the outer Bay where the much lower suspended sediment load permits light to penetrate deeper into the water column. **Hanson** summarizes the outcome of a workshop held in late 2003 that considered the health of eelgrass communities in Eastern Canada. Participants discussed changes in its distribution and abundance, the importance of eelgrass in coastal ecosystems, and some of the possible causes for the dramatic declines seen in many areas. Eutrophication, the invasion of green crabs and other environmental changes are probably all contributing factors. There is clearly an urgent need for a comprehensive program of mapping eelgrass beds, and trend analysis to facilitate the conservation of this important habitat. One such mapping approach is described by **Gagnon et al.** who used a compact airborne spectrographic imager (CASI) to map the distribution of marine plants in shallow waters around islands in Mahone Bay, NS. This study focuses on the invasive species *Codium fragile* and its pattern and rate of spread in the area. However, the technique could also be used for mapping resource species such as rockweed, Irish moss and kelp as well as other productive habitats such as eelgrass beds.

Several papers were devoted to aspects of salt marsh ecology, attesting to the great importance of this habitat in the Bay of Fundy. The paper by **van Proosdij and Townsend** documents the sediment accumulation and marsh grass colonization of the extensive mudflat that began to form immediately below the Windsor Causeway soon after construction was completed in 1970. Aerial photographs reveal that for more than two decades there was little evidence of any marsh grass. However, by 1992 the built-up sediment had consolidated sufficiently for the cord grass *Spartina alterniflora* to gain a firm foothold and to begin spreading exponentially over the area. The formation of satellite colonies by ice rafting of rhizome material is an important factor in this rapid spread. **Ollerhead et al.** also analyzed historical aerial photographs to document changes over a 60-year period in the seaward margins and tidal creek networks in salt marshes around Cumberland Basin in the upper Bay of Fundy. They observed several cycles of salt marsh expansion and contraction. By evaluating some of the geomorphic controls on the stability of marsh margins and tidal creeks they hope to better understand the dynamic nature and cyclic evolution of salt marshes and thus more accurately predict future changes. **Baker and van Proosdij** also use historical aerial photographs of Cobequid Bay, situated in the other arm of the upper Bay of Fundy, to look at long-term (1938–1994) changes in salt marshes. Prior to this, there were major losses of salt marsh as a result of reclamation (dyking) and erosion. Between 1938 and 1975, the net salt marsh expanse in the Bay decreased only slightly, although there were significant increases or decreases in size in specific locations. From 1975 to 1994 there was a noticeable net expansion in salt marsh habitat. The study suggests that large changes in the area of individual salt marshes can occur rapidly, followed by a period of relative equilibrium until the next large change occurs.

It has long been known that salt marshes are important habitat for many species of wildlife. **Hanson** surveyed salt marsh bird populations in 160 marshes throughout the Maritimes, looking particularly at habitat characteristics such as vegetation type, marsh size, proximity to ponds, etc., in relation to the type and abundance of birds present. The species richness is greater in larger marshes and the density of some, but not all, species was positively correlated with marsh size. These results are helpful in establishing policies and conservation activities for marshes that will ensure the maintenance of optimum bird habitat. **Noel et al.** look at a restored salt marsh that had been used as agricultural land for more than a century. Saints Rest Marsh, near Saint John, NB, originally dyked between 1786 and 1864, was eventually abandoned and flooded in the 1950s. Several palaeoecological techniques are used to identify and corroborate the depth of the historical surface (reclamation surface) of the farmland. These include the presence of fossil rhizomes of marsh grasses, changes in sediment color, plant pollen, and the presence of spores of fungi usually associated with cattle droppings. **Bowron** describes recent and ongoing efforts to conserve a salt marsh and educate the public about the ecological importance of such coastal wetlands. The objective is to eventually restore a more natural flow to the salt marsh at Cheverie Creek, Nova Scotia, by eliminating a tidal restriction created by an undersized culvert. The results of a pre-restoration monitoring program here and at a nearby reference marsh will be used to monitor the recovery of the marsh after a larger culvert has been installed. Part of this study also involves identifying marshes with similar tidal restrictions along Fundy's Nova Scotia coast that might be additional candidate sites for restoration projects.

10. Ecosystem Modeling in a Macrotidal Estuary—Cobscook Bay, Maine

A contingent of researchers from the United States present a suite of papers that gives an excellent overview of aspects of the oceanography and marine biology of Cobscook Bay, located at the mouth of the Bay of Fundy adjacent to Passamaquoddy Bay. **Brooks** describes results derived from a circulation model developed for the Cobscook-Passamaquoddy Bay system that estimates tidal flushing rates and circulation patterns. The model clearly shows that neutral particles carried in the tidal flow readily cross the border in both directions. This suggests that diseases associated with salmon aquaculture could spread quickly through the whole system. Such cross-boundary tidal coupling of the bays emphasizes the need for international integrated management planning for the whole area, particularly with regard to locating aquaculture sites. **Brooks** also looks at another implication of the dynamic tidal circulation within this complex of bays; namely, the possibility of harnessing the water's considerable energy to produce electricity. His analysis suggests that modern, low-head turbines moored in the channels between some islands and headlands could generate sufficient electricity at fairly low cost with little if any adverse effects on the environment, fisheries or navigation. **Garside et al.** examine the distribution and sources of dissolved nutrients in Cobscook Bay. They find that the Bay is nutrient rich throughout the year and, with more nutrients present in the surface waters than primary producers can readily use, potentially eutrophic. Most of these nutrients are imported into the area from the Gulf of Maine as a result of upwelling of cold, nutrient rich, deeper waters. Except in a few very localized areas, the input of nutrients into the Bay from human activities is relatively insignificant. The year-round elevated nutrient level fuels the Bay's high biological productivity and thus is of great ecological and economic importance to the region. Seaweed and eelgrass contribute much of this productivity. **Vadas and Beal** estimate the seasonal and annual productivity of several of the dominant plant species found in Cobscook Bay. In terms of the rate of turnover of biomass and the quantity of carbon produced each year, rockweeds are the most productive of the cold-water assemblages and contribute the largest amounts of carbon to this marine system.

Trott considers changes in intertidal macroinvertebrates that have occurred over a 20–35 year period by comparing results of his recent surveys with earlier studies at the same sites. He finds dramatic changes in composition of the intertidal community, indicating that a significant faunal shift has taken place. Assemblages characteristic of hard substrate have been replaced by well-established mussel beds with a much reduced faunal diversity. It is thought that this change is largely attributable to increased siltation arising from large-scale scallop and sea urchin dragging operations in the Bay that stir up large quantities of bottom sediments. In addition, the expanding mussel beds facilitate the deposition and accumulation of this suspended sediment in the intertidal zone. **Larsen** also provides data on the benthic macrofauna collected almost three decades ago at various sites in Cobscook Bay, but in this instance from subtidal habitats. Infaunal burrowers and tube dwellers are abundant at certain stations while others are dominated by surface-dwelling epifauna . These distinct communities are chiefly defined by the strength of the tidal current, which in turn determines the bottom substrate. Infauna dominate in the sandy sheltered coves while epifauna thrive in the current-swept channels. The decades-old data may chiefly be useful as a baseline against which to measure the ecological impacts of subsequent port and aquaculture developments in the region. **Campbell** details a sweeping synthesis of all the energy inputs and transfers that underlie the biological productivity and ecological organization of the Cobscook Bay ecosystem by applying the concepts of emergy analysis. This approach is based on an alternate value system for energy that has objective measures of ecological costs and benefits of different ecosystem components and processes. He describes how such an emergy analysis can be employed in planning and decision making in coastal marine ecosystems and concludes that salmon aquaculture may be a good human use of the Bay's rich emergy signature.

11. Poster Session

The 26 posters presented at the workshop are grouped into the following four themes:

a) Salt Marshes and Tidal Restrictions

Given the considerable importance of salt marshes to the productivity of the marine ecosystem in the upper Bay of Fundy, it is not surprising that several posters focused on this habitat, particularly in relation to its loss, degradation and opportunities for restoration. **Campbell and van Proosdij** analyzed aerial photographs taken over 25-year period (1977–2002) to measure changes in the spatial pattern and area of a salt marsh near Kingsport, Nova Scotia. Their preliminary results suggest that there is an approximate balance between erosion and accretion of marsh in this area. Although these results need to be better ground-truthed for accuracy, the project demonstrates the potential utility of geographic information systems (GIS) for monitoring spatial changes in salt marshes over time. **Robinson et al.** also use GIS to assess historical changes in agricultural dykeland practices and their effects on the salt marshes in Cobequid Bay in the upper Bay of Fundy. They note the degree of modification of each marsh and rate intertidal habitat as being eroded, accreted or converted to agricultural land. There is a great deal of variation in the extent of erosion and accretion of different marshes at different times, indicating very dynamic and complex processes taking place in the region. **van Proosdij et al.** compare the suspended particulate matter concentrations and sediment deposition rates at three low salt marshes in the Minas Basin, as part of ongoing studies of sediment dynamics in the region. Samples collected over 15 tidal cycles at several marsh elevations reveal the greatest deposition occurring at the still evolving marsh just below the Windsor Causeway. **Eisan and Van Proosdij** have incorporated into a GIS database environmental and other data collected as part of an audit of tidally restricted salt marshes along Fundy's New Brunswick coast. In addition to classifying the marshes as restricted or partially restricted, note is also made of accessibility, land use, density and suitability as salmon habitat. Querying this database will assist in identifying and assigning priority to marsh areas potentially suitable for restoration projects.

In an award winning student poster, **Chiasson and van Proosdij** assess some of the factors controlling vegetation characteristics in a partially tidally-restricted salt marsh at Cheverie Creek, flowing into the Minas Basin. They consider species richness, density and mean vegetation height in relation to marsh elevation, organic matter, frequency and duration of flooding, and distance from the creek. The only significant correlation is between elevation and species richness. An undersized culvert impedes tidal flow into the marsh and this vegetation study provides a baseline for monitoring recovery if the restriction is ever removed. **Gregory** presents baseline data for another likely marsh restoration project, involving a Ducks Unlimited freshwater impoundment on the Cogmagun River in the Minas Basin watershed. The dykes here are not being maintained and are periodically naturally breached by the tides. Salt marsh recovery is expected to occur gradually as the dyke system continues to fail. Vegetation and fish, as well as temperature, salinity and depth, are being studied within the impoundment and in an adjacent salt marsh. The results will help understand how such reclaimed land reverts to salt marsh and thus aid in planning other intentional restoration projects. **Dobek et al.** report on the ongoing development of a digital database of georeferenced information about a wide range of environmental measurements collected in the Southern Bight of the Minas Basin and its watershed at different times. The data serves as a baseline for monitoring any changes or cumulative impacts that may occur following construction or removal of tidal barriers in the region. A poster by **Harvey et al.** summarizes the results of a comprehensive audit of tidal barriers carried out by the Conservation Council of New Brunswick and partners along the northern shore of the Bay of Fundy. The resulting database, which indicates the type and location of each restriction as well as the current flow and general site characteristics, identifies specific salt marsh areas and migratory fish stocks that might be threatened by the restriction. It also identifies sites where the restrictions could be removed or their environmental effects reduced at minimal cost.

b) Biology, Ecology and Habitat Protection/Restoration

In another award-winning poster, **Paesani** examines the variation in the genetic makeup of the common marine diatom, *Thalassiosira nordenskioeldii*, collected at three different sites in the Bay of Fundy. A knowledge of their spatial and temporal genetic variation can be useful in ascertaining the adaptability of this microalgae. The degree of genetic variability may be indicative of the ability of the population to respond successfully to changing environmental conditions. **Drolet and Barbeau** report on the distribution and scale of patchiness of the burrowing amphipod *Corophium volutator* in its mudflat habitat in the upper Bay of Fundy. Although the distribution pattern seems to consist largely of patches of about 10 cm and one meter, a significant level of unexplained variation suggests that patches smaller than 10 cm may also be present. Such statistical information about the population may be useful in designing sampling programs to look at some of the factors that influence distribution and patch size.

Environment Canada's Environmental Damages Fund (EDF) is a special holding account set up to manage funds acquired as compensation for environmental degradation caused by pollution incidents. **Hennigar et al.** note that the fund operates on the polluter pays principle for income and then provides compensatory awards for eligible damages resulting from incidents such as oil spills, toxic chemical releases or habitat disruption. This process ensures that any compensation paid for pollution incidents in the Bay of Fundy supports remedial activities to restore the Bay's ecosystems. The poster provides an overview of the general EDF framework and notes some projects the Fund has supported. Underground explosions, such as those used to fracture rock in quarrying operations, produce several different types of seismic waves. **Roma and Mahtab** analyze the effects of such factors as distance from a body of water, depth of explosion, weight of charge, substrate type, and shape of excavation on the attenuation of Rayleigh waves, which are readily transmitted from solids to liquids. They conclude that adequate protection of nearby coastal fish habitat from these rolling, surface waves requires that the setback distances for explosives be much greater than the Department of Fisheries and Oceans guidelines based on body waves. Baltzer's Bog is a 72-hectare wetland in the Annapolis Valley that has been subjected to peat mining for several years. Public pressure closed the operation, but only after about three-quarters of the bog area had been severely degraded. **Manning et al.** describe ongoing efforts to restore the area as a functioning and productive wetland. Some of the options being investigated include blocking drainage ditches, recreating a variable topography, encouraging wetland vegetation, and establishing a protective buffer zone.

c) Ecosystem Tools and Techniques—Fundy Organizations

Buzeta et al. present the results of an ongoing study of the invertebrate communities of sublittoral, hard-bottom habitats around the mouth of the Bay of Fundy. By analyzing extensive historic transect data and information from long-term oceanographic monitoring programs, they are mapping large-scale patterns of species richness in the region and thereby locate areas of high biodiversity and productivity. This information may help identify areas suitable for legal protection and assist in creating a framework for their management and conservation. Several posters focus on the development and use of Web-based GIS tools for the presentation, analysis and sharing of environmental data. **Pancura and Lines** describe a prototype, on-line GIS mapping system designed to assist users in assessing the impacts of different climate change scenarios on specific geographic regions. This system, particularly intended for those studying climate change impacts and adaptations, uses both historical and predicted data on maximum and minimum temperature and precipitation for sites throughout Atlantic Canada. The program is being upgraded to increase its accuracy and its ability to create a wider range of future climate scenarios.

A number of papers and posters describe the use of aerial photographs to study changes in salt marshes over time. Most of them rely on time-consuming manual digitization of the geographic information. **Mahoney and Hanson** describe a much faster automated classification system used for identifying and mapping areas of salt marsh from aerial photographs. Such an approach is particularly useful for monitoring temporal changes in the extent of salt marsh habitat over broad geographic areas. **Ng'ang'a** discusses the challenges he faced in acquiring, analyzing and mapping the diverse types of environmental data collected in connection with developing the proposal for the Musquash marine protected area. He uses an Internet-based GIS program (Caris Spatial Fusion™) to synthesize and retrieve the large amounts of information needed to identify and characterize the many options available to the decision-making process. **Martin et al.** at the Atlantic Reference Centre at Huntsman Marine Science Centre have completed development of an interactive Web-based database containing information about marine species found in the Bay of Fundy, including marine algae, most macroinvertebrates, fish, shorebirds and marine mammals. The Species Information System (SIS) provides readily accessible information about a species' taxonomy, habitat, and any particular scientific, ecological, economic or social value, as well as references to relevant taxonomic and ecological information.

Several BoFEP Working Groups presented posters outlining their recent activities. **Singh et al.** describe the objectives and projects of the Sublittoral Ecology and Habitat Conservation Working Group. This group disseminates information about the sublittoral ecosystems of the outer Bay of Fundy and locates and defines the extent of benthic habitats of high conservation and ecological value. This aids in identifying priority areas for protection and highlights any important information gaps that need to be addressed. The group also maintains linkages with relevant organizations working in the Fundy region. The Minas Basin Working Group, one of the oldest of the working groups, seeks to facilitate cooperative activities and partnerships in order to sustain the environmental quality of the Minas Basin ecosystem and its watersheds and to promote the sustainable use of its natural resources. **Brylinsky et al.** describe a series of recent consultations with groups in communities around the Basin to identify their priority environmental issues and to help them develop action plans to tackle some of the more pressing issues. The working group is also actively involved in projects pertaining to groundwater resources in the watershed, promoting coastal planning, examining impacts of causeway construction or removal, and identifying suitable indicators of marine environmental quality for the Minas Basin. **Etheridge** outlines the UNESCO Biosphere Reserve Program that is designed to foster the health and integrity of human communities as well as the ecosystems they inhabit and depend on. He reviews the effort being made to have the upper Bay of Fundy region in New Brunswick designated a biosphere reserve, highlighting some of the advances and a few problems encountered along the way. He describes the ongoing efforts to build an effective organizational framework, acquire adequate funding, engage the communities of the region, and develop a strong, persuasive case for creating such a reserve in the Bay of Fundy.

d) Contaminants—Fates and Effects

Municipal sewage effluents contain a variety of endocrine disrupting compounds (EDCs) that mimic natural reproductive hormones and thus may alter the sexual development of aquatic organisms. **Robinson et al.** examine the amount, behaviour and fate of estrogenic EDCs released through sewage outfalls into Halifax Harbour. Relatively high concentrations occur near the outfalls. However, the amounts present in sediment samples decline rapidly within 48 hours after collection and are undetectable by two weeks. Adsorption onto organic particles seems to be an important process that speeds up the breakdown of the compounds by micro-organisms. There have been several fish kills in rivers on Prince Edward Island attributed to the runoff of widely used agricultural pesticides. **Hellou et al.** analyzed water and sediment samples, collected near two rivers that flow into Summerside Harbour, for 18 commonly used pesticides. Concentrations are below the detection limits in all samples except one. A more complex analytical procedure is being used to enhance sensitivity and quantify any trace amounts. **Wells et al.** provide a comprehensive overview of studies being undertaken by members of BoFEP's Corophium Working Group. These include an examination of factors controlling the amphipods' distribution and abundance, characterization of their sediment habitat, assessment of the seasonal dynamics of the populations and ascertaining the effects of polycyclic aromatic hydrocarbons on them. Other related studies focus on the ecology of their principal diatom food and predation on Corophium by shorebirds. These amphipods are also being used in toxicological bioassays. Members of the working group are also contributing to a comprehensive review and bibliography on *Corophium volutator*. **Wells et al.** present a summary of the sampling procedures, collection sites and the results obtained during the first nine years (1993–2001) of the Gulf of Maine Council on the Marine Environment (GOMCME) GulfWatch contaminant-monitoring program. Analysis of blue mussels collected at many sites around the Gulf of Maine, including several in the Bay of Fundy, provides a concise overview of the geographic distribution and temporal trends in the concentration of several key contaminants. In 2002, GOMCME sponsored a workshop to look at sewage management issues in the Gulf of Maine–Bay of Fundy. The objective was to find ways to enhance wastewater management practices in the region and to clarify some of the links between sewage discharges and human and ecosystem health. **Hinch et al.** review the principal recommendations from the workshop and consider the progress being made in implementing them.

Round Tables at the Workshop

Following the future-oriented plenary session on the final morning of the workshop, the participants formed three round tables to discuss the future of the Bay of Fundy in relation to:

1. The Health of the Bay
2. The Management of the Bay and its Resources
3. The Coastal Communities of the Bay

The ensuing discussions were thought provoking and animated. However, in the short time available it was only possible to focus on a limited number of facets of each of these broad topics. Nevertheless, a number of very interesting points were explored by each group and presented in the final plenary session. These discussions are summarized as follows:

1. The Health of the Bay Round Table

We found it impossible to select a small number of topics that we could all agree on and instead created a shopping-list of issues that were considered important by various people in the group. The most critical concerns raised, in no particular order of priority, included the following:

- reduction in biodiversity
- introduction of invasive species
- intertidal harvesting and the resulting habitat disturbance
- presence of a variety of contaminants in water, sediments and biota
- biological effects of low levels of contaminants
- climate change consequences
- water quality concerns, particularly in relation to sewage and heavy metals
- environmental impacts of physical barriers (dams and causeways) on rivers
- environmental impacts of habitat restoration efforts (such as causeway removal or dyke breaching)

Next we considered useful techniques that are available to assess changes in ecosystem health associated with the above issues. It was noted that many innovative techniques had been described in the various papers and posters presented during this workshop. A number of concerns were raised. There is a need to clearly define biodiversity in the Bay of Fundy context in order to be able to develop effective programs to monitor this critical indicator of overall ecosystem health. There is also a need to understand the functioning and ecological importance of salt marshes in a broader context, particularly in relation to the marine productivity of the Bay. It is also important to develop effective ways for measuring and monitoring the short and long-term impacts of human activities in the intertidal zone.

A number of gaps in our knowledge need to be addressed in order to develop effective ways of assessing and monitoring the state of the Bay. We need to develop a regionally appropriate suite of marine environmental quality criteria, particularly a comprehensive set of guidelines that include both biotic and environmental components. The more important biological, chemical and physical interactions occurring within the Bay's ecosystem need to be much better understood—we need to better understand how the system works. There is also a special need to identify a number of sensitive indicators that will provide an early warning of a general deterioration in ecosystem health.

There was general agreement that it would be worthwhile to expand the terms of reference of the existing BoFEP Contaminants and Ecosystem Health Working Group in order to further explore many of the ideas raised by the round table and to seek creative ways of addressing some of the important issues identified.

2. The Management of the Bay and its Resources Round Table

In the limited time available, we focused our discussions on a) a few points pertaining to the acquisition and dissemination of the information required for effective management and on b) some of the roles that BoFEP might play with regard to management of the Bay of Fundy.

A. Data Collection, Sharing and Management

Data Sharing. Data can serve multiple purposes, but often it does not because it is not in an organization's mission or mandate to use it or make it available for other purposes. Indeed, the mandate of an organization may specifically proscribe sharing of information or data. How are we to co-share information if it is not in the mandate of the organization that collected the data? Who funds the collection of this data? How do you release mapping and other data in view of some of these ownership issues? There is a clear need for protocols on information sharing and decision making. In addition, co-sharing of information and its management is often an issue of leadership.

Communication. How are we to communicate the information to others? How do we disseminate it to different user groups? How do we get information to people in a timely manner (e.g., emergency measures)? Data is not always available to all, however, the data needs to be processed and the information made available to all that require it. The need for data processing is a strong argument in support of information management protocols that could be developed to address the requirements of data processing.

Use of the information. The user-base of data and information broadens over time, as different community and other groups are given access to the data in a useable form. This allows them to increase the sophistication of their questions. However, care is needed in making information available to the public in order to ensure that it is understood and used properly. There is a concern about the possible misuse of information provided, including illegal misuse.

Demand-Driven Information. The provision of information should be demand-driven, and the demand side (who wants information?) needs to be defined. There may be many different players on the demand side. This brings us to the question of scale. Knowing who wants the information enables us to develop effective ways of getting the information to them. We need to do this for different types, scales and levels of groups.

Scale. Information needs to be provided on a scale useful to the recipient—on a 'macro' scale, for large institutions such as the government of Canada and on a 'micro' scale for local or community groups such as the Minas Basin Working Group.

Participation. A great deal of ocean management pertains to living and non-living resource management, which traditionally does not involve the public. It is not sufficient to just hold an information workshop for the public to attend; we must allow for public input into management plans before they are even developed. However, it is not clear how best to get them all to the table.

Information Systems. There needs to be an integrated approach to incorporating information systems into the management process. Ideally, everybody should have access to a regional database of Fundy information, possibly by means of a consortium agreement in which all organizations provide some of the funding in return for access to the information. The information system should have one central official portal, but with a distributed system of databases. The important questions are: where will it be located and who will maintain it over the long term?

Digital Library. A digital library makes it possible to scale up and down, but where do we have the capacity for such a digital library? Dalhousie University has the capacity, but not the funding, for such a system. However, if it could secure the funding to initially set it up, it might have some permanence, since once it becomes part of such an institution it usually doesn't "die off" easily. We have yet to scratch the surface of the technological capabilities, the possibilities for information sharing and enhancing the information management design process. Georgia Basin in British Columbia/Washington is an example of how such technologies can improve communication. It is essential to have good information accessible at a central location, but it must be part of a distributed information system.

B. Ideas for BoFEP: Future Role in Managing the Bay, Linkages

Role of BoFEP. To what extent does BoFEP speak for the Bay of Fundy at present? What role should BoFEP play in the management of the Bay, particularly in integrated management? Should it play an active role? Or is its principal role advocacy, information dissemination and providing advice? How do we communicate amongst ourselves and with our partners on an ongoing basis and not just at periodic meetings? We need to let people know what BoFEP is doing.

Federal/Provincial Agreements. A good example of such an agreement is the Canada/BC federal/provincial memorandum of understanding (MOU) recently put in place to implement the *Oceans Act*. Details of this agreement can be found in the next Atlantic Coastal Zone Information Steering Committee (ACZISC) e-newsletter update. The Bay of Fundy could be part of a similar East Coast MOU in the future. It would be helpful if BoFEP could be there to influence it, to make sure that the interests of the whole Bay of Fundy are considered, not just specific provincial interests. Specifically, BoFEP could coordinate management on an ecosystem level, to ensure that the Bay of Fundy is managed as an ecosystem, rather than simply drawing a line through it and stating that New Brunswick and Nova Scotia are responsible for their respective sides. What should be the role of local areas in a large-scale MOU such as this? That public participation needs to be built into the design process for the agreement is a clear message from direct experience with land-use planning

ESSIM. It is important to understand and share with other areas the ESSIM (Eastern Scotian Shelf Integrated Management) Project and its process. A draft management plan will be ready for spring 2005. ESSIM is developing a series of ecological use and human use objectives. The former is moving forward and has about 170 objectives that are becoming very well organized. The framework for human-use objectives is more difficult as there are few appropriate examples in the world or in the agency (i.e. DFO) itself. BoFEP has linkages to community-based groups whereas ESSIM does not. Perhaps the two organizations could develop a working relationship and learn from each other.

3. The Coastal Communities of the Bay Round Table

The discussion focused primarily on what is going on in the Bay's coastal communities with respect to their participation in the management of renewable resources and how to enhance this participation. It was an opportunity to tell some of the more informative community stories from the region, to share some of the successful collaborative experiences, and to learn from and support each other in our ongoing efforts.

For example, in northern Maine, a network of lobster fishermen has been working effectively together for a number of years. Shocked by the dramatic collapse of the groundfishery, these fishermen wanted to make sure that a similar thing didn't happen to their lobster fishery. Initially, the group was rather small and it took some time to build the necessary level of trust among those involved. Typically, fishermen are fiercely independent and sharing information about their resource and their activities doesn't come naturally. However, they managed to develop a set of mutually acceptable principles that facilitated their working together in a trusting and constructive manner. They managed to get beyond their initial self-interest and came to recognize their many mutual interests and the benefits of working together effectively as a team to address the issues and protect their livelihoods.

In Atlantic Canada, the Atlantic Coastal Action Program (ACAP) supported by Environment Canada is probably one of the most successful government-initiated programs involved with community social and economic development and promoting the sustainability of coastal communities.

It was noted that there are many organizations throughout the region dealing with different aspects of environmental conservation, the sustainable use of natural resources, and the economic and social well-being of coastal communities. The number of such groups is increasing steadily in response to the proliferating issues, with a resulting increase in competition amongst them for limited volunteers and funds. There is concern about the likelihood of burn-out amongst volunteers who are involved in too many issues with inadequate support. It was noted that, typically, the more successful organizations have at least one part or full-time paid staff person to co-ordinate the organization's activities and to provide much-needed support to the volunteers.

It is important to find ways of encouraging and assisting the many different groups to work together to advance their goals jointly and to reduce overlap and duplication of effort. It might also prove advantageous if several such groups could work together to prepare joint proposals for submission to potential funders instead of regarding each other as competitors for the limited funds available. Foundations and other funding groups are more inclined to look favourably on broader, more diverse projects involving several different, but complementary, partners. Innovative multi-partner projects that engage the public often catch the eye of funders.

Although some coordination of community groups may be beneficial, it is probably not necessary, or even desirable, to have a large umbrella organization to coordinate the efforts of the many individual organizations. However, there should be a centralized clearinghouse as a source of relevant, up-to-date information that could be easily accessed by the different groups. This might include a database of potential funding sources, information on government policies and program initiatives, and sources of technical expertise and other support. It was noted that a principal objective of BoFEP is to facilitate the sharing of scientific and other information amongst its partners and with community groups all around the Bay. Its several working groups, its website and the now biennial Fundy science workshops play important roles in information sharing, as well as in fostering collaborative conservation and research activities among interested groups.

BoFEP Awards

A number of awards were presented at the Workshop Banquet. The first BoFEP "Environmental Stewardship Award" was presented to Patricia Rae Hinch of the Nova Scotia Department of Environment and Labour. This award recognizes an individual who has "contributed significantly to the environmental health/sustainability of the Bay of Fundy", preferably someone best described as an "unsung hero", who has worked hard behind the scenes, out of the limelight, in advancing the Mission and within the Principles of BoFEP. Pat Hinch was recognized for her steadfast vision, energy and dedication toward a healthy Bay of Fundy and Gulf of Maine during recent times when provincial coastal policies and commitments have been in a period of uncertainity and change. She exemplifies an individual who cares about our coasts, coastal communities and marine resources, and one who translates such concern into action, making significant contributions to sustainability of the ecosystem. BoFEP was proud to honour Pat with its first Environmental Stewardship Award as a fitting tribute to her achievements over many years on behalf of the Bay of Fundy.

A "Special Recognition Award" was presented to Graham Daborn of the Acadia Centre for Estuarine Research at Acadia University. The award recognizes his long-standing leadership of the Bay of Fundy Ecosystem Partnership, both as a founding member and the first BoFEP Chair, a position he has served with exceptional dedication and ability for seven years.

Awards were also presented for the best papers and posters presented by students during the Workshop. The winners were:

First Place Paper–Ashley Sprague, University of New Brunswick, Fredericton, NB. *“Factors Affecting Movement of Semipalmated Sandpipers (Calidris pusilla) Migrating Through the Upper Bay of Fundy”*

Second Place Paper–Sam Ng’gang’a, University of New Brunswick, Fredericton, NB. *“The Proposed Musquash MPA: A Case Study on Boundary Delimitation Concepts”*

First Place Poster–Vanessa Paesani, Mount Allison University, Sackville, NB. *“Intraspecific Genetic Variation in the Centric Diatom Thalassiosira nordenskioeldii Cleve”*

Second Place Poster–Nancy Chiasson, Saint Mary’s University, Halifax, NS. *“Controls on the Distribution of Vegetation Characteristics in a Tidally Restricted Macrotidal Salt Marsh”*

Fundy Festival And Showcase

Members of the public joined delegates in a Fundy Festival and Showcase held immediately after the workshop banquet on Friday evening.

In the keynote presentation of the evening, Moira Brown, a Senior Scientist at the New England Aquarium, gave an illustrated talk entitled *“Struggling in an Urban Ocean—The Plight of the North Atlantic Right Whale”*.

In her presentation Moira provides a fascinating overview of several aspects of her extensive research on North Atlantic right whales carried out in the Bay of Fundy over the last 25 years. She reviews the long history of whaling in the western North Atlantic that has led to the present greatly reduced population of only 350 right whales, which are now classified as endangered. A right whale catalogue, comprising photographs and sighting information of individually identified, and often named, animals has proven extremely useful in understanding their migratory patterns, reproductive characteristics, social behaviour and family relationships. Yet, despite years of study, it is still a mystery as to where fully two-thirds of the whales spend the winter or where they go to mate. Almost all of the young seem to be born in December and January, in the warmer waters off the southeastern United States. In spring, two-thirds of the mothers with calves begin moving north to a summer nursery area around the mouth of the Bay of Fundy, while the destination of the other third is unknown. Moira discusses some of the likely causes of the exceptionally low reproductive rate and the high mortality rate that is hampering the recovery of the population. Much of this mortality stems from the whales becoming entangled in fishing gear or being struck by ships. Given the perilous state of the population, a great deal of effort is being devoted to reducing the number of accidental deaths. This is accomplished by encouraging fishermen to modify their gear to reduce the likelihood of entanglement, and by working with maritime regulatory agencies to move shipping lanes away from areas frequented by whales, and with vessel operators to alert them to the presence of whales in their vicinity.

Moira also describes some of the innovative genetic research that she and her colleagues are carrying out on the whales. This work is not only helping to develop family trees linking related individuals, but is also yielding some useful insights into historical whaling activities in eastern Canada and the likely abundance of right whales when commercial hunting began. In spite of the many difficulties and daunting challenges, Moira remains optimistic that the right whales can continue to survive in the "urban ocean" that we have created along the east coast of North America, provided that Canada and the United States jointly launch a comprehensive recovery program without delay.

This presentation was followed by a public viewing of the Fundy Showcase, comprising some 15 informative displays presented by organizations from all around the Bay of Fundy, as well as the many scientific posters presented at the workshop.

Plans for the 7th BoFEP Bay of Fundy Science Workshop

At the BoFEP Annual General Meeting held during the 6th Workshop, it was agreed that the 7th BoFEP Bay of Fundy Science Workshop, sponsored by the Huntsman Marine Sciences Centre, will be convened at The Fairmont Algonquin Hotel in St. Andrews, New Brunswick from October 25th–27th, 2006. The Workshop theme will be *"Challenges in Environmental Management in the Bay of Fundy-Gulf of Maine"*.

Acknowledgments

Preparing for the increasingly popular Bay of Fundy Workshops is no small task. Fortunately, a host of talented and enthusiastic BoFEP members and other supporters stepped forward yet again to help plan and stage this Sixth Workshop. The members of the Program Committee and the Local Planning Committee met regularly for over a year to carefully craft a program and a workshop experience that participants, on their evaluation forms, subsequently rated as most worthwhile and enjoyable. We extend warm thanks to members of both Committees (listed on page xl) for their creative input, hard work and ongoing encouragement.

Sincerest thanks are extended to our four superb keynote speakers: Moira Brown, Heather MacLeod, Arthur Bull and Art Hanson, for their thoughtful and stimulating presentations. Thanks also to the chairs and co-chairs of the sessions for keeping the presentations flowing smoothly and reigning in the odd garrulous speaker. The smooth flow of the presentations is also attributable to the efforts of Jocelyne Hellou of DFO and Megan Moore of WVDA who coordinated the audio-visual equipment and the knowledgeable “techies”. Laurie Porter, Brian Robinson and Sean Stellar did an exceptional job loading and operating all the high tech equipment.

The Workshop was made possible with the contributions of the authors of the record number of excellent papers and posters. We particularly salute the many students who participated so enthusiastically in all aspects of the workshop. Hats off also to Mick Burt and his team of intrepid judges for courageously tackling the daunting task of evaluating and selecting the best student posters and papers.

We thank the many sponsors (listed on page xli) who generously provided the financial and in-kind support that is so necessary for mounting a successful workshop. We greatly appreciated the exceptional efforts of Annapolis Basin Conference Centre Manager, Carol Jefferson, Catering Head, Candra Payson, and their friendly and always helpful staff. Special thanks also go to the staff of the Bay of Fundy Marine Resource Centre, particularly Martin Kaye, Elena Frost and Pat Gamborg, as well as to Amanda Tree of the BoFEP Secretariat, for working long and hard over many months to ensure the smooth operation of the registration and accounting procedures. We appreciate the support of the local media and CBC radio, for bringing the workshop and Bay of Fundy issues to public attention.

Susan Rolston deserves special thanks for not only working tirelessly at the Workshop with authors and presenters but also for applying her exceptional skills in organizing and copy editing the Workshop Proceedings in a timely manner. Finally, we want to recognize the invaluable contribution of Peter Wells, the Vice Chair of BoFEP and the organization’s Science Secretariat, throughout the planning, implementation and post-mortem periods of the workshop.

Jon Percy and Alison Evans
6th BoFEP Workshop Co-Chairs

Workshop Organizers

Workshop Co-chairs
Jon Percy and Alison Evans

Program Committee
Mick Burt, University of New Brunswick, Fredericton, NB
Mike Brylinsky, ACER, Acadia University, Wolfville, NS
Graham Daborn, ACER, Acadia University, Wolfville, NS
Jocelyn Hellou, Fisheries and Oceans Canada, Dartmouth, NS
Patricia Hinch, NS Department of Environment and Labour, Halifax, NS
Barry Jones, Gryffyn Coastal Management, Fredericton, NB
Deborah MacLatchy, University of New Brunswick, Saint John, NB
Trefor Reynoldson, Environment Canada, Dartmouth, NS
Peter Wells, Environment Canada, Dartmouth, NS
Maxine Westhead , Fisheries and Oceans Canada, Dartmouth, NS

Logistics Committee
Pam Comeau, Bay of Fundy Marine Resource Centre, Cornwallis, NS
Leslie Fredericks, Western Valley Development Agency, Cornwallis, NS
Janice Harvey, Conservation Council of New Brunswick, Waweig, NB
Stephen Hawbolt, Clean Annapolis River Project, Annapolis Royal, NS
Martin Kaye, Bay of Fundy Marine Resource Centre, Cornwallis, NS
Angela Martin, Huntsman Marine Science Centre, St. Andrews, NB
Megan Moore, Western Valley Development Agency, Cornwallis, NS
Roger Outhouse, Bay of Fundy Discovery Centre, Freeport, NS
Andi Rierden, Gulf of Maine Times, Granville Ferry, NS
Dave Scarratt, Dave Scarratt and Associates, Bridgetown, NS
Amanda Tree, BoFEP Secretariat, Acadia University, Wolfville, NS

Student Awards Judges

Coordinator - Mick Burt

Judges for "Best Papers"
Mick Burt
Andy Didyk
Gerhard Pohle

Judges for "Best Posters"
Al Hanson
Maria-Ines Buzeta
Dave Scarratt

Sponsors

Acadia Centre for Estuarine Research
AMEC International
Bay of Fundy Ecosystem Partnership
Bay of Fundy Marine Resource Centre
Clean Annapolis River Project
Coastal Planners
Department of Fisheries and Oceans Canada - Maritimes Region
Environment Canada - Atlantic Region
Gryffyn Coastal Management
Gulf of Maine Council on the Marine Environment
Huntsman Marine Science Centre
Municipality of the County of Annapolis
Nova Scotia Department of Agriculture and Fisheries
Nova Scotia Department of Environment and Labour
SeaPen Communications
Town of Annapolis Royal
University of New Brunswick
Western Valley Development Agency

Exhibitors

Acadia Centre for Estuarine Research
Acadie 2003-2005
Atlantic Coastal Zone Information Steering Committee
Bay of Fundy Discovery Centre
Bay of Fundy Ecosystem Partnership
Bay of Fundy Marine Resource Centre
Canadian Parks and Wilderness Society - Nova Scotia Chapter
Clean Annapolis River Project
Eastern Habitat Joint Venture - Nova Scotia
Environment Canada
Hyperspectral Data International Inc.
Municipality of Digby
Southern Gulf of St. Lawrence Coalition on Sustainability
World Wildlife Fund

Awards Presented at the Workshop

First BoFEP Environmental Stewardship Award

Patricia Rae Hinch, Nova Scotia Department of Environment and Labour

This award recognizes an individual who has “contributed significantly to the environmental health/ sustainability of the Bay of Fundy”, preferably someone best described as an “unsung hero”, who has worked hard behind the scenes, out of the limelight, in advancing the mission and within the principles of BoFEP. Pat Hinch was recognized for her steadfast vision, energy and dedication toward a healthy Bay of Fundy and Gulf of Maine during recent times when provincial coastal policies and commitments have been in a period of uncertainity and change. She exemplifies an individual who cares about our coasts, coastal communities and marine resources, and one who translates such concern into action, making significant contributions to sustainability of the ecosystem. BoFEP was proud to honour Pat with its first Environmental Stewardship Award as a fitting tribute to her achievements over many years on behalf of the Bay of Fundy.

Special Recognition Award

Graham Daborn, Acadia Centre for Estuarine Research, Acadia University

This award recognizes Graham’s long-standing leadership of the Bay of Fundy Ecosystem Partnership, both as a founding member and its first Chair, a position he has served in with distinction, dedication and ability during the first years of BoFEP’s existence.

First Place Student Paper

Ashley Sprague, University of New Brunswick, Fredericton, NB
Factors Affecting Movement of Semipalmated Sandpipers (Calidris pusilla) Migrating Through the Upper Bay of Fundy

Second Place Student Paper

Sam Ng’gang’a, University of New Brunswick, Fredericton, NB
The Proposed Musquash MPA: A Case Study on Boundary Delimitation Concepts

First Place Student Poster

Vanessa Paesani, Mount Allison University, Sackville, NB
Intraspecific Genetic Variation in the Centric Diatom Thalassiosira nordenskioeldii Cleve

Second Place Student Poster

Nancy Chiasson, Saint Mary’s University, Halifax, NS
Controls on the Distribution of Vegetation Characteristics in a Tidally Restricted Macrotidal Salt Marsh

The Bay of Fundy Ecosystem Partnership (BoFEP)

The Bay of Fundy Ecosystem Partnership (BoFEP) was formed to identify and try to understand the problems confronting the Bay and to find ways of working together to resolve them. It is a flexible and still evolving organisation for encouraging and facilitating communication and co-operation among individuals and groups with a stake or an interest in Fundy and its resources. BoFEP is set up as a "Virtual Institute", whose main objective is to foster wise conservation and management of the Bay's natural resources and diverse habitats, by disseminating information, monitoring the state of the ecosystem and encouraging co-operative research, conservation and other activities.

BoFEP welcomes all partners who share the vision of a healthy, diverse, productive Bay of Fundy, be they individuals, community groups, First Nation groups, resource harvesters, scientists, resource managers, coastal zone planners, businesses, government agencies, industries or academic institutions. By sharing our knowledge and coordinating our individual efforts we can ensure that present and future generations will be able to benefit from Fundy's rich and varied bounty and continue to appreciate its awesome beauty and diversity.

To learn more about BoFEP visit: <http://www.bofep.org>

Gulf of Maine Council on the Marine Environment (GOMCME)

The Gulf of Maine Council on the Marine Environment is a United States-Canadian partnership of government and non-government organizations working to maintain and enhance environmental quality in the Gulf of Maine to allow for sustainable resource use by existing and future generations. The governors and premiers of the five Gulf jurisdictions—Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia—created the Council in 1989 as a regional forum to exchange information and engage in long-term planning. The Council organizes conferences and workshops; offers grants and recognition awards; conducts environmental monitoring; provides science translation to management; raises public awareness about the Gulf; and connects people, organizations, and information. The Councilors are leaders of state, provincial, and federal agencies, non-government organizations, and the private sector. With no central office, the Council is administered through an annual Secretariat that rotates among the jurisdictions.

BoFEP and GOMCME are now formally linked through an agreement (2004–2007) that promotes shared goals and objectives, and common projects in the Gulf of Maine.

To learn more about GPAC visit: <http://www.gulfofmaine.org>

Environment Canada

Environment Canada is responsible for preserving and enhancing the quality of the natural environment, including water, air and soil quality; conserving Canada's renewable resources, including migratory birds and other non-domestic flora and fauna; conserving and protecting Canada's water resources; carrying out meteorology; enforcing the rules made by the Canada-United States International Joint Commission relating to boundary waters; and coordinating environmental policies and programs for the federal government. Environment Canada's seeks to make sustainable development a reality in Canada by helping Canadians live and prosper in an environment that needs to be respected, protected and conserved. With approximately 4,700 employees and a more than half billion dollar budget, Environment Canada works in communities across Canada and with thousands of partners in every province and territory and around the globe.

To learn more about EC's programs visit: <http://www.ec.gc.ca/envhome.html>

Acadia Centre for Estuarine Research

The primary objective of the Acadia Centre for Estuarine Research is to focus research attention on the estuaries and nearshore coastal waters of Eastern Canada, with emphasis on the estuarine systems of the Bay of Fundy and the hydrographically-related Gulf of Maine and Georges Bank. The Centre was established in September 1985 with a grant from the Centres of Specialization Fund, administered by the Secretary of the State of Canada. Space and additional funds were provided by Acadia University. The Centre actively encourages cooperative, multidisciplinary research programmes that involve scientists and students from regional, national and international institutions.

To learn more about ACER, visit: <http://ace.acadiau.ca/science/cer/home.htm>

Bay of Fundy Marine Resource Centre

The Bay of Fundy Marine Resource Centre (MRC) offers services, facilities and technical support to achieve viable and sustainable coastal communities in the Bay of Fundy region based on innovation, learning and community stewardship of natural resources. Work at the Centre is focused on community-based resource management, aquaculture, regional marine tourism promotion and marketing, digital data storage and retrieval, training within the fisheries, and ecological, market, legal, technological and social research and information relating to marine resources. MRC, a not-for-profit organization, was established in 1997 by the Western Valley Development Authority and the Fundy Fixed Gear Council. MRC's facilities, located in Cornwallis Park, Annapolis County, include meeting and training facilities, a walk-in information and referral centre with on-line access to information on marine-related topics, training classroom, and a GIS mapping centre (Coastal Marine Resource Mapping Project).

To learn more about MRC visit: <http://www.bfmrc.ns.ca/>

Plenary Lecture: The Past

EARLY PERSPECTIVES ON THE FUNDY ENVIRONMENT

Heather MacLeod,
Atlantic Canada Studies, Saint Mary's University

Heather MacLeod teaches environmental studies in the Atlantic Canada Studies graduate program at Saint Mary's University, Halifax, Nova Scotia. Her academic research interests include regional environmental history, landscape perception, ecological identity and 'environment and behavior'.

Abstract

Early 17th and 18th century European narrative accounts of the Bay of Fundy environment provide baseline records of ecological abundance that seem fantastical by contemporary environmental realities. Since natural history played an important role in the struggle for empire, explorers and travel writers penned 'discovery' literature that catalogued the land, rivers, harbours and flora and fauna with commodity value as subtext. Local natural history written by early resident colonists provided a sense of the impact of early land use, the need to better understand nature to improve community livelihoods and the necessity of preventing the overexploitation of nature. Also revealed are the considerable efforts made to understand and explain ecological change and natural history phenomena before a scientific vocabulary or profession existed to label and define such patterns. Altogether, these written accounts provide an overview of Fundy watershed ecological patterns and environmental issues identified by 17th, 18th and 19th century observers.

Introduction

This year, 2004, marks the 400th anniversary of the arrival of French colonists to the Bay of Fundy, the beginning of colonization attempts and the first written texts on the region. Narrative accounts from early 1600s onwards offer a sense of how the Bay of Fundy was perceived and used by humans in the 17th, 18th and 19th centuries. These early accounts serve as key sources on Fundy's environmental history as it was conveyed by diverse peoples—aboriginal inhabitants, early explorers, missionaries, travel writers, colonists, traders, naturalists, and officials of two imperial powers.

The history of the contact and colonization period in this region spans three centuries, since settlement attempts in the Maritimes developed slowly until the late 1700s. Even though written knowledge of Acadia begins with the French in 1604 and the subsequent Acadian inhabitation had reached 10,000 by 1755, this region as a whole was sparsely populated and traded back and forth between the French and English as a strategic economic zone buffering bigger colonial territories. The Atlantic region offered great wealth in the cod fishery—an economic activity which bankrolled many European ports, but which could be pursued by seasonal visits without the expense of maintaining a colony while settlement efforts were concentrated elsewhere. Significant population increases only came with the British establishment of Halifax and the subsequent arrival of planters, loyalists and many other colonists who often settled on the favoured sites of the Mi'kmaq, Maliseet and Passamaquoddy peoples and in the process transformed ecologies and landscapes.

The origin of the word 'Fundy' is believed to be traceable to 16th century Spanish and Portuguese mariners. Their use of the word "Rio Fondo" (meaning deep river) on early imprecise maps was thought to refer to the Bay (Ganong 1892). By the time of Champlain's maps, Fundy was fairly accurately portrayed and now named Bay Francoise. The lands surrounding the Bay were known by two early names, Arcadia and L'Acadie, before the establishment of 'Acadia' as the regional identifier. Italians mapping North America in the 1500s labelled the northeast coast as 'Arcadia', which eventually came to refer to the Fundy-New England area. This may have alluded to Arcadia—the mythical

Greek land of pastoral tranquility and pleasing landscapes. However, the origin of 'Acadia' was more likely derived from the Mi'kmaq word 'Acadie', meaning 'dwelling place'. French explorers use of the Mi'kmaq term to refer to these lands appears to be expressed by the related names—Coste de Cadie, L'Arcadie, and Lacadie, and L'Acadie—which cartographers applied on various maps (Rayburn 1990; Brown 1888: 33). 'Acadie' referred to the dwelling place of the Mi'kmaq as a people and could also mean the dwelling place of plants or animals when affixed to place names. Shubenacadie, as an example, meant the dwelling place of groundnuts. Mi'kmaq place names reflected an intimate knowledge of the ecology of their land. Colonial place names created by the British often honoured British leaders and British places but sometimes also reflected local ecology in the 17th and 18th centuries (e.g., Salmon River, Caribou)—ecological references that often no longer still apply.

Since exploration was driven by economic interests, natural history played an important role in the struggle for empire as gaining environmental knowledge of new territories meant better understanding of how to exploit resources, develop colonies, generate profits and ultimately consolidate European power. From 1600 to the 1800s, French and English 'discovery' literature contained natural history in the form of systematic accounts of natural phenomena. Even at the end of the 19th century, such texts continued to be written as guides to potential British immigrants on 'the lay of the land' or more specifically, where the 'good land' could be found. Narrative accounts catalogued and classified the land in terms of its spatial features (rivers, valleys, harbours, bays, fishing banks), its substrate (soils and mineral deposits), and its wildlife (trees, plants, birds, animals, fish), often with commodity value as subtext. Residents penned more detailed accounts of the natural history of specific flora and fauna and the ecological changes that came with settlement and resource use, generally as a critique of land use practices or a concern with better understanding nature in order to improve livelihoods and community economies. Mi'kmaq speeches also reveal the ecological changes in the land taking place that were destroying their way of life.

Early Perceptions of Fundy Landscapes and Ecology

The first significant description of the Fundy watersheds begins with Champlain as he coursed along the Bay looking for copper and iron mines, good harbours and navigable rivers. Marc Lescarbot provides more details in his account of the 1606 Port Royal habitation in which he pays considerable attention to the Annapolis Basin and the meadow land of the Annapolis Valley.

> [The harbour] was a wonderous site for us to see, its fair extent and the mountains and hills than environed it… We explored the country up the river, where we found continuous meadows for more than twelve leagues, among which flow numerous brooks, rising in the neighbouring hills and mountains. It is like unto the land God promised to his people: "The Lord thy God bringeth thee into a good land, a land of brooks of water, of fountains and depths that spring out of the valleys and hills, a land where in thou shalt eat bread without scarceness, thou shall not lack for anything." (Lescarbot 1911: 312, 314)

Through the centuries the Annapolis Valley and upper Fundy watershed lands were often described in biblical terms as the 'Eden' of Nova Scotia, since their fertile soils stood in contrast to granite, rocky headlands of the Atlantic coast that were frequently judged to be sterile unless featuring 'beech hills' or drumlins. For Europeans, the meadowlands or intervales found along rivers symbolized good soils and potential agricultural prosperity. One goal of the Port Royal habitation was to cultivate the soil and grow grain, which the expedition did—returning to France with a harvest of wheat and rye to report on (Lescarbot 1911: 317). Meadowed river valleys and their coastal estuaries were also preferred locations for the Mi'kmaq as these sites offered good hunting and fishing, and for the Maliseet of the Saint John River Valley, good soils for planting corn. Early observers noticed that the larger meadows, marshlands and fertile soils of Fundy estuaries and valleys were attributable to its soft-rock geology and immense tidal range. As Lescarbot explained, "the expansive meadows of Port Royal are caused by the high tides especially those of March and September, which overflow the banks in this district and hinder the trees from taking root" (Lescarbot 1911: 321). The significant presence of meadowland was commented on in accounts from the 1600s through to the mid-1800s. By the 19th century, it was also noted that the overhunting of beaver resulted in more meadowland since abandoned beaver dams released pond waters and the exposed land grew up in grass (Gesner 1849: 171).

Watersheds were important to the fur trade. Established as a fur-trading fort, Port Royal was situated in proximity to a significant watershed where aboriginal people hunted, lived and traveled. Along the Bay of Fundy, forts emerged on the Cumberland Basin, Minas Basin, Annapolis Basin and the Saint John River. Records reveal that fur trading activity was quite intense, for both Aboriginal people and colonists. As one example, over a ten-year period (1765 to 1775) colonists in one settlement on the Saint John River, exported to New England: "40,000 beaver skins, 11,022 musquash, 6,050 martin, 870 otter, 258 fisher, 522 mink, 120 fox, 140 sable, 74 racoon, 67 loupcerine, 8 wolverines, 5 bear, 2 wolf, 50 caribou, 85 deer and 1,113 moose besides 2,265 pounds of castor oil and 3,000 pounds of feathers" (quoted by Raymond 1910: 309). Under this kind of hunting pressure, the beaver and moose were extirpated from watersheds at different times throughout the 17th, 18th and 19th centuries, while bird populations declined through the feather trade, habitat destruction, sport hunting and egg harvesting—the latter would particularly apply to Grand Manan Island (Thurston 1990: 128–9).

Forests were pervasive unless natural conditions such as wet soils discouraged tree growth. To see a landscape so dominated by trees was strange and oppressive for French and English observers. Early accounts reveal that large areas featured trees characteristic of the climax forest of northeastern North America—the Eastern Hemlock, White Pine, northern hardwood forest, also known as the Acadian Forest. In a mature state this forest would include Red Spruce, Hemlock and White Pine; and Sugar Maple, Yellow Birch and American Beech—with trees frequently five or more feet in diameter and as old as 300 or 400 years, if conditions were optimal (Gesner 1849: 96). The size and mix of species varied by soil drainage, topography and climate. As a result, the impression of forests varied with locality, from "beautiful and wonderfully high" forests at St. Croix (Lescarbot 1911: 249) to "miserable spruce, fit to be inhabited only by wild beasts" along other portions of the Fundy coast (Campbell 1792: 101). Particularly impressive were the forests growing on the slopes of river valleys including those of the Shubenacadie, Avon, Stewiacke and Saint John. Here were found an abundance of "the finest oaks, elms, maples, beech and yellow birch". As Nicholas Deny's noted in 1685, "those woods of the coasts are nothing in comparison with those which are inland and on the upper parts of the rivers. The trees there are much more beautiful in height and thickness, and stand more open and less confused. One could chase a moose on horseback." The Mi'kmaq frequently preferred these more open, parkland-like forests with large mature trees. As they told Denys, "there are not little trees [there] which hinder … the hunting of the moose" (Denys 1971: 112, 377). A 1764 account of the Saint John River Valley affirms this, describing the forests bordering the extensive intervale as being "very park-like as far as the eye could see with extremely large, tall trees, chiefly hardwoods and no underbrush, so that you could drive a cart and oxen through the trees" (quoted by Raymond 1910: 357). In this area, big pine trees for large masts were found farther back, bordering the smaller rivers. Pine woods were also noted to be peculiarly open and easy to traverse, as were hemlock woods. This stood in contrast to the tangled, dense growth of spruce woods which were castigated as being very difficult to pass through and indicative of poor, thin soils.

Beyond an abundance of trees, there were descriptions of great ecological abundance of many types of wildlife. First and foremost were accounts of prolific marine life. The numbers of cod were marvelled at, as was their great size and fatness. Fish "six fingers thick" were a common catch (Lescarbot 1911: 363). In 1852 Moses Perley reported that, "the largest cod, designated bank cod, came from the deep waters off Nova Scotia, and the entrance to the Bay of Fundy, between Brier Island and Grand Manan, often attaining a great weight, sometimes more that 70 or 80 pounds" (Perley 1852: 209). Mackerel were so plentiful it was "impossible to conceive of the extent of their armies; shoals are seen from two to five miles in diameter and so closely crowded that the sea is rendered smooth…living masses of fish obstructing the passage of boats" (Gesner 1849: 138). Halibut attained an enormous size, weighing half a ton and upwards, and the effort needed to land them was the curse of fishermen (Gesner 1849: 122; Perley 1852: 155). An account of Port Royal by Richard Guthrie in 1629 described "lobsters as big as little children" (Griffiths and Reid 1992: 504)—crustaceans that could be caught from underneath rocks close to the shore without use of a net or boat (Lescarbot 1911: 320). Denys described an infinity of huge scallops and immense oysters larger than a shoe and very plump that were common in harbours (Denys 1971: 356). In the early 1600s, the Governor of Acadia remarked that the sea was 'paved with salmon'. On Salmon River the smallest size salmon were reported to be 3 feet long and elsewhere sturgeon were seen "eight, ten, eleven and twelve feet in length, as thick in body as a sheep" (quoted Dunfield 1985: 12, 16). One of the most amazing sights was the spring spawning runs of fish coming up streams. Pierre Biard wrote in 1611, "Anyone who has not seen it could scarcely believe it. You cannot put your hand into the water without encountering them" (Whitehead 1991: 36). Equally amazing, was the endless abundance of shad in the Bay of Fundy during the summer months, described by Amos Seaman as an "inexhaustible supply" (Perley 1852: 152).

Writers also commented on the multitudes of seabirds on certain islands and waterfowl on the Fundy salt marshes. The scene so impressed Acadians that the name Tantramar was derived from the Acadian word "tintamarre", meaning the mighty roar of wingbeats during waterfowl migratory stopovers. Also striking were the great flocks of passenger pigeons that Deny's described as "plaguing us by their abundance" (Denys 1971: 199).

Although this biological bountifulness varied by season and circumstance, the sheer number of these descriptions of plentitude serve to verify the claims even if hyperbole and bias were sometimes at work. Today, tales of such ecological abundance are unimaginable by contemporary environmental realities, given the over-exploitation and depletion of the ocean's fish, declining bird populations, endangered species and other indicators of a weakened web of life. Early descriptions of such ecological abundance provide important baseline data of ecosystems operating at prime (Pauly and MacLean 2003: 21; National Research Council 1995: 57).

Land Use and Ecological Concerns

The introduction of European agricultural practices began with the Acadian dyking of the extensive upper Fundy salt marshes to create fertile farmlands. When colonists later took over the dykelands of the deported Acadians, the structures were in need of repair. This resulted in early environmental legislation—the 1760 'Act for Appointing Commissioners of Sewers', whereby communities chose officials to monitor dykes and oversee repairs. It took some time for the newcomers to establish flourishing dykeland agriculture like that of the Acadians. In the 19th century, dykeland hay became a major crop when prosperous lumbering and mining interests needed hay to fuel their horses—a cash crop that only lost its value when cars replaced horses. The expanse of dykelands significantly altered upper Fundy watersheds. By the 1980s, the total area of dykeland protected in New Brunswick and Nova Scotia totalled 33,000 hectares or 82,000 acres (Province of Nova Scotia 1987: 5, 42). Changes to Fundy salt marsh ecology that came with dyking were first examined by New Brunswick scientist W. F. Ganong in his 1903 paper, "The Vegetation of the Bay of Fundy Salt and Diked Marshes: An Ecological Study" (Thurston 1990: 82).

The transition to agriculture in the rest of the Fundy area represented the more traditional engagement with 'making land'—cutting and burning down forests. Location of good soils was an enigma beyond those to be expected in river valleys. Forest trees were used as a gauge for soil fertility and there were many delusions in discovering the nature of soils beneath ground cover (Haliburton 1829: 361). Also mysterious was the new growth that occurred after trees were felled. The fact that beech trees were not the first to spring up after a grove of old beech trees was cut down was puzzling and figuring out the rotation of what trees grew after different types of forests were cleared remained a topic of considerable debate in the 1800s. Pioneer ecologist and surveyor Titus Smith, who keenly studied the transformations occurring in these landscapes, was one of the first to write a detailed account explaining the stages of forest succession in his "Natural History of Nova Scotia" article which appeared in London's Magazine of Natural History in 1835.

The timber industry transformed Fundy watersheds, as it was the foundation of much of the New Brunswick and Nova Scotia economy in the 19th century comprising the lumbering, shipbuilding and carrying trade. First, white pines were sought after for masts, then for square timber and sawn logs when the lumber business accelerated in the early 1800s due to British market demand. Trees were removed from coastal areas and river valleys where they could be easily transported downstream to seagoing vessels. By 1835, barely a tributary of major rivers remained unexploited and sawmills were pervasive—Nova Scotia had 1,401 by 1861 (Census of Canada 1875). This resulted in decades of struggle between government officials and mill owners over sawdust pollution, which accelerated in the late 19th century when New Brunswick exported 500 million board feet of lumber each year (Allardyce 1995: 122). Sawmill operations got bigger, with two of the largest Fundy coast enterprises at the mouths of the Salmon and Point Wolfe rivers. Sawmill dams, mill rubbish and sawdust significantly altered river ecology. Naturalist Moses H. Perley who was commissioned by the provincial government in 1850 to conduct a study of the New Brunswick fisheries, feared for the future of the shad weir fishery at the mouth of the Salmon River. "The catch of herring, he noted, was already falling away, and if precautions were not taken, the shad he feared, would go the same way. The real crisis however, was in the salmon streams along the shore" (quoted by Allardyce 1995: 121). River obstructions impeded migrating salmon causing population decline and the occasional presence of fish ladders did not seem to alleviate the problem. First sawdust regulations were legislated provincially (Nova Scotia 1854) and later federally (1887), however, without adequate enforcement they were ineffective. Moreover, lumber barons were prepared to exert their political influence, even using bribery—making the classic argument of jobs versus the environment—rather than comply with the legislation. Fishing interests were small compared to that of the large lumber interests and widespread complaints had no real impact. As one fisherman protested, "Instead of netting herring in the morning, I have seen nets full of mill trash that took till noon to pick out" (quoted by Allardyce 1995: 128). In 1894 the fishery minister made the case that science had proven that sawdust harmed the gills of shad, but that argument had little effect, as in 1900 the question was still 'under study'. By the end of the century, the shad fishery was in decline, which many feared was attributable to the sawdust pollution shad encountered on their spawning run up the Saint John River. Later it would be learned that river obstructions and pollution along the American eastern seaboard during shad spawning runs were largely responsible for this decline.

During the mid-1800s, Fundy fisheries included shad, cod, pollock, halibut, salmon, herring, hake and flounder—most of which were reported by Perley to be plentiful in specific areas of the Bay of Fundy during particular months but occasionally scarce with fluctuating environmental conditions. Shad was such an important fishery in the Cumberland Basin that a Nova Scotia Act of the Legislature was passed in 1840, appointing overseers to enforce regulations on the setting of nets. Since shad from the head of the Bay were considered the fattest and tastiest, they were in greatest demand and a lively export trade to Boston developed. The traditional ecological knowledge of shad by Fundy fishers in the 19th century put forth that shad came in three distinct summer runs, moved with the strongest current, and came to Fundy not to spawn, but to feast on shad worms on the upper mudflats, the evidence of which was found in their stomachs. Opinions flared over which shad fishing methods were most overexploitive—weir-nets, stake-nets or drift nets—and why Fundy fishermen should improve their methods of drying and curing shad, as specific places were notorious for poor quality product which resulted in low prices for everyone in the vicinity. Fisherman were also critical of damage done to fishing grounds when fishing schooners indiscriminately dumped offal overboard—a common practice. Perley's 1852 report made numerous recommendations: halt the fishing of spawning herring on Grand Manan to protect stock; stop the obstruction of rivers by mill dams and sawdust; increase the value of the fishery by enacting inspection laws; legislate the use of stake-nets and weir-nets for specific seasons only; instruct fishermen on proper cure methods; establish schools for fishermen; regulate net mesh size to protect juvenile salmon and shad; and enforce existing laws (Perley 1852: 145–155, 177). As insightful directives, some of them still have currency today. By the end of the 19th century the fishery would change with the federal fishery act, the development of lobster and herring canneries, new technologies such as purse seines and trawling, and the start up of the Digby scallop fishery in the 1890s. Dramatic changes would follow with the decline of the salt fish trade that came with refrigeration and replacement of schooners with industrial trawlers in the first half of the 20th century. Fear of resource over exploitation grew as new technologies increased harvesting capacity. Fisheries science would advance with the establishment of the St. Andrews Biological Station in 1899. Up to this point, fisheries science had been restricted to "describing and identifying various fish species and determining their distribution" (Johnstone 1977: 22).

The study of natural history was practiced by numerous people, many self taught, who made important contributions, but by the latter half of the 19th century scientific professionalization had developed with the advent of knowledge specialization, university science departments and government regulatory agencies. Luminaries who pioneered 19th century study of the Bay of Fundy included Sir William Dawson, Sir William Logan, Sir Charles Lyell, W. F. Ganong, Abraham Gesner, Moses Perley plus numerous other individuals who wrote articles on Fundy tides, gaspereau, salmon, geology and any number of topics for the Nova Scotia Institute of Science and the Natural History Society of New Brunswick which were formed in the early 1860s.

By the end of the 19th century, the Bay of Fundy also became an aesthetic landscape for the nascent tourism industry as Americans flocked to the 'Land of Evangeline' to witness "the mythical poetry of the Bay of Fundy" and its "forest primeval" under the influence of Longfellow's best-seller—and the marketing savvy of local railway companies. This generated a new type of discovery literature as Americans penned dozens of books on 'Evangeline's Land', often in a deliberate search for the landscapes mythologized in Longfellow's poem, "this is the forest primeval, the murmuring pines and the hemlocks, bearded with moss and in garments green", as they explored Grand Pré, Fundy shores and Acadian villages (Griffiths 1982). By the late 1800s it was an 'old growth' landscape long gone. The widespread concerns over the over-exploitation of many life forms—tree, birds, fish and 'game animals'—fostered the conservation movement of the early 1900s and the beginnings of more serious wildlife protection, resource regulation and land conservation. As a result, the twentieth century would bring many important developments to the Bay of Fundy—the establishment of protected bird sanctuaries, parklands and marshlands; resource management strategies; and the many valuable scientific studies which have so vastly increased our understanding of Fundy's amazing ecological uniqueness. Early perspectives on the Fundy environment in the 17th, 18th and 19th centuries provide a rich historical background to this ecological uniqueness.

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Plenary Lecture: The Present

THE BAY OF FUNDY AT A TURNING POINT

Arthur Bull,
Saltwater Network

Arthur Bull is founding member of the Saltwater Network and an Associate Staff Member of the Bay of Fundy Marine Resources Centre, Past Chair of the Coastal Communities Network, the Co-Director of the Rural Communities Impacting Policy Project, and Chair of the Digby Neck Community Development Association. He is currently a director with the Western Valley Development Association, the Bay of Fundy Ecosystem Partnership, the Nova Scotia Coastal and Rural Community Foundation, as well as a member of the Saltwater Network and the North Atlantic Right Whale Recovery Team. In the recent past he has worked with inshore fishermen in the capacity of Executive Director of the Fundy Fixed Gear Council and President of the Bay of Fundy Inshore Fishermen's Association.

I would like to start off my presentation with a contest. I am going to read a poem about the Bay of Fundy, a very famous poem by a Canadian poet. I won't read you the whole poem, just a bit to give you a flavour of it:

> The sun goes down, and over all
> These barren reaches by the tide
> Such unelusive glories fall,
> I almost dream they yet will bide
> Until the coming of the tide.
>
> And yet I know that not for us,
> By any ecstasy of dream,
> He lingers to keep luminous
> A little while the grievous stream,
> Which frets uncomforted of dream—
>
> A grievous stream, that to and fro
> Athrough the fields of Acadie
> Goes wandering, as if to know
> Why one beloved face should be
> So long from home and Acadie.

I'll stop here, it goes on for two more pages. Does anyone recognize this poem? (At this point someone in the audience called out "Low Tide at Grand Pré" by Bliss Carman.) Very good. I'm sorry, but there is no prize.

I have been asked to talk about the Bay of Fundy in the present, so I began this morning with this poem because it is about someone experiencing the Bay of Fundy. The poem was written by an English Canadian in the 1890s, responding to the Bay of Fundy, responding (obviously) to the tides, responding to what happened in this place to the Acadians, and relating it to where he is in his own life. Even through the fog of Victorian melancholia, we are aware of someone's experience of this bay.

I'm going to talk about not just the Bay of Fundy in the present, but the *presence* of the Bay of Fundy. Also I want to talk specifically about the way the human and the natural interact in the Bay of Fundy, about that big overlapping zone between the world of culture, history, economics and society and the world of biology, geology and the non-human. That's the zone I'd like to focus on this morning in my comments, because I think you have to look at the Bay of Fundy that way, if you want to understand it at all.

A couple of nights ago I was sitting on the porch of my camp watching the sun go down over the Bay of Fundy. I could see New Brunswick, the "Wolves" sticking up over there and the sun bright red going down. It could have been the most remote part of this country: it seemed that pristine and wild.

All of a sudden I heard a little putt-putt sound, the sound of an engine, and a little Cape Island boat went across the sunset. Then I looked harder, and off in the background I saw the silhouette of a great big oil tanker on the horizon. I kept looking, and eventually I saw all these black ducks that I hadn't noticed before, at least three dozen ducks. I'd never seen so many down there before, all bobbing and diving. Then my eye wandered up onto the rocks, I saw the remains of the *SS Columbo*, a ship that was wrecked on those rocks in the 1920s, with the loss of dozens of lives. This is the Bay of Fundy, I thought. That is what the Bay of Fundy is, a complete interpenetration of the human and the natural, a place where those two things are always interconnected.

In adult education we describe three different kinds of learning: *knowledge* (I know that there is a whole lot of knowledge about the Bay of Fundy in this room, that's knowing stuff); *skills* (knowing how to do stuff, management might fall under that, for example); and finally there is *awareness*. I am not going to give a scientific overview of the state of the Bay of Fundy today because I am not qualified to do that. Today I want to talk about awareness, because that is what happens in the present. Awareness only happens in the present. What is that moment when you say, "Ah hah, I get it", when you finally grasp something? And I'll touch on some of the trends that are affecting the Bay of Fundy today in the present and some of the responses that are emerging around the Bay in the communities and among the people of the Bay of Fundy. Then maybe I'll draw out a few general conclusions, a few tentative observations about all of this, with a view to, showing how we can be aware of such trends and responses.

In terms of trends, I think it is important to realize that the Bay of Fundy is a very little bay up in the corner of northeastern North America. Most of the things that affect the Bay of Fundy originate outside the Bay of Fundy. There are some very big trends on this planet that we are not exempt from. Globalization, corporatization and all the other "izations". I heard somebody use the term "Atlanticize" the other day. So Atlanticization is apparently another one. Maybe that means making it smaller. I can imagine at some point somebody will say 'you know we have to Atlanticize the horizontality of integrated management'. We won't let that happen!

So we have these big trends and they affect the Bay very clearly. One of the biggest of these trends is corporatization. I don't mean something abstract here; I mean something that is really happening. Thinking about the town of Digby; fifteen year ago driving into Digby you drove through Conway and drove down the main street where most of the stores were. You came to the wharf, the federal government wharf where there were 80 to 100 independent scallop boats, the famous Digby scallop fleet. Today, you go through Conway and it is all big box stores with a Wal-Mart coming soon. There is clearly a completely different situation in that town. You drive down main street and come to the wharf and the scallop boats that are there are owned by about five companies. All the quota that those boats fish is owned by roughly five companies. The wharf they are tied up to is owned now by a private company from outside Digby. Most of the groundfish quota is owned by the same few companies. You can look all around the Bay of Fundy and see this same pattern, it is part of a larger pattern, this is not a one-off thing. It is important to see this as a larger trend.

I am not just talking about corporatization as an economic trend either, because it is just as much an ecological trend as well. It has environmental consequences. This year in the Bay of Fundy, among the inshore boats on the Nova Scotia side anyway, there were no groundfish taken. The groundfish in the Bay of Fundy were not there. This is not the 1991 collapse of the northern cod, this just happened while we were talking. So there are very severe environmental implications as well.

At the same time, globalization is affecting life around the Bay. We hear this term so often, but we sometimes miss what it really means to us, right here. On Digby Neck it means that we have come into a relationship with a very big need in the United States, an $80 billion need for aggregate rock for building. The largest aggregate and cement company in the United States has discovered the Bay of Fundy, not just White's Cove on Digby Neck, but the whole Bay of Fundy. Here it is, right next door! Cheap, scarcely regulated, and no royalties are necessary. What a gold mine! Many people believe that this is not a one off activity; this is really the breaking crest of a whole wave of natural resource extraction from the Bay of Fundy that is coming on. We are dealing with these great trends, these large trends, not just that are going to happen in the next five to ten years but are hitting us right now.

Other trends that are affecting the Bay are common to rural communities all over Canada. We are not exempt from them either. Bay of Fundy communities are mostly rural, except for Saint John, Moncton and Truro. When you look at rural communities you see a decline in populations, declining access to services and information, and eroding infrastructure, e.g., wharves and roads. This is not unique to the Bay of Fundy region. I chaired a group of rural community networks from all over the country and they all say the same thing. I bet you could go south of the border and find rural communities dealing with the exact same thing. Those are issues that rural communities are facing everywhere.

And finally, there is a major trend related to information. People don't even mention the 'information age' anymore, we are so used to it. We are in the middle of that wave as well. The odd thing about information is that is seems to always be either feast or famine. On the one hand, there is this huge wave of information that we are dealing with all the time. In terms of the Bay of Fundy, just think about how much information there is, how much work has been done. On the other hand, it is very hard to get information that you need when you need it. It is hard to have access to information. The quarry for example, the people in the community learned about the permit after it had been issued. The information we needed to be part of that process just wasn't there. There are so many other examples: hydraulic dredging for clams is now happening in St. Mary's Bay. Whether that is good, bad or indifferent, hardly anybody knows about it. And that's a new gear type in this area that has an effect on habitat. There is a huge amount of information, but it is hard to get your hand on the information you need in order to do what you want to do as a community.

The above trends (corporatization, globalization, information accessibility) are all broader trends that come to the Bay of Fundy from elsewhere, and are not unique to this region alone. What's interesting is that when you look at the responses to these trends, you see a wealth of local, homegrown initiatives, many of which are unique to our region.

Here I can only draw in broadbrush strokes, since so many varied activities are going on. I will miss a lot, but I want to set the scene a little bit. Again, I am only going to pick a few that I am familiar with. I could pick any range of responses, e.g., the Atlantic Coastal Action Program (ACAP) organizations. I will start with community-based management in the fisheries, particularly the ground fisheries in Nova Scotia and New Brunswick, around the Bay of Fundy. This has been going on since 1996 and is basically self-regulation and self-governance in the fisheries. These are not huge fisheries overall. What is important is that they show that community-based management works and that fishermen and fishermen's organizations can self regulate and manage the fisheries. That continues.

You also have communities setting up resource centres like the Bay of Fundy Marine Resource Centre, which I hope you have visited while in Cornwallis Park. These are all community-based civil institutions in a sense. They were created to support community-based conservation and management work. We have another centre in Eastport, Maine, the Cobscook Bay Resource Centre, new resource centres in Meteghan, Canning, and one that is emerging in St. Andrew's in southwest New Brunswick. It is interesting to see these organizations coming together as a kind of network.

Saltwater Network has also been part of the same development. Saltwater Network emerged several years ago, and is entering in its third year of operation. Saltwater Network is a kind of bioregional community foundation that combines a grant-making network with a range of other supports for community-based management and conservation around the Gulf of Maine. It is cross-border in its organizational structure. Its foundational belief is that the health of the communities around the Gulf of Maine and the health of the marine ecosystems of the Gulf of Maine are inextricably interrelated. It is an ongoing initiative, doing grant making, convening meetings, capacity building and linking groups around the Gulf of Maine. Basically it emerged from informal sharing and peer support around the Gulf of Maine.

There are lots of other community organizations pulling together in this way. For example, in Nova Scotia there is one in Hants County on that shore and there are groups like the one on Digby Neck or in Annapolis County that are forming in response to particular issues. In New Brunswick, there is one in Beaver Harbour. We see more and more of such groups forming. Despite this very quick overview, it is clear that it is not as if it is all doom and gloom. These are examples of several very powerful responses to the major trends affecting the Bay of Fundy. This has been going on for the last ten years. Some real momentum is building here.

This starts to get rather complex now. You see all the different trends and the different responses all over the place. It is very difficult to sort out. One way I want to sort this out is to look at the Bay of Fundy today, in terms of the different ways people relate to it, the different kinds of attachment. Maybe that will help us sort out the complexity.

First there is very clearly the prehistoric attachment, that is, the attachment the Mi'kmaq, Passamquoddy and Malaseet peoples have to the Bay of Fundy. You just have to read the Glooscap stories and look at Blomidon to realize how deep that connection goes. When you are coming back from Halifax and you come over that rise at Hantsport and you look down at Blomidon and see the light breaking across it, you have to know that it's a special place on the planet, a place of great power and beauty, like Ayers Rock or Delphi. There is an incredible amount of presence at Cape Blomidon. And then there are all the historical connections, starting with the Acadian connections to the Bay of Fundy, deriving from the whole history of the Acadian peoples. Then there is the attachment of others who came later, like the Loyalists, and all the growth of the maritime economies around the Bay. All those generations who lived around the Bay, all of them experienced life and death. It all makes for some very strong and varied connections.

Another kind of connection to the Bay has to do with work. I think that needs to be singled out as a very special kind of attachment. The people who actually go out on the Bay and make their livelihoods and work on the water have a connection to the Bay of Fundy that is unique. It has to be recognized in terms of fisheries and livelihoods and the relationship between economies and society, community and ecologies. There is another group of people, those who are interested in the Bay of Fundy, curious about the Bay of Fundy, ask questions about it, are studying it. They want to figure it out for a whole range of reasons. It has to do with knowledge, understanding of research. Some of those people might live around the Bay while others might live in Manitoba, but they all have an attachment that is more than intellectual and they can be very highly motivated as well.

Then there is another group of people, more like corporations, who look at the Bay of Fundy solely as a place from which to extract wealth. That is really a major human connection to the Bay of Fundy and a growing one as well. I make the distinction here between people who work and live around the Bay of Fundy and whose livelihoods are based on it and larger interests who are looking all over the world for places to extract wealth from, whether it is Indonesia or Namibia or the Bay of Fundy that is right next door. That is a very important group today as well.

In terms of all these different kinds of relationships, I would like to put forward the thought that the first group, those people who live and work around the Bay of Fundy, those with historical attachment to the place, are primary. That is, they have the primary role in the future of this place. It sounds like such an apple pie kind of thing to say, but it doesn't exist in any policy. It is something many people would agree with, but the idea that the people in a place have a primary role in the future of that place is critical. Somebody said that we live in a age when there is power without places and places without power. I think it is very important to respond to that by saying *people in this place have a primary role in determining its future*. That doesn't mean they have the only role. That means there are a whole lot of roles in terms of how people relate to the future of Fundy. But the people who live here are primary. That's why community-based management is such a critical piece in all of this.

I draw a few general conclusions and observations from all of this. The first thing is that to really think about the health of these communities and the health of the ecosystems of the Bay of Fundy, we are going to have to talk about change. The status quo is what is happening now and change happens by people acting, by people getting organized and taking action. Knowledge alone does not create change. Maps don't create change. Databases don't create change. Those are important tools. Change is created by people working together for change. That's a critical element in the future of the Bay of Fundy. If that doesn't happen, then all the rest of it won't help the future of the Bay of Fundy.

The second point is that it is very important for us to see the Bay of Fundy in a holistic way, to really look at the culture, the economy, and the ecosystems all at once. This is not a model we are talking about, it is a place with people in it. It is very important to see the Bay as a whole. I think that if we miss that again, we will miss the boat. We will not be able to do what we want to do. That means when you are working on shellfish habitat conservation work, you are really doing anti-poverty work by creating sustainable livelihoods among clam diggers. We have to start seeing our work as a whole, in a way where the social, economic and the ecological are one piece. It takes an effort to do that because the way our world is set up we are always being tempted to divide those spheres up. We are always being posed the question, choose the economy, or choose the environment, which side are you on? I think we have to refuse the question. I think we have to say we will only deal with the world, and the Bay, with the whole, as it is.

How do you do that? One way is through sustained commitment. When people talk about sustainability, the most important thing to sustain is our own personal and rural community commitment to this place, almost a sense of devotion to this place. More than anything, we have to sustain hope about the Bay of Fundy. I think we do that by connecting with the actual Bay, not a theoretical Bay, not seven generations of the Bay down the road, but the Bay of Fundy right now, the one that people experience and live and work in. How we maintain that commitment is likely through our own personal experience. I would suggest that if anybody is unsure about that, I would suggest that you go swimming in the Bay of Fundy. That will remind you that it really is there, and it really is cold. I was once at a baptism on the beach at Sandy Cove, where an Anglican minister took an infant down to the water's edge to baptize him. He suddenly realized that he didn't have holy water, so he blessed the whole Bay. So we now know that according to Anglican liturgy, the Bay is all holy water.

Most of us feel that at some level anyway, that's how we connect with the Bay of Fundy. In any case, it is important to connect with it in some really primeval way in order to sustain the kind of commitment, the kind of work that we want to do.

I started with a poem and I will end with another by a more recent writer about the Bay of Fundy. People in the audience who came across the Bay might recognize the ferry coming into Saint John.

Bay of Fundy Crossing
(after Wang Wei)

Water matte aqua
Black vein of land
Sky-streaks radiating

From where
the sun would be

Oil tanks like
white pills lined up on the rock

Blue diamonds
from a lighthouse
spark daylight

From smokestack pencils
lines widen to clouds

The refinery smell
of burnt sugar

An iced over buoy lays
wake ripples on the tide

woodframe houses built
right down to the water
the pale pastels
of laundry fluttering

I look back toward
the place I left

and six shades of blue
dissolve to grey

and then are gone
away for good.[1]

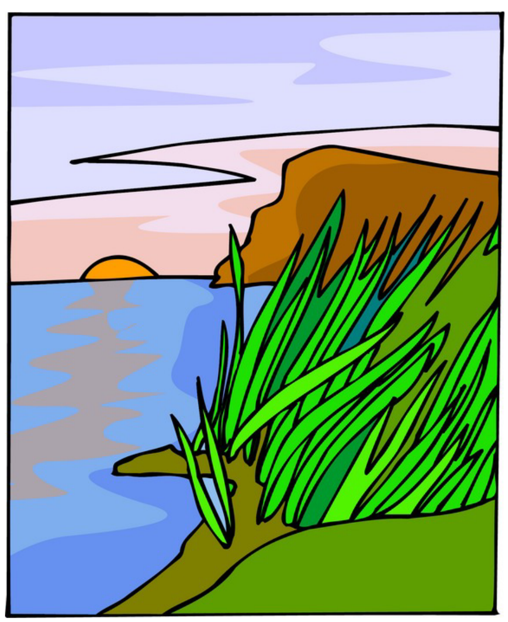
I'll end on that note. Thank you.

[1] Arthur Bull. 2000. *Key to the Highway.* Roseway Publishing, Lockeport, NS.

Plenary Lecture: The Future

WHO SHOULD SPEAK FOR THE OCEANS: NEW AND EMERGING IDEAS FOR OCEAN MANAGEMENT

Art Hanson, Distinguished Fellow,
International Institute for Sustainable Development



Arthur J. Hanson was named an Oceans Ambassador by the Minister of Fisheries and Oceans from June 2000 until June 2004. In August 2003, he was appointed an Officer of the Order of Canada. Art is presently a Distinguished Fellow with the International Institute for Sustainable Development (IISD) following his term as President and CEO of the organization from 1991–1998. Dr. Hanson is currently a core faculty member of the Sustainable Enterprise Academy at York University, a member of the Canada Foundation for Innovation and the Canadian Biotechnology Advisory Committee. He is a board member of the China Council for International Co-operation on Environment and Development, an advisor to the Volvo Environment Prize, a member of the Selection Committee for the North American Fund for Environmental Co-operation, and serves on numerous Canadian and international environment and development committees. In May 1994, he was appointed by the Prime Minister of Canada to the National Round Table on Environment and Economy. From 1978 to 1991, Dr. Hanson was Professor of Environmental Studies at Dalhousie University, Halifax, NS, and was Director of the University's School for Resource and Environmental Studies for a decade.

> It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form of that life. But the sea, though changed in a sinister way, will continue to exist; the threat is rather to life itself.
>
> Rachel Carson, *The Sea Around Us* (1951)

When preparing my talk, I went to Rachael Carson's book because she is a very inspiring figure. Certainly, she was one of the first persons who sent an early and cogent signal on the problems facing the oceans.

Making any predictions concerning the future of the Bay of Fundy is a difficult task. I would be the last one in the world to say that I know what the Bay of Fundy is going to be like in 400 years. My only prediction is that the Bay of Fundy is going to be here in 400 years.

It is very important to take a long-term view of the oceans. I am an ecologist by training, and ecologists tend to have what I call medium-term views. For long-term perspectives, you have to go to the geomorphologists and climatologists, and others like that who see phenomena in terms of thousands of years. We need to think about the Bay of Fundy, and all marine ecosystems from a four or five hundred-year perspective. That is the only way we are going to be able to sort out the mix of signals from important phenomena such as climate change.

However, when looking at events that are going to affect our management decisions, I tend to look to a much shorter horizon. First, what is the situation now? And second, what decisions are we taking now that are going to affect us in the next twenty to twenty-five years? This time frame is by and large that which most economic analysis currently takes us. Considering infrastructure issues, and issues such as the populations of recovering whales and others, even twenty to twenty-five years is too short. We really need to start thinking in forty to fifty year time frames, and probably even longer than that, into the hundred-year timeframe. But use as a time frame is what you can use and do now, given all the current constraints and opportunities, so as to influence decisions that will go into the middle of this century at least, and in some cases beyond.

When asking those sorts of questions, most people ignore you because they say we have enough crises on our hands now and they don't want to take a long-term view. That is a problem. Hence, we have to look at robust methodologies and methods such as back-casting scenario development, etc., for forecasting. What we need least of all are linear extrapolations, which is what many people produce. Because we have certain problems now, we extrapolate that they are going to be much bigger in the future. But we know that the reality is that human behaviour changes and our technologies change, making predictions of the future of the Bay difficult.

Trends Affecting Ocean Use

I would like to talk about "biological economy", a term I invented. The term is extremely useful as we are moving into an era where biology is again going to become extremely important. It always has been, but we have new drivers now. Some of them are highly relevant to the oceans. One of the drivers is biotechnology: whether it is for fish farming or for new medicines, biotechnology is going to have a role in our life. Another example is bioremediation.

We are also trying to work at the level of ecosystems now. In my view, one of the great transformations in how we think about the Bay of Fundy is that we take an ecosystem approach to its management. While we are doing it awkwardly now, if we are doing it at all, there are drivers that will push us towards a more sophisticated understanding of biology, ecology and ecosystems. These in turn are going to become extremely important in our future economy. Within five to ten years, these drivers are going to become much more important, whether it is sustainable resource management of fish, whether it is biotechnology, or whether it is ecosystem management and even, in some cases unfortunately, areas like bioterrorism. You can see how much money is being put into disease control labs, etc. to try and counteract what we see as the impact of invasive species (e.g., the avian flu viruses, cholera bacteria). You might ask, what does the avian flu have to do with the Bay of Fundy, but you can think of all sorts of other problems that might come into the Bay of Fundy through shipping and by other means. The fundamentals of climate change are going to be mediated through biological systems. One of my predictions is that the national economy and the economy of this Bay are going to be more oriented towards biological phenomena. That has a lot of implications in terms of the way we manage our activities and the ecosystem and the knowledge base that communities will need to address change(s) in the system.

One of the most interesting recent books is by Susan Greenfield, a neurologist from Great Britain. It is called, *"Tomorrow's People: How Twenty-first Century Technology is Changing the Way We Think and Feel"* (Allen Lane 2003). It is an astonishing look at how the combination of information technology, nanotechnology and biotechnology will influence people's lives in ways that will fundamentally alienate them from the environment and change their perspectives and their expectations. Clearly, we have to think of how the natural system might change but, more importantly perhaps, we have to think about how people are going to change. The kind of people Greenfield describes are your grandchildren. When they grow up, they are going to be exposed to entirely different expectations concerning medicine, food, computers and so forth, and that is going to have amazing implications for how we manage ecosystems. If you live in an urban area, largely divorced from the natural world, you are not going to think about the oceans in the way that we do now in small communities around the Bay of Fundy.

As we look into the future, we have to think not only about the natural system changing, but the attitudes, institutions, and perspectives of people changing. I chose the title for this talk about the future of the Bay of Fundy, "*Who Should Speak For the Oceans: New and Emerging Ideas for Ocean Management*", for a specific set of reasons. First, we must recognize the great diversity of agencies, stakeholders and citizens who believe they have a legitimate role in shaping ocean management everywhere, whether it is the Bay of Fundy, or the west coast of Vancouver Island, or the Arctic or Indonesian waters. The reality is that there is a cacophony of voices who think they represent views about the oceans, the different sectors, the uses and so forth. They do have legitimate roles, but most often these voices reflect self-interest as opposed to interests of the oceans. That is my second point. The third point is that if we take into account our best documents on oceans in Canada, including the relevant laws, and the recent *Oceans Act* and Oceans Strategy, it is clear that there is much mention about partnerships and the need to bring people to work in collaborative relationships. If we in Canada are serious about ocean management, then the question of who speaks for the oceans and who really listens becomes very important.

The person who first drew my attention to this rather profound question was the Honourable John Fraser, a few years ago in Vancouver. He made the point that nobody speaks for the oceans in Canada. Nobody speaks in the way they should be speaking for the truly sustainable use of the oceans. He was not saying that in absolute terms. I would say that the type of forum that has been going on here for the past few days is probably one of our better efforts at actually defining that kind of voice needed for the future. The reality is that there are often no clear voices and no clear questions. And particularly within government, there is not much receptivity or listening capacity for oceans. Even more troublesome is the deafening silence on many issues. There is no voice at all. There is only a cacophony of sound from the various sectoral interests that are often working at cross-purposes and for their own self-interest. The ocean tends to be the loser in such a process.

Such a trajectory is dangerous. But the reality is that we do not have a clear voice for the oceans, a clear understanding in this country, a country where most people do not live by the oceans, but rather inland and away from the ocean experience. We must develop this oceans voice. I am not going to call it balanced, but a more sensible arrangement of our relationship with the oceans. This will allow us to influence the use of the oceans, and the management of our use of the oceans, towards a sustainable future for the Bay of Fundy and every other ocean area in Canada.

An important message is that we should not expect government to be that voice. We have the Department of Fisheries and Oceans, which is clearly not a department of oceans and fisheries. We know all about the trials and tribulations of that. We have some twenty-five other departments in the federal government alone that have an interest in or are assigned responsibilities in the oceans arena. Just engaging those disparate units of government has proven extraordinarily difficult, let alone developing any kind of unified voice for the Canadian oceans.

Capacity is another important issue. In Canada, we cannot produce a current state of the oceans report. There is no single document available in Canada that gives a comprehensive and fair assessment of whether the oceans in Canada are in crisis, or whether the oceans are getting better in terms of contamination or other stresses. It is even difficult to get an overview of our economic use of the oceans. It is not that we do not spend money on the oceans; indeed, we spend billions of dollars in our management of the use of the oceans, but we do not have an overview. This is not unique to Canada, and it something that has been called for. Developing such a report is one way that we can develop a unified view of who is speaking for the oceans. The document should speak for itself. It should tell us the condition of communities that use the oceans and the state of the oceans in Canada. But that report is not going to come, in my view, easily out of government.

Responsibility and Accountability

Finally, looking at the third element of sustainable development, we have a very range of views about the social dimensions of ocean use.

Both responsibility and accountability measures on the part of all of us are key to thinking about the future of the oceans. No matter what positive or negative things we have to say about how the Bay of Fundy will change, we will be no further ahead thirty or fifty years from now unless we address the issue of responsibility and accountability. In my view, we will be worse off. I will only remark on measures that could be implemented now, or be thought of now and one hundred years hence, i.e. the current scope of people who are trying to change the course of events. Some of the measures are obvious. In looking into the future, we must recognize that whatever is said about such scenarios generally tends to be wrong. But that is not to say you cannot use the information effectively for management purposes. I will return to this point.

In searching for the truth, whatever that truth happens to be, we need to think carefully about options foreclosure. In essence, what we are saying is that if we make certain decisions now, then habitats or species might not be there in the future, or one use of a site now, such as putting up a refinery, may preclude aquaculture or other activities down the road—that is options foreclosure. This is one of our worries about the future of the Bay of Fundy—one use precludes another.

Equally important is the failure to recognize opportunity. Again, this is not new to anybody in Atlantic Canada as we are all searching for opportunities. Organizations such as ACOA are funding opportunities. In reality, we do not have much foresight to understand what these opportunities are going to be. New technologies, new working relationships, or new investment approaches could bring about new opportunities. A good example is sea kayaking, which has become a major economic driver on the west coast of Canada. It started in this region a few years ago but it is pursued far more vigorously out west than here. This is the kind of opportunity that was not recognized on this coast for a long time. Since the 1980s, it has probably meant million of dollars of lost opportunity to some small coastal communities.

The transactional costs of doing business between sectors and of having poor relationships between sectors are also a heavy burden. The Atlantic coast petroleum industry's figures suggest that Canada has high transactional costs to conducting offshore development. Now, some people would say that this is a good thing, but others say that it is bad because people are less likely to invest here. In general, we need to understand the transactional costs of ocean uses. How long does it take to get an environmental assessment done? How long does it take to develop the necessary knowledge base?

These are three very practical considerations for thinking about the future of the Bay of Fundy: options foreclosure. Failure to recognize opportunities and transactional costs.

Approaches to the Management of the Bay of Fundy

Now, let us think about the management, rather than the ecological, side of the Bay of Fundy. That may sound backwards, but it is not. I want to go rather systematically through some of the trends, the drivers, from outside of Canada, that is the agreements that we take on internationally or that in some cases we helped to formulate. We need to ask the question: are these activities going to drive us as managers in this country as we look to the future of the Bay of Fundy? I think that is the way we go about it. Science will provide certain facts about ecosystems. Geographers and climatologists will give us the big picture of change, but it is going to be very murky for a few years, about as murky as the water when the Fundy tide rolls in. But we can be clear on the management directions. I think that there is a coherent set of management and legal approaches that are now available that was not available ten years ago. It is going to guide us for at least the next twenty to thirty years.

If we step back from the narrower picture of the Bay of Fundy and look at the broad picture of where the world is going, we see that there are some inflection points around the year 2030. If we do not stop some of the things we are doing today to the CO_2 levels, we are going to be paying a very heavy price from about 2030 to 2050 onward, everywhere on the planet, including the Bay of Fundy. If we do not deal effectively with biodiversity issues, whether marine or terrestrial, whether it is with coral reefs in the tropics or the effects of trawlers in the marine benthic environment, we know without a doubt that we will have induced significant ecosystem and ecological changes. It is logical to start thinking about what we can do today, between now and 2010, that is going to make those inflection points go the way we want them to go by 2030. And that is why we need to think hard about management now, as opposed to just saying that we need the ecological information now and we can talk about the management in the future. In my view, the consideration of management decisions comes first as we look at the future of the Bay of Fundy.

Four points can guide us with these management decisions. First, obviously, is the ecology, what I call “ecological quality”. We have an approach now, under the *Oceans Act*, where we talk about developing guidelines, standards and parameters for marine environmental quality (MEQ). In essence, this approach is trying to take a hard look at the ecosystem and what is important and how we can measure change in it. Is there a set of MEQ guidelines and standards for the Bay of Fundy at this time? No! And the same is true, unfortunately, for all the marine ecosystems in Canada. This set has not been produced and compiled yet. It has been called for, but it has not been done. Why? Why does it take so long? Why is it that with our knowledge, which is considerable, we cannot set down those MEQ guidelines for an ecosystem like the Bay of Fundy if we think they are important? What will it take to do it? I think that this is an important set of questions to ask as we think ahead to the future of the Bay of Fundy. Developing the approach for MEQ and its components, as in the *Oceans Act*, is a focus for research, but even more important, it is a focus for developing a practical dialogue between communities, resource users, and the people who are concerned about speaking for the oceans and who recognize we need MEQ guidelines. I think that if we are looking at cumulative actions, this is one of the critical things that we have to do. Until we do this, no matter how much we talk about the Bay's future, we won't be doing more than wringing our hands about it. We need to have some management tools, tools that can contribute to the important state of the ocean reporting that I spoke about earlier.

The second, equally important point is what I call either sustainable ocean economies or sustainable economics for the oceans. While we have a framework to think about the economics of the oceans, we do not have a good framework to think about the sustainable economics of the Bay of Fundy. And that is a problem. My challenge to you is to consider what happens if we double or triple the economic contribution of the oceans. What are the implications for the Bay of Fundy? How would we do it? Who would be the beneficiaries? Would it be the coastal communities of Fundy, would it be Canada, or would it be the international world? I think that it is realistic to ask these questions because that is what is going to be demanded of the oceans in the future. A major future trend that we can identify is increasingly complex uses of the ocean and its resources. We have seen this consistently on this coast, on the West Coast, and, even more of concern, in the Arctic. People are going to extract more resources from the oceans. Whether such extraction is sustainable or not is another question.

In my view, we cannot predict all those future extractions for the Bay of Fundy ecosystem. For example, what is the future of tidal energy? We looked at it in great detail in the 1970s and rejected it, but what is going to happen in ten or twenty years? Will that discussion be back on the table? Will it be focussed around hydrogen economies? If it is, maybe it would not be double or triple, or it might be ten times the current contribution to the economy of the Bay of Fundy, but would it be sustainable? What are the implications? These are important questions but it is extremely difficult to get any comprehensive picture about ocean economics in Canada. While a picture is starting to emerge, I do not think anybody has yet been able to put together a picture of what we would have to do to make it a sustainable ocean economy.

That leads to the third leg of the stool of sustainable development: the social dimension. I would address this dimension by asking the following questions: Who are the beneficiaries? Will the flow of benefits from the future use of the Bay of Fundy be local, which is what many communities would be asking for, or would they be at the regional, national or even international levels? It may be that many of the future benefits will be at the international level and driven by international demands, e.g., climate change or the Convention on Biodiversity. These are not all strictly economic benefits, as they also encompass ecological services, for example, the desirability of having species such as oxygen producing algae and whales remaining with us. Who is going to benefit and who is going to pay the costs? These are very important questions. If we look at tourism, other forms of development (e.g., the gas terminal, underwater pipelines, shipping natural gas to the United States), tidal power or other forms of power development that fuels the hydrogen economy, the answer as to who is going to be the beneficiary becomes very complex. I would reformulate the question to: What is the appropriate mix of investors and beneficiaries? How do you ensure that there is the right mix of beneficiaries? These are questions that are not posed clearly enough in dealing with this region in terms of the oceans.

The fourth leg of the stool of sustainable development relates to security. Security issues include ports, communities and combating terrorism. In recent years, governments have shifted many of their security-related expenditures, reducing the funds available for the other legs of our stool.

Sustaining the Bay of Fundy

How can we focus our attention on the four legs of sustainability (ecology, economy, social and security) in the context of the Bay of Fundy? First, we must reinforce our international responsibilities in the region, e.g., such as through the Gulf of Maine Council on the Marine Environment. We must think of the Bay of Fundy not only at the level of a large ocean management area, but also at the level of individual coastal management units. This will involve creative use of the various tools of integrated coastal management (ICM).

In Canada, this ICM process has continued formally with the development and implementation of the new *Oceans Act*. We must also look carefully at joint Canada-US efforts to manage coastal and marine waters adjacent to the Bay, i.e. in the greater Gulf of Maine, as well as Canadian efforts to manage the adjacent Scotian Shelf. The good news is that we have already identified the directions in which we must move. While it may take 20 to 30 years to put integrated coastal management into place in Canada, we have taken the first steps and now have a framework to work within.

We must also continue to establish a network of marine protected areas in the Bay of Fundy. While we have appropriate management tools to accomplish this goal, we have been slowed by institutional will. We must work to overcome this barrier. Sustaining local strategies will also be a component of the larger process. Obviously, we want to make sure to use the right kind of strategies.

As confirmed at the 1992 Rio Conference on Environment and Development, we must protect the biodiversity of the oceans, including the Bay of Fundy. The issue of invasive species will become more important in the Bay in the coming years. Other issues that will need to be dealt with include land-based sources of marine pollution (now called land-based activities), particularly as they affect salmon populations and river management. What is the future of the Bay of Fundy 50 to 100 years hence with regard to biodiversity and habitat protection? Have we begun to consider this issue in our economic projections for the region? When we look at native salmon, for example, how much value do we place on maintaining this resource in the long term?

Clearly, as we look into the future of the Bay of Fundy, several issues will need more attention. We will have to improve our environmental monitoring of the region. We will need to implement our commitments under Rio and the *Oceans Act* more effectively. This will require that we form new local, national and regional partnerships. We will also need to improve our capacity to value ocean resources. This will involve looking beyond the oceans and integrating land-based activities into the valuation process (so called $H^2$0 – hilltop to oceans).

Conclusion

I conclude with some observations on trends affecting the Bay of Fundy:

- We have area-based management needs.
- We will need to develop a shared knowledge base to address these needs. Tools such as geographical information systems (GIS) and digital databases will assist us in sharing this knowledge.
- The Canadian government is focussing on other regions right now (e.g., Arctic, the British Columbia offshore). We must speak vigorously on behalf of the Bay of Fundy, emphasizing the four legs of the sustainability stool.
- We must link this region to other marine regions in the northwest Atlantic.

In addressing these trends, we can identify several other key principles that will guide our actions: the polluter pays principle, the precautionary approach, basing decisions on a firm knowledge base, and subsidiarity. Clearly we will need to adopt the tools of adaptive management and further develop the capacity of coastal communities and institutions in the region.

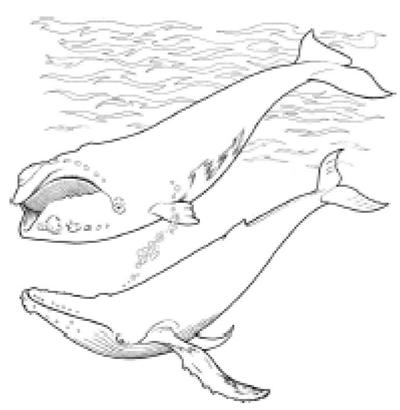
When considering who should speak for the oceans, I would like to suggest that there should be a voice for everyone committed to the oceans. Building on the ten years of success of the Bay of Fundy Ecosystem Partnership, I see a clear future for BoFEP and its partners in speaking out for, and acting on behalf of, the Bay of Fundy. I look forward to celebrating this success 30 years hence. Thank you.

Note: this paper was revised and edited from the original taped draft by the editors.

Fundy Festival: Public Lecture

STRUGGLING IN AN URBAN OCEAN: THE PLIGHT OF THE NORTH ATLANTIC RIGHT WHALE

Moira Brown, New England Aquarium and Canadian Whale Institute



Moira Brown is presently Senior Scientist in the Edgerton Research Laboratory at the New England Aquarium in Boston, and Scientific Advisor to the Canadian Whale Institute. From 1997 to 2003 she served as Senior Scientist at the Center for Coastal Studies in Provincetown, Massachusetts, where she was Program Director for Right Whale Studies. From 1995-1997 she was Professor of Biology, at the College of the Atlantic in Bar Harbor, Maine. She was the Founder, Executive Director and a Research Scientist with East Coast Ecosystems, a research organization, based in Nova Scotia. Dr. Brown's primary research interests since 1985 include studies on the distribution, population biology and genetics of North Atlantic right whales and beluga whales, behavioural studies of bowheads, fin and minke whales. Her primary conservation interests include mitigation of collisions between ships and right whales, technical support for relocations of Canadian shipping lanes in the Bay of Fundy, and mitigation for reducing risk of entanglement of right whales in fishing gear.

Introduction

The Right Whale Project has become so huge in breadth of research that it is not possible to talk about it all in one lecture, so I am going to select a couple of my favourite parts and take you through some of the science and policy work we have accomplished in the Bay of Fundy over the last 25 years.

History of Exploitation

The demise of the North Atlantic right whale (*Eubalaena glacialis*) is not at all a mysteryl. This whale was hunted by the Basques between the years 1530 and 1610 in the vicinity of present-day Red Bay, Labrador. It has been estimated that between 25,000 and 40,000 whales were taken out of the area during that time period and it was thought that probably half of those were bowheads and half right whales. At least that is what we thought until about a year ago. I'll return to that part of the story later.

Whaling started along the eastern seaboard of the United States shortly after the first European settlers arrived, and right whales were the preferred target because of their coastal dwelling habits and the fact that they floated after death. The right whale was prized for the thick coat of blubber, which is up to 10 to 12 inches thick in some animals, and of course for the long baleen. The two products were the oil and plastic of their time.

During colonial whaling along the coast of the United States in the 1700s, during one ten-year period, enough oil was shipped to the United Kingdom to represent about 1,000 right whales. Right whales first were thought to be commercially extinct by 1750. Right whaling resumed once again along the shore and also as pelagic whaling by the Americans in the late 1800s and the early 1900s. About 50-60 right whales were killed per decade between 1850 and 1890 along the east coast of the United States. By the early 1990s, catches had fallen and only a few tens of right whales were thought to remain.

Right Whales in the Twenty First Century

There is still a scarcity of right whales in the western North Atlantic, as about 350 remain. This is the only species of large whale that has not recovered from commercial whaling. This population may have been reduced to just a few tens of animals in the early 1900s. There is only one single primary cause and that is commercial whaling. Right whales still face a loss in their numbers from interactions with human activities, now from ship strikes and gear entanglement. These detrimental human activities only became known to us in the 1980s and 1990s.

Right whales also have an inherently low reproduction rate in comparison to other right whale species in the southern hemisphere. Why? We are trying to address many questions in our research: How many right whales were in the North Atlantic before whaling began and how many are there today? How are they distributed seasonally and spatially in the past and in the present? Where do they calf, breed, rear their young and feed? You'd think we would have this figured out after 25 years of research. We have a few things figured out but far from all of them.

Other questions also remain: What are the trends through time? Is the population constant? Have there been episodes of decline or increase and how small was it when it was at its smallest? There is a recovery plan for right whales and it is soon going to be revised in order that it is in compliance with the new species at risk legislation in Canada. There are three primary elements in the plan: numbers, distribution and viability. Is there enough genetic variation for the right whale to survive given the level of human impact? A consortium of researchers in Canada and the United States is tackling all of these questions with varying success.

Right Whale Research

The right whale research program, started in 1980 by Scott Kraus from the New England Aquarium, was actually doing an environmental impact study regarding the proposed Pittson Oil refinery to be located in Eastport, Maine. This company had suggested that there were no whales in the Bay of Fundy so there would be no impact, but no one had looked. Luckily they did the environmental impact study and on August 29, 1980 researchers found a number of right whales including four mother-calf pairs in the Grand Manan Basin. That was the first clear indication that right whales were still around, still reproducing; perhaps a viable population persisted. The New England Aquarium research team has returned to this area every year since 1980. Our research is based on photographic identification of the callosity pattern on the head of the right whale. We've used the same boat all this time, three engines but the same hull. We also carry out aerial surveys in a small high wing twin-engine plane called a Cessna 337 Skymaster.

We have a terrific team of professional researchers who travel all along the east coast of North America and work on the right whales in different seasons and different habitat areas. Since 1980, a total of 31,078 sightings of 459 individual right whales have been archived, of which 342 were thought to be alive as of 31 December 2003, plus the 17 calves that were born this year (2004). The catalogue allows researchers to carry out analyses on population biology, reproduction, behaviour, distribution and migratory habits as well as scarring from interactions with human activities and health assessment.

Right whales are distinguished from one another by the pattern of callosities on the top and sides of their heads as well as the pattern of white pigmentation found on the chin and belly of some individuals. The flukes are generally black, and there is no dorsal fin. Scars from entanglement in fishing gear and interactions with vessels can be used, in addition to the natural markings, for individual identification.

Since 1980 we have been taking photographs of right whales in a lot of different habitat areas. A consortium of right whale researchers in the United States is primarily made up from the New England Aquarium, Center for Coastal Studies, Woods Hole Oceanographic Institution, and the University of Rhode Island. In Canada, we collaborate with academics at Trent and Dalhousie Universities and a number of the smaller non-profits and Fisheries and Oceans Canada (DFO).

What have we learned in taking all these photographs? The only known calving ground for this species is down in the southeast United States, roughly between Brunswick, Georgia, and Cape Canaveral, Florida. Right whales tend to arrive in this area in December. Most calves are born in December and January. Mother and calves start their migration up the coast through the mid Atlantic probably within 30 miles of shore. They'll start migrating up the coast towards the end of March. Right whales are also present in Cape Cod Bay in wintertime, but the number increases dramatically in the spring as well as in an area east of Cape Cod Bay called the Great South Channel. This is the beginning of the feeding season for most right whales. Usually by the end of June, right whales have gone north to Canadian waters for the summertime and are found in the Bay of Fundy between Nova Scotia and Grand Manan Island, New Brunswick. The second Canadian habitat area is Roseway Basin between Browns and Baccaro Banks on the western Scotian Shelf.

Other areas where we have seen right whales include waters off Greenland, Norway, Newfoundland, the Gulf of St. Lawrence to Tadoussac, the Gulf of Mexico and Bermuda. For example, a mother and calf pair was found in the Gulf of Mexico this spring and they showed up in the Bay of Fundy in September. So these animals still do a lot of things to surprise us.

We still don't know the winter distribution of most of the right whales. Between the mother and calves in the southeast United States and a few whales in Cape Cod Bay, the numbers never account for more than a third of the known population. So we are missing two thirds of the known population in the wintertime. What's more, we don't even know where to go looking for them.

We still don't know where the mating area is for right whales. We assume the gestation to be similar to southern right whales, 12 to 13 months. Most of the calves are born in December and January so that means mating must take place perhaps the previous November, December, or early January somewhere. Again, we don't know where to go look. Also there is a second summer nursery. As far as we know all of the calves are born down in the southeastern United States, but about one third of the mothers take their calves somewhere else other than the Bay of Fundy in the summertime. We haven't located that second summer nursery yet. Mothers are capable of having a calf every three years, but the average is close one every to five to six years. On average over the last twenty years there have been eleven to twelve calves born per year in the population. Given the size of this population and the number of females in this population, if right whales in the North Atlantic were anything like right whales of the South Atlantic, they should be producing 30 calves a year on average. And so North Atlantic right whales are producing at only about one third of their biological potential.

There are a number of potential causes for the low reproductive rate including nutritional stress, disease, marine biotoxins, genetics, and pollution; they may all play a role individually and synergistically. In addition to low reproductive rates, there are high mortality rates. We have observed 62 deaths in the last 34 years since 1970. Of the 62 deaths, 21 were from shipstrikes, including 5 calves. Six right whales died from entanglement in fishing gear, and there have been 18 deaths from unknown causes and 17 neonate mortalities. The entanglements hit the two sexes in approximately the same numbers, however juveniles routinely tend to run into gear more often than the adults. This does indicate that there may be some learning going on.

The shipping and fishing industries look at our data and the fishermen say this isn't their fault, as many right whales are being killed by ships. And it's true, three times as many. However, we've looked at the survivorship of right whales last seen entangled in fishing gear that haven't been seen since and that number jumps up another ten animals, so both ship strikes and entanglements are causing right whale deaths. The mortality figures are minimums because if a whale dies at sea and is not discovered, its death goes unrecorded. At this time, in addition to the 62 known mortalities, there are at least another 80 catalogued right whales that are presumed dead after no sightings for six consecutive years.

There have been some attempts to model the population by Fujiwara and Caswell at the Woods Hole Oceanographic Institution. Their work shows that this population is in such a delicate balance right now that just reducing mortality by two females per year could reverse a declining population trend. If the trend is not reversed, they predict right whales could be gone from our waters in less than 200 years.

The solution is to work with fishermen in such a way as to modify fishing gear so that it can still catch fish but be much less likely to entangle any of these whales and to work with the shipping industry to determine how to reduce the potential for a collision with a right whale throughout their range. Those deliberations are going on in Canada and the United States. But as you can imagine, it is a very long process to try and determine how not to catch or hit a right whale and then implement the solutions.

Right Whale Stewardship in Canada

We have been able to make the most stewardship progress with the shipping industry in the Bay of Fundy. Right whales apparently do not get out of the way of ships. We don't know if they don't detect them, or they hear them and simply ignore them! We've seen right whales out in the Bay of Fundy swim up beside a ship to within a couple hundred yards and then fall asleep at the surface as this big ship goes by. There have been four right whale death in the Bay of Fundy attributed to ship strikes and one off Halifax.

In 1993, two conservation areas were designated by Fisheries and Oceans Canada without the support of any legislation but rather as an educational tool so we would have a specific area to talk about where the right whales were located. The boundaries of the conservation areas were based on 95 percent of sightings in Canadian waters between 1980 and 1992. Of course, in 1993 we documented the beginning of a very interesting shift in right whale distribution. Between 1980 and 1993, we would typically see between fifty and seventy-five right whales per summer in the Bay of Fundy; they were mostly mothers and calves and juveniles so we called it the nursery. Out on Roseway Basin, that was where the action was. We saw mostly males, juveniles and adults, lots of females, and lots of social activity. We dubbed this area "the singles bar" and at one time we actually thought that this was the mating ground. However, the whales are there from August through October and it doesn't match with the twelve-month gestation and the calves being born in December and January. In 1993, no right whales were seen on Roseway Basin but there were over a 100 animals in the Bay of Fundy. The annual numbers in that habitat kept going up through the latter part of the 1990s until we reached over 200 animals in the Bay of Fundy in 1998 where it has remained for a couple of years. Not only were the animals there in greater numbers, but instead of just being in the Bay of Fundy in August, September and October, they were now there in June through November with even an occasional sighting from the Grand Manan ferry just after Christmas.

There is a shipping lane or traffic separation scheme that goes through the outer Bay of Fundy to Saint John. All vessel traffic greater than 65 feet (20 meters) in length must transit the Bay of Fundy in these lanes; there is an overlap of right whales and ships in the outbound or southbound lane. In addition to the obvious overlap and some sightings of whales and ships in close quarters, three dead whales were attributed to ship strikes in the Bay of Fundy in 1992, 1995 and 1997 respectively. In 1993 we visited Fundy Traffic in Saint John (it was part of Coast Guard then, now it is part of DFO). The operators at Fundy Traffic monitor by radar all of the traffic coming up and down the shipping lanes twenty-four hours a day and they are in radio contact with the ships. We thought that they could warn the ships about right whales and that would reduce the chance of ship-whale collision. After a couple of hours of discussion, they agreed to tell ships about whales and this was the beginning of the mariner education program for right whales. Although education is important, the overlap between right whales and ships was a concern and we were looking for solutions to reduce the potential for collisions. We worked with Chris Taggart from Dalhousie University who retrieved the shipping data from Fundy Traffic and overlaid the shipping traffic data with the right whale data and came up with a probability of a whale-vessel collision. This work resulted in a proposal to move the shipping lanes away from the high density of whales. In placing these lanes, we also looked at fin, minke and humpback whales, as we didn't want to reduce collisions with right whales only to increase them with other species. A proposal was written and submitted by Transport Canada to the International Maritime Organization (IMO), London, because Canada can't move these shipping lanes on its own. Even though they are within Canada's territorial sea, the lanes were mandated by the IMO in 1983 and any changes require IMO adoption. The amendment was passed and implemented in July 2003 with the unprecedented level of commitment and help of many stakeholders, government representatives and scientists.

While listening to Stephen Hawbolt's talk yesterday, I realized that we had used the camel principle. This involves getting somebody a little bit interested, getting them to realize that you are not all that strange because you study whales for a living, and to realize that there is probably a solution and that they can be part of it. We used data from the New England Aquarium's right whale study and colleagues from all these different walks of life sat in a room to decide how to deal with right whales and ships in the Bay of Fundy. I must say that I was completely overwhelmed with the amount of interest, particularly from some of the companies involved. We basically had enough support not only from industry but also fishermen's organizations to allow the change to go forward. The one group that had the most impact were the Nova Scotia fishermen because now they were going to be fishing in an area where ships would be coming through where previously they hadn't, the ships would have been further to the west. But many of the fishermen are involved in the whale watching industry or have family who are and they understood the importance of trying to reduce the human impact on whales. It was really terrific to see the results in 2003. If we hadn't moved the shipping lanes in 2003, 30 percent of the whale sightings would have been in the shipping lanes. Instead only 1.5 percent of the animals were in shipping lanes. We are able to monitor the results of our conservation measures and their effectiveness from year to year.

I am now going to briefly discuss our genetics research program. We collaborate with a colleague at Trent University, Brad White. We go out in the boat and take photographs of right whales to identify them and track the progress of this population. For Dr. White we bring home a small skin sample that is roughly the size of an eraser on a pencil. The geneticists identify individual whales from DNA banding patterns. Although I prefer to see the actual whales, the genetics work reveals far more amazing data than can be obtained from photographs alone.

The project started in 1988. At that time I was a graduate student with the late Dr. David Gaskin of Guelph University. I learned how to use a crossbow and came home from the Bay of Fundy with 25 skin biopsies. He said, “Wow, this is great!” I said, “Well I’m going to go back next year.” And he said, “What do you mean you are going back next year? Are you going to biopsy them all?” When I said “yes”, he laughed! We now have 72 percent of the known population biopsied and are working on the remaining 28 percent. There is a team of graduate students at Trent University that carries out a full suite of genetic analyses on each sample. For example, for each right whale sampled, we can determine its gender and family relationship or matriline. A genetic profile is generated for each sample that permits paternity and maternity testing as well as individual identification.

One aspect of right whale life history we are trying to piece together is the family tree. By blending the sighting histories of individual whales with the photographic data it is possible to learn about the relationships of all the living right whales, similar to a genealogy for your family back through time. One of the most interesting aspects of the genetics work is the impact DNA analyses have had on the interpretation of the historic whaling data from Red Bay, Labrador. Earlier I mentioned that historians had interpreted that roughly 50 percent of the Basque hunt of whales in Labrador in the 1500s was comprised of right whales. Over the last five years, we made three trips to Red Bay to sample 400 year old bones from the Parks Canada excavations at the Red Bay historic site. To date, we have only found one right whale bone, all the rest have been bowhead. This finding changes our backward projections of how many right whales must have been alive in the North Atlantic prior to exploitation. In all likelihood there were fewer right whales than previously thought, perhaps numbered in the thousands rather than the tens of thousands. The one right whale found has a very similar genetic profile to the ones living today, yet it was found within the Basque context, so it not likely a modern right whale that swam astray. Another factor that probably reduced the North Atlantic right whale population to a smaller size prior to exploitation, perhaps a glaciation event. Regardless, this shows that history is subject to interpretation and that it is important to investigate to the fullest the approach that might have taken place hundreds of years ago.

Does the North Atlantic right whale have a chance to survive in the urban ocean along the east coast of the United States and Canada? I believe the answer is yes, but it will take a very dedicated group of people using a well-planned recovery strategy that is implemented bi-nationally and as soon as possible. Canada has taken a significant step toward that process with the relocation of the shipping lanes in the Bay of Fundy. Now the challenge is to find and implement solutions to the other detrimental human interactions with right whales throughout their range.

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See Whale Net Right Whale Bibliograpy, online at <http://whale.wheelock.edu/whalenet-stuff/rw_bib.html>.

Session One

CONTAMINANTS AND ECOSYSTEM HEALTH

Chairs: Jocelyne Hellou, Fisheries and Oceans Canada, Dartmouth, Nova Scotia,

Peter Wells, Environment Canada, Dartmouth, Nova Scotia

and

Phil Yeats, Fisheries and Oceans Canada, Dartmouth, Nova Scotia

A. NUTRIENTS, DEGRADABLE WASTES AND MICRO-ORGANISMS

THE MANAGEMENT OF WASTES FROM ATLANTIC SEAFOOD PROCESSING OPERATIONS

Jeffrey C. Corkum[1], M. T. Grant[1], and Chris J. Morry[2]

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Nutrient enrichment from land-based activities has been identified as a priority area for action by Canada's National Programme of Action (NPA) for the Protection of the Marine Environment from Land-Based Activities, Atlantic Region Team. Sources of excess nutrients include food processing, municipal and industrial wastewater, agricultural fertilizer runoff, nutrient enriched groundwater, aquaculture operations, and soil erosion from agricultural and forestry practices.

Little work has been done to characterize wastewater discharges from seafood processing operations in the Atlantic Region since several studies conducted in the 1970s. Although treatment of these discharges has been somewhat guided by the 1975 *Fish Processing Operations Liquid Effluent Guidelines,* which recommend fine screening of wastewater prior to discharge, much generally goes untreated. At the same time, substantial growth has occurred in the seafood processing industry in the Atlantic Region, with the number of facilities almost doubling since 1969. Therefore the NPA–Atlantic Regional Team chose to focus a project on seafood processing. The purpose was to gain a better understanding of the waste discharges and potential impacts to the environment from these operations.

The objectives of this project were to identify and obtain currently available seafood processing data and to develop a database to facilitate the assessment of the environmental impacts from the seafood processing industry. Following a thorough search of available data sources it was found that the information fell short of original expectations. However, on the basis of the information gathered, recommendations have been made for eliminating data gaps, as well as for follow up work to refine the sector profiles, and analyze potential impacts.

At the same time as the NPA was beginning to explore the issue of seafood processing effluents, a workshop was held in Shippagan, New Brunswick, in February 2003. This workshop brought together a broad range of participants, including government agencies, industry representatives, technology experts, academics, community representatives and non-government organizations. Out of this workshop, the New Brunswick Seafood Processing Effluent Working Group was formed. The initial focus of this group has been on the development and application of best management practices in the industry, with future work examining alternate wastewater treatment technologies.

In November of 2003, the Natural Sciences and Engineering Research Council (NSERC) and Environment Canada announced their agreement to co-fund a Canada Research Chair in Water Quality and Treatment at Dalhousie University's Centre for Water Resource Studies. With one area of initial focus on environmental technologies related to seafood processing effluents, research was undertaken to characterize the regulatory environment outside of Atlantic Canada and internationally. As well, the application of effluent treatment technologies in the industry was explored and a survey of processing facilities was conducted.

In the summer of 2003, scientists in Environment Canada's Atlantic Region conducted an effluent characterization study at six processing operations in New Brunswick, Nova Scotia and Prince Edward Island. It is anticipated that this study will be expanded during this processing season. As well, Environment Canada's Pacific and Yukon Region contracted a study in 2004 to assess changes in the fish processing sector due to expansion in aquaculture farming, develop a comprehensive profile of existing fish processing operations, review current pollution prevention and effluent treatment practices employed, and consider any new advances in pollution prevention or technology with the fish processing sector.

The individual initiatives underway all demonstrate a renewed interest in the management of effluents from the seafood processing industry. Much has changed within the industry and a concerted effort is being made to more clearly understand the effects of the industry's discharges on our coastal waters. It is anticipated that future work in this sector will include a review of processing operations and waste discharges, which will in turn lead to the identification of pollution prevention opportunities and recommendations for best management practices sector wide. Discussions have been initiated nationally to share information and look toward the potential for the development of a national strategy for the management of wastes from seafood processing operations.

CHARACTERIZATION OF FISH PROCESSING PLANT EFFLUENTS IN THE ATLANTIC REGION – 2003

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Introduction

The fish and shellfish processing industry is an important commercial activity in Canada, particularly in the Atlantic Region. In 2000, catches in the Atlantic Provinces totalled 819,361 tonnes, which was 85 percent of the national total (AMEC 2003). The highest production in the region is in herring, shrimp, snow crab, scallop, cod and lobster. In that year, the Pacific fishery accounted for 14 percent of the nation's total production, and freshwater catches from across Canada accounted for the remaining one percent.

Water is used in almost every step of the fish processing operation, from storage on vessels to rinsing fish and equipment in butchering, packaging and clean-up operations (NovaTec 1994). Water consumption is variable and is generally dependent upon the size (tonnes) of the catch. Water consumption, in m^3/tonne of fish, has been found to be higher on low volume processing days (NovaTec 1994), although total water consumption, in m^3/day, is greater in plants with high volume processing. Through its use in the plant, process water may become contaminated with fish offal, cleaning chemicals, pesticides, and possibly chemical residue from the fish catches themselves. Untreated wastewater with a high contaminant loading can be toxic to local aquatic and marine organisms (Vassos et al. 1994).

Environmental effects of fish processing plant effluents have become of increasing concern in recent years, particularly with respect to the potential nutrient loading that those discharges add to the receiving environments, and in some cases, metal contamination. However, the potential for organic chemical contamination from fish processing plant effluents has not been adequately determined.

This study is a preliminary characterization of Atlantic region fish processing plant effluents, through organic and inorganic analyses, as well as a suite of toxicity tests. In the spring and summer of 2003, effluents were collected from six fish processing plants in Nova Scotia, Prince Edward Island and New Brunswick. The plants included a frozen pollock processor, a clam processor, a mussel processor, a lobster processor and two snow crab processors. An attempt was made to evaluate as many different types of processors as possible, however, site selection was limited by a reluctance of some plant managers to participate in the study.

Sample Collection

Samples of final effluent (after screening) were collected using a two Sigmamotor 900 series automated samplers. Samples were collected on a time-composite basis over a 24-hour period, or over the daily production in cases where operation was less than 24 hours. In most cases, the samplers were run through the cleanup period in the plant as well, generally at the end of the shift.

One of the two samplers was calibrated to draw 12 litres of sample into a glass bottle packed with ice. The other sampler was calibrated to draw litres of sample into a clean plastic drum, intended for bioassay analyses. Once the processing day and cleanup was complete, the samplers were turned off and samples were subdivided into the appropriate containers for analysis. Field measurements collected with each sample were dissolved oxygen, pH, effluent temperature, total/free chlorine and salinity. The samples were shipped by courier and all arrived within 12 hours at either Environment Canada's laboratory in Moncton or Stantec's laboratory in Winnipeg.

Toxicity tests conducted included the Microtox® acute test, sea urchin fertilization test, threespine stickleback survival, and a 7-day growth test using inland silversides. For samples with a salinity <10 parts per thousand, rainbow trout acute lethality tests were conducted as well.

Results and Discussion

Field measurements for salinity and pH were consistent with measurements taken in the lab. Dissolved oxygen (DO) concentrations in samples sent for toxicity analyses were found to be much lower than the field measurements by the time they arrived in the lab (Table 1).

Organic chemical analyses revealed that three persistent organic pollutants, P,P'-DDE, Alpha-benzenehexachloride, and PCBs, were present in low concentrations in the effluent of one of the six plants sampled (SC2). No other effluents contained measurable concentrations of persistent organics. It is of note that the plant with measurable concentrations of POPs also had much higher concentration of oil and grease in its wastewater. Because those organics have a high affinity for oil and grease, it is difficult to determine if the higher concentrations at SC2 are due to higher concentrations in the catch, or that the facility simply has less effective treatment systems for removing the oil and grease from the effluent prior to discharge (Table 2).

Results of toxicity testing are depicted in Figure 1 below. Those results indicated that only the clam processor exhibited no toxicity in any of the tests performed. The frozen pollock and mussel processor effluents exhibited some toxicity in the test (30.9 percent and 41.1 percent decrease at full strength) but no toxicity in other tests performed. The lobster processor and both snow crab processors had effluents that were toxic in at least one test performed. One of the snow crab processing effluents (SC2) was very toxic to all organisms tested.

Although this study has provided data on fish processing plant effluents that has not been collected previously, more samples are required to fully characterize the industry. Additional plant types that will be approached for future sampling efforts are sea cucumber, herring, shrimp and groundfish processors. Also, more data on processing in the plant, waste treatment processes, process-water volumes, and origins of the daily catch will be collected this sampling year.

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Table 1. Summary of physical and inorganic chemical characterization results for six fish and shellfish processing plant effluents

	Processing Plant Species[1]					
	FP	**C**	**M**	**L**	**SC1**	**SC2**
Field Measurements						
Total chlorine, ppm	0.25	0.25	0.1	0.5		
(CWQG – Freshwater)	(0.005)	(0.005)	(0.005)	(0.005)	0.1 (0.005)	0
DO, mg/L	11.4	11.19	5.85	9.46	8.28	8
Temp, °C	6.1	7	8	10	11	15
pH	7.4	8	7.4	8.3	7.9	7.5
Salinity, ppt	18	28	22	0	0	1
DO, mg/L	11.4	11.19	5.85	9.46	8.28	8
Inorganic Parameters						
Sulphate, mg/L	1731	2444	1888	29.92	372.3	25.47
Nitrate, mg/L	<0.20	3.47	5.84	0.06	<0.02	<0.02
Ammonia dissolved, mg/L				7.61		
(CWQG – temp and pH)	Interf	Interf	Interf	(0.34)	1.33 (1.04)	55.5 (2.22)
Mg dissolved, mg/L	713.1	1127	867.7	23.38	14.42	9.55
K dissolved, mg/L	278	357.5	261.4	7.73	6.22	27.2
N, Ammonia, mg/L	12.3	0.06	2.01	0.34	1.22	3.43
Total N, mg/L	33.24	<0.01	7.47	2.9	7.35	131.3
TOC, mg/L	101.1	52.3	212.9	94.9	7.4	1134
P, mg/L	7.546	0.162	1.885	0.574	1.468	9.616
Total PCBs, ng/L	<1.0	<1.0	<1.0	<1.0	<75	233
BOD diss, mg/L	147	40	66	24	104 R	2230
TSS, mg/L	69.7	55.1	558.6	9.5	<1.0	1192
Total Hg, ug/L	0.04 (0.02)	<0.02	0.03 (0.02)	<0.02	0.04 (0.02)	0.15 (0.02)

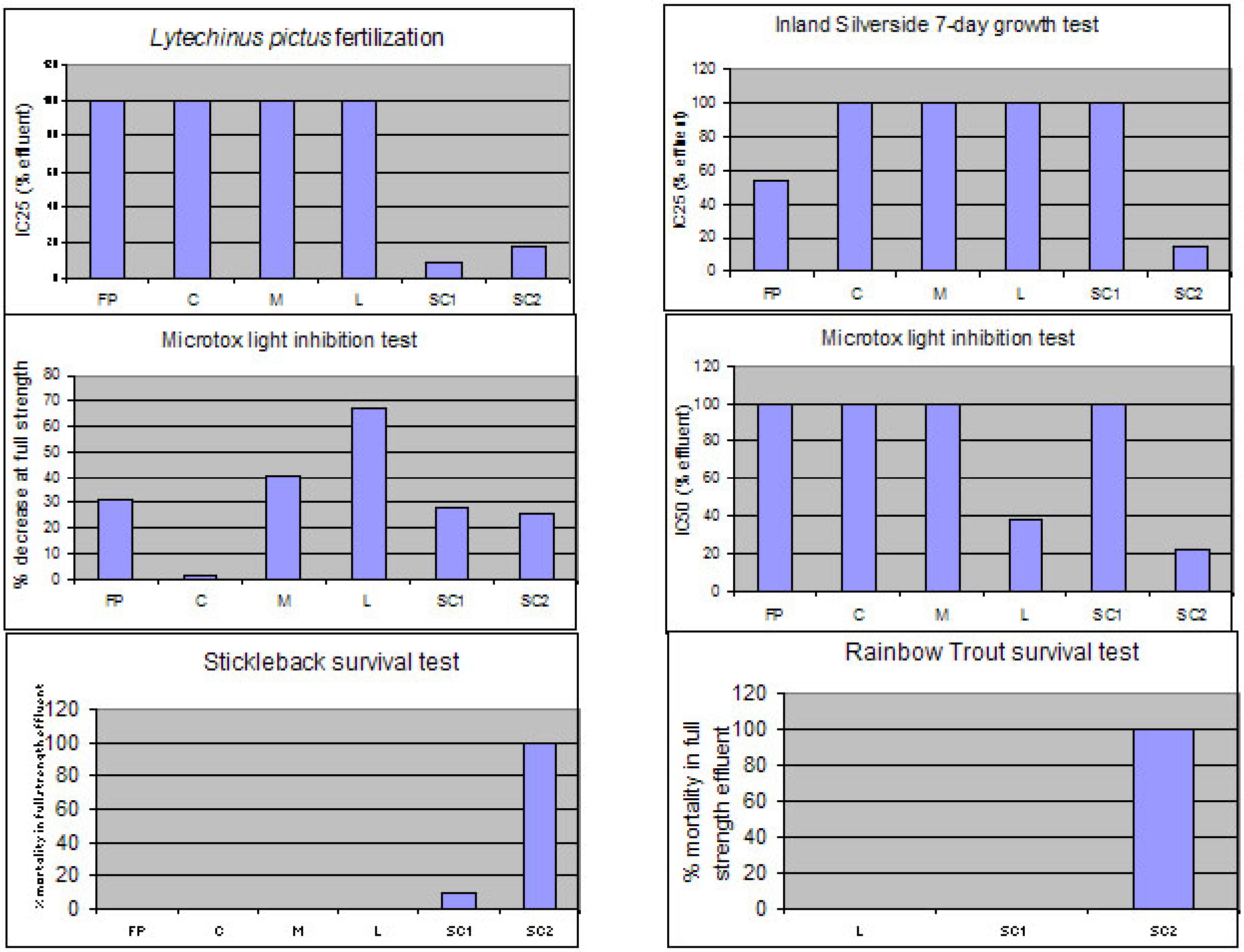
[1] FP = pollock; C = clams; M = mussels; L = lobster; SC = snow crab

Table 2. Summary of organic chemical characterization results for six fish and shellfish processing plant effluents

	Processing Plant Species[1]					
	FP	**C**	**M**	**L**	**SC1**	**SC2**
Oil and Grease, mg/L	NA	<1.0	4	11.8	12.1	1117
Total PCBs, ng/L						
(PCB Treatment and Destr. Regs)	<1.0	<1.0	<1.0	<1.0	<75	233 (500)
Alpha-benzenehexachloride, ng/L	<0.5	<0.5	<0.5	<0.5	<14	36
P,P'-DDE, ng/L	<0.5	<0.5	<0.5	<0.5	<10	139
Dieldrin, ng/L	<0.5	<0.5	<0.5	<0.5	<7	17
Aldrin, ng/L	<0.5	<0.5	<0.5	<0.5	<9	<11
Alpha-chlordane, ng/L	<0.5	<0.5	<0.5	<0.5	<8	<11
Gamma-chlordane, ng/L	<0.5	<0.5	<0.5	<0.5	<11	<14
O,P'-DDD, ng/L	<0.5	<0.5	<0.5	<0.5	<11	<13
P,P'-DDD, ng/L	<0.5	<0.5	<0.5	<0.5	<9	<11
O,P'-DDE, ng/L	<0.5	<0.5	<0.5	<0.5	<6	<11
O,P'-DDT, ng/L	<0.5	<0.5	<0.5	<0.5	<7	<11
P,P'-DDT, ng/L	<0.5	<0.5	<0.5	<0.5	<9	<11
Alpha-endosulfan, ng/L	<0.5	<0.5	<0.5	<0.5	<42	<51
Beta-endosulfan, ng/L	<0.5	<0.5	<0.5	<0.5	<6	<14
Endrin, ng/L	<0.5	<0.5	<0.5	<0.5	<10	<14
Heptachlor epoxide, ng/L	<0.5	<0.5	<0.5	<0.5	<9	<11
Gamma-benzenehexachloride, ng/L	<0.5	<0.5	<0.5	<0.5	<4	<11
P,P'-methoxychlor, ng/L	<0.5	<0.5	<0.5	<0.5	<13	<15
Mirex, ng/L	<0.5	<0.5	<0.5	<0.5	<12	<15

[1] FP = pollock; C = clams; M = mussels; L = lobster; SC = snow crab

Figure 1. Toxicity test results for samples collected at six fish and shellfish processing facilities in the Atlantic region



* Rainbow trout is a freshwater species and was tested only on effluents that had a salinity <20 ppt

CHARACTERIZATION OF THE *ESCHERICHIA COLI* POPULATING THE AQUEOUS, SEDIMENT AND ANIMAL COMPONENTS OF A BAY OF FUNDY-ASSOCIATED ESTUARY

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The Thornes Cove estuary is located on the north shore of the Annapolis Basin, Annapolis County, Nova Scotia. Its extensive mudflats serve as a fertile area for the growth of soft-shelled clams (*Mya arenaria*) that are dug by commercial harvesters. The cove and its waters have a history of chronic low-level pollution with the fecal coliform bacterium, *Escherichia coli*. Because the latter is used as an indicator of potential health risk to humans, its detection at Thornes Cove has resulted in numerous partial or complete closures of the clam beds. When this occurs, the independent harvesters are either deprived of a major portion of their livelihood, or are forced to lower their incomes by having to sell to middlemen with depuration facilities.

With a view to ultimately correcting the situation by means of remediation or source removal, we set about characterizing the Cove and its immediate environs with regard to the incidence, persistence and behaviour of its *E. coli* population. With this we hoped to determine the sources and/or reservoirs of the *E. coli* contaminating both the clams and the water column.

An environmental survey identified numerous potential influences on water microbial quality: i) two of the three brooks were impacted by animal activity (beavers, waterfowl and raccoons in and around the central Thornes Brook; beef cattle in and around the easterly Burke's Brook); ii) apparent seepage from two year-round residences; iii) daily influx of salt water of questionable quality (the southern shoreline of the Basin is heavily contaminated with *E. coli*); and iv) the daily presence of large numbers of gulls feeding on the mudflat at low tide. Microbiologic monitoring over a fifteen month period confirmed the continuous presence of *E. coli* in all three brooks (upper regions and mouths), in the seepage (summer and winter), salt water (ebbing and rising tides), the clams themselves (two sampling sites), in gull feces and in mudflat sediments (six sampling sites). Thornes Brook carried average *E. coli* densities of 56 and 79 cfu/ml during the two summer periods; average seepage water counts decreased from 44 to 5 in the winter; salt water densities ranged from 43 (ebbing) to 85 (rising) cfu/ml and in the latter instance, shallow water (5 cm) carried greater numbers than did deeper (30 cm). These densities were inversely related to water column turbidity. Gulls feces had high *E. coli* loads (10^6 cfu/gm). Average *E. coli* densities in marine sediments ranged from 15 to 26 cfu/gm over the two summers. These counts were 27–30 times larger than detected in the overlying water column. Clams carried 5 to 69 cfu/10 gm of *E. coli* over the two sampling seasons.

This broad distribution prevented the identification of a specific source in this manner. Hence, DNA typing (in the form of pulsed-field gel electrophoresis) was used to determine the relatedness of a representative number of the *E. coli* isolates (total = 265).

A high degree of similarity of clam types with those from another matrix would be indicative of a connection between the two. *E. coli* populating fresh and salt water displayed considerable heterogeneity in their strain-types (60 types among 66 fresh water isolates for a diversity index (DI) of 0.91; 63 types among 84 salt water isolates, DI = 0.75), while those associated with sediments, clams and gulls were more homogenous (DIs of 0.07, 0.08 and 0.18, respectively). There were four instances of high levels of relatedness among the isolates that implicated gulls as the source of clam *E. coli* (three clam-gull sets with Dice coefficients of >70 percent and one clam-salt water set with a Dice coefficient of >80 percent). Since sample numbers were small, this requires confirmation.

The high diversity among water isolates is reflective of both temporal and geographic variability: different *E. coli* strains were detected at each sampling time and at the same sampling time different strain types occurred in each brook. Is this indicative of a transient bacterial population that is (requires?) continuously re-inoculated from multiple sources, or, is it a manifestation of the aquatic system's assimilative capacity for microbiologic insult? If the latter, can this be quantified by determining the ratio of culturable (i.e. non-adversely affected) cells to the total bacterial population in water?

A plot of these values derived from measurements made during and after a gross bacterial insult (delivered by runoff during a 44 mm rainfall) indicates that the resultant elevated counts began to move toward pre-insult levels within 12 days. Further, compared with culturable aerobic bacteria, *E. coli* numbers were reduced much more rapidly (46–90 percent vs. 13–24 percent), suggesting the preferential "neutralization" of this fecal coliform bacterium.

In contrast to the aqueous population, sediment *E. coli* displayed little diversity (four strain types among 54 isolates) with the same types being detected on more than one sampling occasion and at different sites on the same day. Is this indicative of continuous inoculation from the same source (point re-charge), or, does it suggest that *E. coli* is multiplying within the sediment material (clonal expansion)? If the latter, what is the marine sediment's role here, and to what extent is fecal pollution taking place? This awaits further investigation, as does the contribution of domestic seepage (human sources) to the *E. coli* problem at Thornes Cove.

MICROBIAL SOURCE TRACKING: TOWARDS EFFECTIVE FECAL POLLUTION SOURCE IDENTIFICATION

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Contamination of waterways has become an increasingly common problem in most parts of the world. Presently, one of the leading concerns affecting water quality is fecal contamination. The detection of *E. coli* in waterways has lead to the closure of beaches and shellfish growing areas. This has had strong social, economic, and environmental impacts. Methods traditionally used for monitoring fecal pollution offer only a quantitative analysis and offer no insight into the sources. Without knowing the sources, remediation can be difficult, based only on the knowledge and assumptions of the surrounding land use.

Microbial source tracking (MST) is an evolving technology that allows users to track fecal pollution to its source. MST could prove to be a most essential tool in the struggle against fecal pollution, however, many of the methods are still under development and require more research before becoming reliable remediation and enforcement tools. These, as well as other related issues, were discussed at a MST Applications Workshop in the hopes of developing a clear action plan for the practical use of this tool by government, academia and community groups in Canada.

The presentation provides a brief overview of the different MST techniques as well as the MST Applications Workshop objectives and action plan. Progress since the workshop will be discussed, including the international MST working group, demonstrations projects, and applications for community-based organizations such as the Clean Annapolis River Project.

B. CHEMICAL AND BIOLOGICAL INTERACTIONS

RECENT HEAVY METAL MEASUREMENTS IN THE BAY OF FUNDY

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Understanding the marine ecosystem health of the Bay of Fundy is an important issue for environmental scientists, environmental managers and the general public. Chemical pollution is one the ways that human activity can put stress on an ecosystem resulting in degradation of ecosystem health. In this paper we will describe the results of surveys of metal concentrations in water (dissolved and particulate phases) and sediments conducted in 2002 and compare the results of these surveys with those of earlier ones. Ecosystem health is really about the health of the biological community. The results presented here will describe the potential exposure of biota to heavy metal contamination.

Heavy metal concentrations in outer Bay of Fundy sediment samples collected on our 2002 cruise on *CCGS Hart* were measured using inductively coupled plasma mass spectrometry (ICP-MS). This technique gives results for a much broader range of potential contaminants than has traditionally been available from atomic absorption techniques. Average concentrations from this survey and a companion survey conducted by Maxine Westhead in the Minas Basin (using the same analytical techniques) are listed in Table 1 along with some data from the literature.

It is difficult to identify anything other than the most extreme features such as the high levels of zinc (Zn) under salmon aquaculture sites from tables of averages because differences in grain size and sediment mineralogy have such a large effect on metal concentrations. This natural variability can be accounted for using geochemical normalization techniques. Examples of lithium (Li) normalized contaminant concentrations will be presented. They show essentially background concentrations of all these priority contaminants in the 2002 surveys, except for one high Zn result off the mouth of Passamaquoddy Bay and several high copper (Cu) results in Minas Basin.

Particulate metal concentrations were also measured on the *CCGS Hart* cruise. The results are shown in Table 2. This table shows the range of analytes amenable to ICP-MS analysis.

Metal vs. Li plots for most of these particulate metals show that the particulate metal concentrations generally reflect resuspension of local marine sediments. Cadmium (Cd) is an exception, with particulate Cd concentrations far in excess of sediment Cd concentrations, reflecting the association of Cd with marine organic matter as shown by the similarity of the particulate Cd:P (phosphorus) ratio with the Cd ‘Redfield ratio’.

Table 3 shows dissolved metal results from the Hart cruise as average concentrations from the surface and deep waters of the Minas Basin and the Inner Bay. Only surface samples were collected in

Saint John Harbour and the Outer Bay. As expected, the concentrations of most metals decrease with increasing salinity, but different metal salinity relationships are seen for the progression from Minas Basin to the Inner Bay and Saint John Harbour to the Outer Bay. Cu is higher in the Minas Basin source, iron (Fe) and manganese (Mn) in the Saint John Harbour source. Lead (Pb) and Zn show an unexpected feature of high concentrations on the New Brunswick side of the Inner Bay. We did not collect any samples in Chignecto Bay so we cannot comment on the potential sources of this signal.

The slope of the Minas Basin Cu vs. salinity regression line is higher than expected for uncontaminated coastal waters, suggesting high concentrations of Cu in Minas Basin rivers, but our measurements of Cu in these rivers does not confirm this. Nevertheless, the observation is interesting in the context of the observations of high Cu concentrations in lobster from this area.

Contaminant data are most useful as indicators of marine environmental quality (MEQ) if the concentrations can be related to thresholds that could be used for managerial action. For metals in sediments, two types of thresholds come to mind, those that identify locations where concentrations exceed natural background concentrations, and a second type that identifies locations where concentrations exceed a toxicity threshold. Here we illustrate a stop-light approach to MEQ assessment using sediment metal concentrations as MEQ indicators. In this approach, our yellow light (early warning) indicator is based on background concentrations as estimated by geochemical normalization and our red light on toxicity as indicated by the Canadian Council of Ministers of the Environment's Probable Effects Level Guideline. A similar approach to that for dissolved metals, using background concentrations and water quality guidelines for protection of aquatic life is also described.

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Table 1. Priority contaminant concentrations (means, mg/kg) in the Bay of Fundy

	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Lower Bay of Fundy	10.1	0.08	58.9	17.4	20.0	0.019	28.6	83.4
Minas Basin	8.0	0.06	45.8	16.1	14.3	0.015	23.7	62.6
Lower Bay of Fundy [a]	2.8	0.21	59	15	21	0.038	15	53
Inner Saint John Harbour[b]		0.16		15.9	24.3	0.05	16.3	53.3
Outer Saint John Harbour[c]		0.08		15.1	21.9	0.03		69.2
Saint John Harbour dumpsite[d]		0.06		11.5	18.5	0.03	15.1	44.2
Annapolis Basin[e]	4.26	0.04	76.4	11.8	16.3	0.02	17.1	39.3
St. Croix Estuary[f]	15.3	0.07	56.2	13.7	26.8		27.5	75.4
Passamaquoddy Bay[g]	11.2	0.08	76.2	16.1	24.3	0.019	41.0	95.1
Letang Estuary[h]	10.3	0.16	70.4	20.3	25.1	0.073	37.4	95.0
Maces Bay[i]	6.8	0.08	35.5	13.7	16.9	0.014	17.7	60.6
Musquash Marsh[j]				15.4		0.014		49.1
Cobequid Bay[k]		0.03		17.0				48.9
Minas Basin[k]		0.03		9.3				35.1
Minas Channel[k]		0.02		16.2				46.1
Shepody Bay[k]		0.03		15.0				58.6
Cumberland Basin[k]		0.03		16.8				65.5
Saint John Harbour dumpsite[k]		0.11		19.2				69.4
SW NB aquaculture sites[l]		0.40		29.7	27.5	0.033		137
SW NB aquaculture sites[m]		0.35		31.5	26.7			163
SW NB aquaculture sites[n]	6.67	0.44	122	34.9	22.8	0.012	40.4	138

a. n=72 (Loring 1979); b. n=78 (Ray and MacKnight 1984); c. n=61 (Ray and MacKnight 1984); d. n=6 (Ray and MacKnight 1984); e. n=21 (Loring et al. 1996); f. n=12 (Loring et al. 1998); g. n=13 (BIO database); h. n=45 (BIO database); i. n=51 (BIO database); j. n=14 (Chou et al. 2004); k. n=6to10 (Chou et al. 2004); l. n= 12 (Burridge et al. 1999); m. n=40 (Parker and Aube 2002); n. n=12 (BIO database).

Table 2. Particulate metal concentrations (mg/kg except as indicated) in the Bay of Fundy

	Minas Basin		Inner Bay		Saint John Harbour		Outer Bay		Letang Inlet*	
	avg	s.d.	avg	s.d.	avg	s.d.	avg	s.d.	avg	s.d.
Al (%)	7.22	0.86	6.51	1.14	6.58	0.75	4.31	1.74	4.71	0.94
Sb	0.67	0.17	0.57	0.08	0.56	0.12	0.24	0.19	0.53	0.16
As	13.6	1.2	13.7	1.7	15.9	1.6	11.2	3.0	14.6	1.98
Ba	429	40	383	50	374	32	254	90	314	68
Be	2.6	0.2	2.3	0.4	2.5	0.3	1.5	0.7	1.91	0.31
Cd	1.07	0.33	1.66	1.37	1.11	0.53	2.29	0.80	1.06	0.50
Ca (%)	0.58	0.15	0.54	0.17	0.64	0.17	0.52	0.09	0.55	0.19
Cr	51	19	77	35	95	34	69	35	61	14
Co	19	1	18	2	17	2	12	4	13	2
Cu	25	2	23	4	29	5	20	4	40	26
Fe (%)	4.63	0.37	4.39	0.43	4.67	0.50	2.88	1.16	3.62	0.50
Pb	29	4	29	6	31	5	25	7	38	8
Li	69	5	60	9	62	8	42	15	46	7
Mg (%)	1.11	0.25	1.16	0.27	1.27	0.08	0.95	0.28	0.94	0.22
Mn	1248	140	1176	238	1423	128	1293	521	827	94
Mo	0.81	0.12	1.76	1.57	0.99	0.31	5.83	2.83	2.43	0.93
Ni	42	5	39	4	42	4	31	9	39	27
P (%)	0.12	0.02	0.15	0.04	0.18	0.03	0.32	0.11	0.26	0.05
Rb	115	11	107	12	108	13	72	27	85.9	10.7
Ag	0.28	0.04	0.30	0.07	0.36	0.09	0.30	0.12	0.21	0.11
Na (%)	1.56	0.94	1.79	0.68	1.61	0.61	1.89	1.12	2.15	1.71
Sr	113	18	107	23	112	18	124	21	127	37
Tl	0.71	0.07	0.68	0.07	0.67	0.03	0.56	0.09	0.57	0.10
Sn	4.4	0.8	5.5	2.0	4.9	1.2	4.5	1.4	5.6	5.5
Ti (%)	0.21	0.03	0.20	0.03	0.20	0.03	0.12	0.01	0.16	0.04
U	2.06	0.17	2.03	0.29	1.99	0.35	1.48	0.47	1.77	0.23
V	103	8	115	31	115	13	88	42	91	13
Zn	119	9	122	24	133	14	104	33	137	40

* Letang Inlet data from Yeats et al. (2005), n=42.

Table 3. Dissolved metal concentrations

		SPM mg/l	Sal	Cd µg/l	Cu µg/l	Fe µg/l	Pb µg/l	Mn µg/l	Ni µg/l	Zn µg/l
Minas Basin (s)	avg	2.59	31.11	0.027	0.37	0.30	0.010	0.23	0.27	0.41
(n=7)	s.d.	1.99	1.18	0.003	0.11	0.11	0.005	0.06	0.03	0.14
Minas Basin (d)	avg	2.60	31.14	0.025	0.33	0.24	0.009	0.23	0.25	0.18
(n=7)	s.d.	2.20	1.19	0.004	0.10	0.03	0.005	0.06	0.02	0.09
Inner Bay (s)	avg	1.18	32.38	0.025	0.23	0.28	0.019	0.25	0.24	0.57
(n=7)	s.d.	0.45	0.21	0.008	0.05	0.11	0.016	0.12	0.02	0.45
Inner Bay (d)	avg	1.27	32.41	0.026	0.23	0.32	0.017	0.24	0.25	0.35
(n=7)	s.d.	0.56	0.23	0.004	0.04	0.09	0.009	0.09	0.02	0.17
Saint John Harbour	avg	1.75	28.97	0.024	0.29	1.63	0.014	4.82	0.27	0.30
(n=3)	s.d.	0.21	1.34	0.003	0.02	0.56	0.001	1.36	0.01	0.16
Outer Bay (s)	avg	0.84	32.64	0.024	0.19	0.31	0.015	0.45	0.24	0.26
(n=9)	s.d.	0.26	0.14	0.004	0.04	0.10	0.005	0.18	0.01	0.12

THE ROLES OF *Corophium volutator* AND MERCURY IN COMPROMISING SHOREBIRD MIGRATION

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Each summer, the Bay of Fundy serves as a staging area for many species of shorebirds which, in two weeks or less, must acquire sufficient fat stores to power a non-stop flight of more than 4,000 km to their wintering grounds in South America (McNeil and Cadieux 1972; Hicklin 1987). During their stay, the birds risk varying degrees of exposure to parasites and heavy metals such as mercury. For example, female Semipalmated Sandpipers, *Calidris pusilla*, are the first to arrive on the staging grounds (McNeil and Cadieux 1972; Morrison 1984; Gratto-Trevor 1992) and should, hypothetically, be exposed to fewer parasites than adult males and juvenile birds that arrive later (Didyk 1999).

We know that parasites cause stress in their hosts, more or less proportional to the level of infection, compromising host condition through tissue damage, loss of nutrients and even behavioural changes. Because parasite loads are higher on the staging grounds in the Bay of Fundy than at any other time of the birds' annual cycle (Didyk and Burt, in prep.), parasitism-related stress is likely going to be highest during fall migration.

In considering the possible effects that heavy parasite loads combined with contamination with heavy metals might have on migrating shorebirds, we first turned to a study of a wild population of Atlantic salmon, *Salmo salar*, carried out by a graduate student at the University of New Brunswick in the mid-1990s. Sprague (1964) and Lemly (1994) had already shown that heavy metals such as copper and zinc were acutely toxic to fish at high concentrations and could cause chronic stress in fish even at much lower concentrations, and O'Neill (1981) showed that to be especially true in Atlantic salmon. Luce (1996) hypothesized that parasitized Atlantic salmon were more susceptible to the toxic effects of heavy metals. To that end, she collected and examined salmon parr from four sites in the Miramichi River system. Three of the four sites were downstream from a known source of heavy metal pollutants at a mining operation. Data from Environment Canada (unpubl. data) and MREAC (1992) served to establish contamination levels at each of the sites.

Parasites tend not to be randomly distributed, but instead are typically aggregated. That is, the greater proportion of hosts have relatively few parasites, and large numbers of parasites are expected in only a small number of hosts. The distribution of parasites in salmon parr collected from the uncontaminated site upstream from a mining operation tended to follow the negative binomial pattern expected of an aggregated distribution. At the three contaminated sites, however, the fish had, on average, fewer species and fewer numbers of parasites, and the parasites present tended to be somewhat more evenly distributed. Even though levels of copper and zinc at these sites were below toxic levels, the truncated pattern of parasite distribution suggested that, in contaminated waters, heavily parasitized fish suffer higher mortality (Luce 1996).

Reports produced by Environment Canada (2000) and US Environmental Protection Agency (1996, 1997) indicate substantial levels of mercury are present in the Bay of Fundy. Natural sources contribute an estimated 1,600–4,000 metric tons of mercury into the atmosphere annually in metallic, organic and non-organic forms. The primary source of mercury, however, is long-range, transboundary air pollution, which comes down in the forms of acid rain and snow. This and other human activities add another 2,000 to 6,000 metric tons annually. In water, mercury is methylated by sulphur-reducing bacteria and released into the food chain where it can accumulate in the tissues of animals feeding in the habitat. Bioaccumulation occurs when contaminants such as mercury are taken up more rapidly than they can be eliminated by the animal.

In the Bay of Fundy, shorebirds feed on a variety of prey items, but several species, including the Semipalmated Sandpiper, feed primarily on a burrowing amphipod, *Corophium volutator*, which has been implicated in the life cycles of various microphallids (Meissner and Bick 1999; Jensen et al. 1998; McCurdy 1999; Meissner 2001), nematodes (McCurdy et al. 1999) and cestodes (Didyk, in prep.), that together make up more than 90 percent of the parasite communities we find in the birds (Didyk and Burt, in prep.). On the mudflats, mercury readily adsorbs to diatoms and detritus consumed by *Corophium* and accumulates in the amphipods. Could *Corophium,* then, also be an important source of mercury contamination in shorebirds?

Hicklin and Smith (1979) identified several shorebird species that were dependent on *Corophium* during their staging period in the Bay of Fundy. The relative percentages of *Corophium* in the diets of four of these species are shown in Table 1 below.

Based on an average *Corophium* mercury level of 31.15 ppb, dry weight—determined from samples we collected and analyzed over the last two years using cold vapour atomic absorption spectrometry (CVAAS)—and a conservative estimate of 75,000 *Corophium* consumed over a 10–12 day period (Hicklin, pers. comm.), a Semipalmated Sandpiper, would accumulate 2.3 ppm mercury (Hg) during its stay in the Bay of Fundy (Bourgeois 2004). Predicted values of mercury accumulation for the three other species are predicated on this example. Actual levels of mercury accumulation are available for three of the four species. These are probably understated, however, because the birds analyzed may have only been on the staging grounds for part of the entire staging period of 10–12 days before being collected.

Toxicological studies carried by the Canadian Wildlife Service suggest that mercury levels fluctuate throughout the year (see Figure 1). Mercury levels in liver samples from Semipalmated Sandpipers (n = 10) collected on the breeding grounds at Churchill, Manitoba, and Quill Lake, Saskatchewan, averaged 1.30 ppm Hg (range 1.23–1.37). If, as predicted, birds accumulate an additional 2.30 ppm mercury during their stay in the Bay of Fundy, their mercury levels upon arriving on the wintering grounds could be as high as 3.6 ppm. Data from birds collected shortly after arrival on the wintering grounds varied: juvenile birds showed Hg levels as high as 2.98 ppm, while adult Hg levels were 0.98 ppm (n = 7).

Unlike inorganic mercury, which may be excreted via feces and urine in birds, methylated mercury—the more toxic organic form—is removed from the bloodstream and stored in feathers (Bearhop et al. 2000; Veerle et al. 2004). Mercury levels may be lower in adults arriving on the wintering grounds because they initiate a partial body molt (head, back and breast) during incubation, while juveniles do not begin their first (pre-basic) molt until after they arrive on the wintering grounds. Mercury levels declined to below 0.5 ppm over the winter months as the birds undergo a complete flight feather molt and two body feather molts (Spaans 1984) before starting to increase again in the spring. The availability of heavy metal contaminants such as mercury in horseshoe crab eggs, consumed by migrating shorebirds, was reported by Maghini (1996).

A number of studies indicate that parasite loads are higher in juvenile birds than in adults. Juveniles may also suffer more from mercury related stress than adult birds because they retain more mercury for longer periods of time, including fall migration. In combination, these stressors may interfere with fat deposition, possibly providing an explanation as to why juvenile birds cannot fly as far non-stop as adult birds (Morrison 1984).

Mercury toxicosis affects the central nervous system, disrupting muscle co-ordination, and may also cause kidney failure, anemia, chromosome damage and lower reproductive success (Meyer et al. 1998). Since mercury levels show seasonal fluctuations, some of these effects may be more or less pronounced depending on the time of year. Because so many *Corophium* are consumed per bird—about 75,000 over 10 days—the cumulative affect of mercury and parasites could compromise the successful completion of fall migration, especially that of juvenile birds which have been shown to migrate shorter distances than adults.

There are still a few outstanding questions: Do females benefit from their early arrival in the Bay of Fundy when the prevalence of infection in *Corophium* is believed to be at its lowest? Do higher parasite loads and/or the rapid accumulation of mercury disrupt fat deposition and result in an energy deficit or do they simply extend the birds' stay on the staging grounds? And finally, at what level is mercury toxic for various shorebird species, including the Semipalmated Sandpiper.

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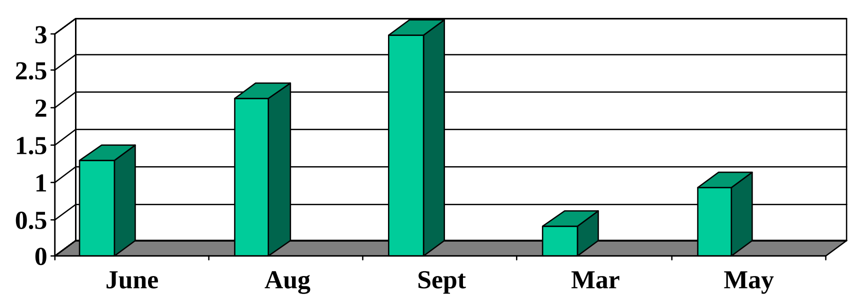
Table 1. Predicted (based on a staging period of 10-12 days) and actual mercury (Hg) levels in four species of shorebirds feeding on *Corophium volutator* in the Bay of Fundy

	% *Corophium* in diet[1]	Predicted Hg levels (ppm)	Actual Hg levels[2] (ppm)
Least Sandpiper *Calidris minutilla*	88.6	2.36	n/a
Semipalmated Sandpiper *Calidris pusilla*	86.3	2.30	2.13
Short-billed Dowitcher *Limnodromus griseus*	70.0	1.86	1.62
Semipalmated Plover *Charadrius semipalmatus*	47.0	1.25	1.08

[1] Hicklin and Smith 1979
[2] Canadian Wildlife Service

Figure 1. Mercury (Hg) levels in Semipalmated Sandpipers, *Calidris pusilla*, collected at various times of the year. Source: Canadian Wildlife Service.



SPATIAL VARIABILITY OF HEAVY METALS IN SALT MARSH SEDIMENTS OF THE BAY OF FUNDY

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Introduction

Spatial variability of heavy metals in surface inter-tidal sediments has been used to infer source and extent of anthropogenic pollution in estuarine systems (e.g., Attrill and Thomes 1995; Emmerson et al. 1997; Spencer 2002). Salt marshes receive inputs of metals through two principal pathways: atmospheric deposition and sedimentation of suspended particles brought in by tidal flooding, but input may also come from catchment runoff flowing into the marsh (Nixon 1980; Windom 1975). Salt marshes have been identified as possible sinks for heavy metals because of their ability to accumulate sediment over time (Nixon 1980).

We studied levels of four heavy metals, in sediments accumulated over a five-year period from 1997 to 2002, in seven salt marshes along the New Brunswick coast of the Bay of Fundy. These study sites geographically span the whole Bay, from Bocabec Marsh near St. Andrews to Wood Point Marsh near Sackville (Figure 1), and therefore encompass a range of tidal and sediment characteristics. Tidal range, for example, is about 6 m at Bocabec and increases to about 10 m at Wood Point. Locations of these study sites were targeted to undisturbed areas and away from point sources of pollution.

Methods

Marker horizons of white clay were established in each of the seven salt marshes in June 1997 as part of a study to monitor surface sediment deposition; detailed descriptions of the sampling design are in Chmura et al. (2001). Briefly, the sampling design consisted of four transects within a marsh, each running perpendicular to the main tidal creek and spaced approximately 10 m apart. Marker plots were placed at three elevations along each transect. For the purposes of this study we consider the upper two plots, which were placed one meter to either side of the transition between *Spartina alterniflora* and *Spartina patens*, thus reflecting differences in frequency of tidal flooding. The lower plots are flooded daily while upper plots are flooded only about once per month or less and thus exposed to the atmosphere for a greater period of time.

Sediments for metal analyses were extracted from the marker plots in May 2002 using a cryogenic coring system (Cahoon et al. 1996), allowing retrieval of a frozen stratified core consisting of the deposited sediment layer, marker horizon and the soil below the marker horizon. Net sediment deposition over five years was determined by measuring the thickness of the sediment layer above the marker horizon. This five-year deposition layer was separated from the rest of the core for metal analyses, which was done by Activation Laboratories Ltd. in Ontario. Samples were subjected to an aqua regia digestion (HCl and HNO_3) and analyzed for metals using inductively coupled plasma mass spectrometry (ICP-MS). Here, we report results for lithium (Li), lead (Pb), zinc (Zn), copper (Cu) and arsenic (As). Care was taken during sample collection in the field and processing in the lab to minimize contamination. All sample vials were acid-washed and stored frozen. Acid-washed polycarbonate blades were used as tools to scrape the surface layer of frozen sediment surrounding the hole formed by the copper cryoprobe, as well as the outside of the core. Samples were freeze-dried and ground using an agate mortar and pestle.

To determine bulk density, sediment was extracted from undisturbed areas adjacent to the marker plots, using a 3.6 cm diameter mini hand piston-corer. Organic matter content was measured by loss-on-ignition (LOI) (Ball 1964). Grain size in the surface sediments of these marshes was determined (Fraser, unpublished data) by the hydrometer method outlined in Black (1965). Clay fraction was used to determine the suitability of using Li as a normalizer for grain size variability (Loring 1990) by examining correlation between percent clay and Li concentration. Correlation analyses of metals to Li and organic matter were carried out using the statistical software package SPSS. Heavy metal fluxes to the salt marsh sediments were calculated from the product of sediment deposition rates (cm yr^{-1}), dry bulk density (g cm^{-3}), and sediment metal concentrations (mg g^{-1}).

Results and Discussion

Sediment deposition rates differed among marshes. Comparison of the high elevation plots showed significantly less deposition in marshes closer to the outer Bay (Bocabec, Dipper Harbour and Lorneville) than in marshes at the head of the Bay (Wood Point). Rates ranged from 0.4 cm yr^{-1} at Bocabec to 1.7 cm yr^{-1} at Wood Point. This spatial trend is less visible at low elevations, possibly due to greater dynamic sedimentation processes.

Grain size analysis of surface sediments has shown differences in clay content between marshes (Fraser, unpublished data). For example, surface sediments from Cape Enrage had less than 10 percent clay content compared with Belliveau Village and Wood Point, where clay content was just over 35 percent. Since metals adsorb more readily to the surface of the finer-sized fraction in salt marsh sediments (Williams et al. 1994), geochemical normalization of the sediment metal data was employed to account for grain size variation. Lithium has been shown to be a good normalizing element for Bay of Fundy sediments (Loring 1990).

Results for lead and zinc were similar. The results for Pb are presented in Figure 2. The bivariate plot between Pb and Li (Figure 2a) shows a strong positive correlation ($r = 0.92$, $p < 0.001$), indicating possible grain size control on variability. Lead fluxes (Figure 2b) show a spatial trend of increasing fluxes from outer Bay (Bocabec) to inner Bay (Wood Point). This trend, however, is lost when Pb fluxes are normalized to Li fluxes (Figure 2c) and normalized fluxes at Lorneville and Dipper Harbour are greater than the other marsh sites. Zinc correlation with Li was significant and positive ($r = 0.87$,

$p < 0.001$). Normalized Zn fluxes at Lorneville were elevated slightly compared to other marsh sites (Figure 3). Lead and Zn did not significantly correlate with organic matter.

Copper showed different results from Pb and Zn. Correlation with Li was not significant (Figure 4a), which may be due to a number of samples with elevated Cu concentrations. There was no consistency among these possible outliers—they were from different sites and different elevations. Figure 4b shows the correlation excluding these samples; the relationship is significant and positive with Li ($r = 0.430$, $p < 0.05$). We are unsure if these results are an artifact of contamination from the copper cryoprobe used in sample extraction, despite our efforts to minimize contamination. Copper did not significantly correlate with organic matter.

Arsenic also had a significant positive relationship with Li ($r = 0.36$, $p < 0.05$), though less strong than Pb or Zn and a bivariate plot showed a clustering of samples from Bocabec and Dipper Harbour with greater sediment As concentrations (Figure 5a). Arsenic may also be strongly associated with the organic fraction in sediments and correlation analysis between As and percent LOI was significant and positive ($r = 0.78$, $p < 0.001$) and results of As fluxes normalized to organic carbon did not reveal any geographical trend (Figure 5b and 5c). Arsenic can be diagenetically mobile in sediments and this may be a reason why no geographical trend is found.

Normalized Pb fluxes were found to exponentially decrease with increased distance from Saint John, which has the greatest concentration of population and industry in the Bay of Fundy (Figure 6). The Coleson Cove coal-burning power generation plant, located between Lorneville and Dipper Harbour, is a probable point source of Pb to these marshes. We will be continuing our analyses on the other metals to see if they follow a similar spatial trend with distance from Saint John.

Measured metal concentrations in these salt marsh sediments from the Bay of Fundy are generally close to the natural levels that have been measured in Bay of Fundy sediments by Loring (1982). Although the Bay of Fundy may be considered relatively pristine with respect to metal contamination in these seven salt marshes, the result of normalized Pb fluxes shows that the influence of a regional source can still be detected in these sediments.

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Figure 1. Map showing locations of the seven salt marshes sampled in the Bay of Fundy, denoted by number: 1. Wood Point, 2. Belliveau Village, 3. Cape Enrage, 4. St. Martins, 5. Lorneville, 6. Dipper Harbour, 7. Bocabec (Figure from Chmura et al. 2001)

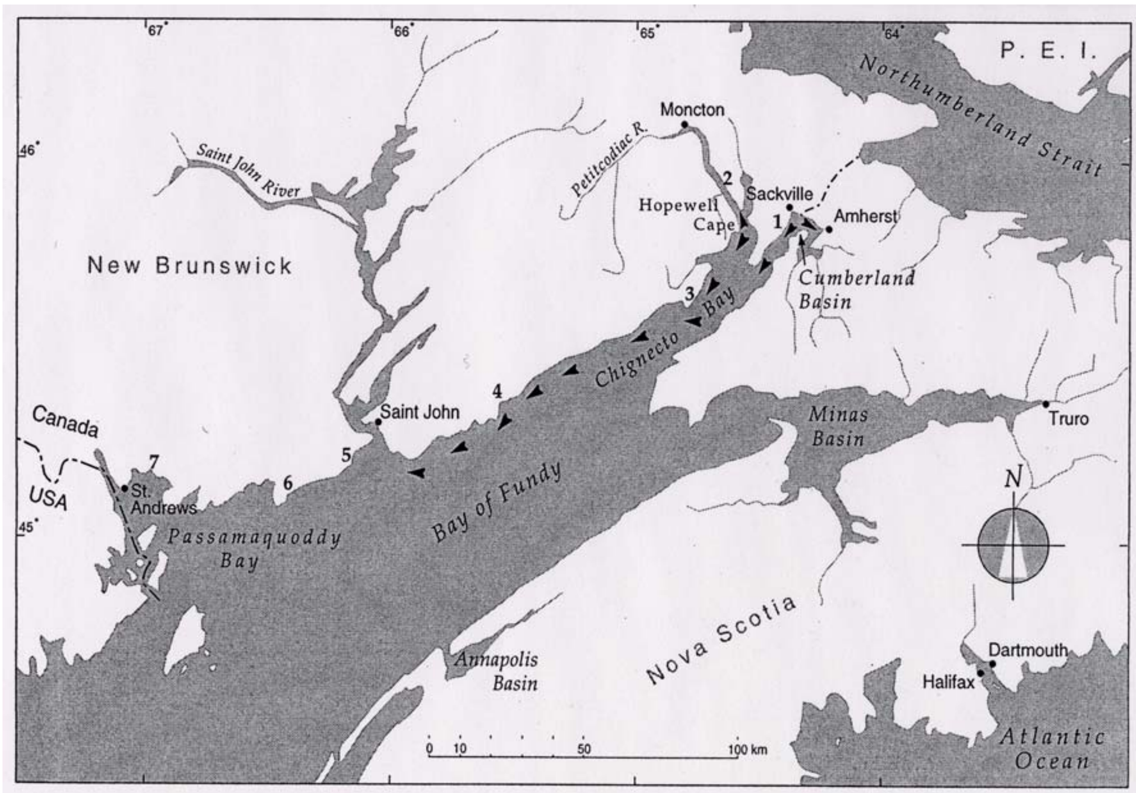
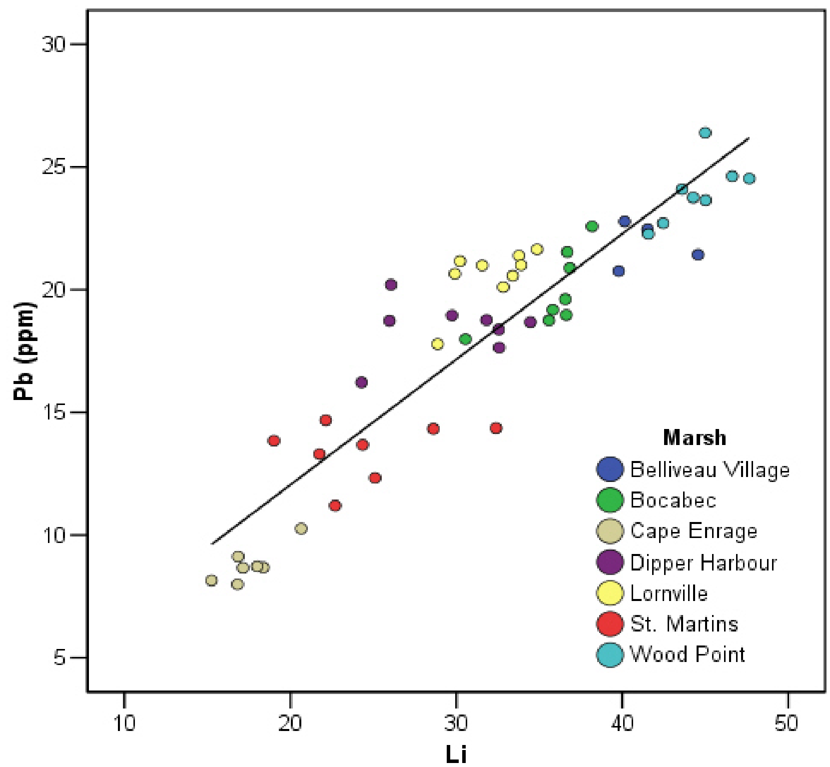
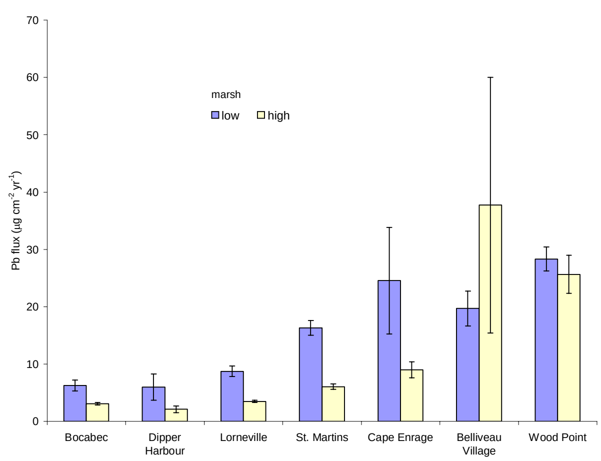


Figure 2. Results of lead analyses: (a) bivariate plot between sediment lead and lithium concentrations, (b) sediment lead fluxes by elevation for each marsh (Error bars represent ± one standard error) and (c) normalized lead fluxes by elevation for each marsh (Error bars represent ± one standard error)

(a)



(b)



(c)

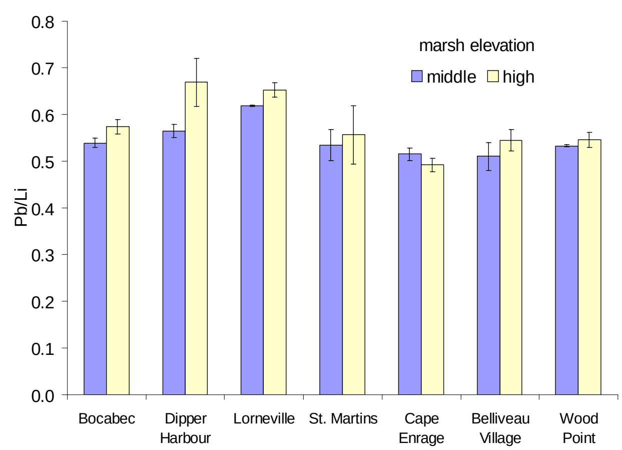


Figure 3. Normalized zinc fluxes by elevation for each marsh. Error bars represent ± one standard error

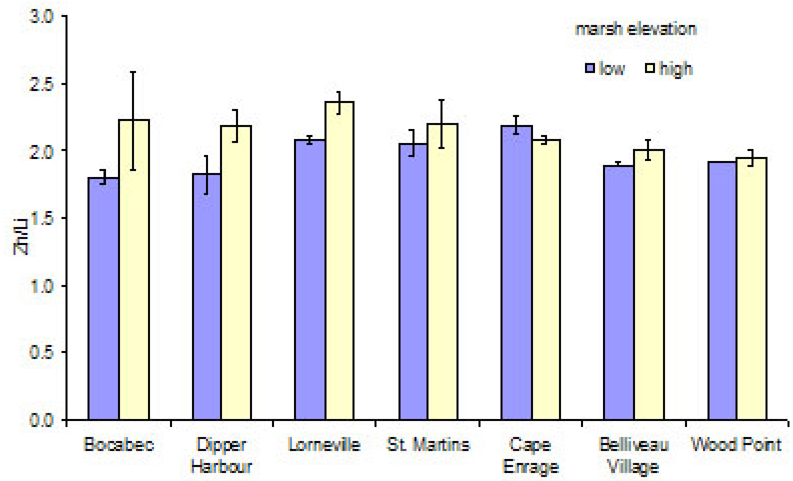


Figure 4. Bivariate plots of sediment copper concentrations and lithium: (a) including all data and (b) excluding the possible outliers

(a) (b)

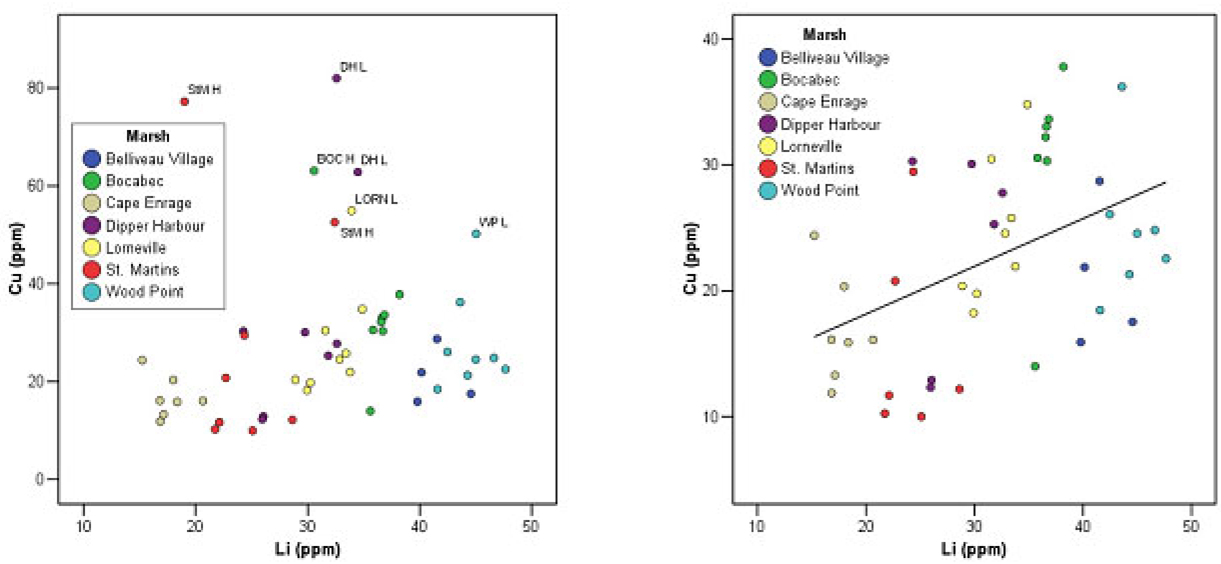


Figure 5. Results for sediment arsenic analyses: (a) bivariate plot of arsenic and lithium, data points from Bocabec marsh are circled, (b) bivariate plot of arsenic and percent LOI and (c) normalized arsenic fluxes to organic carbon

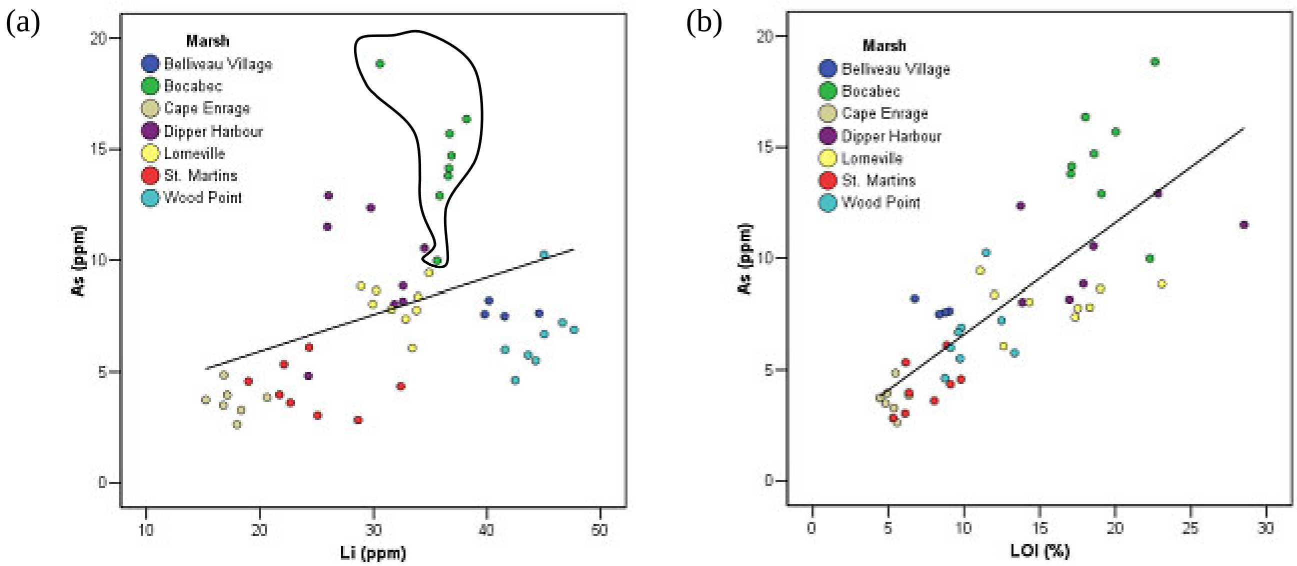
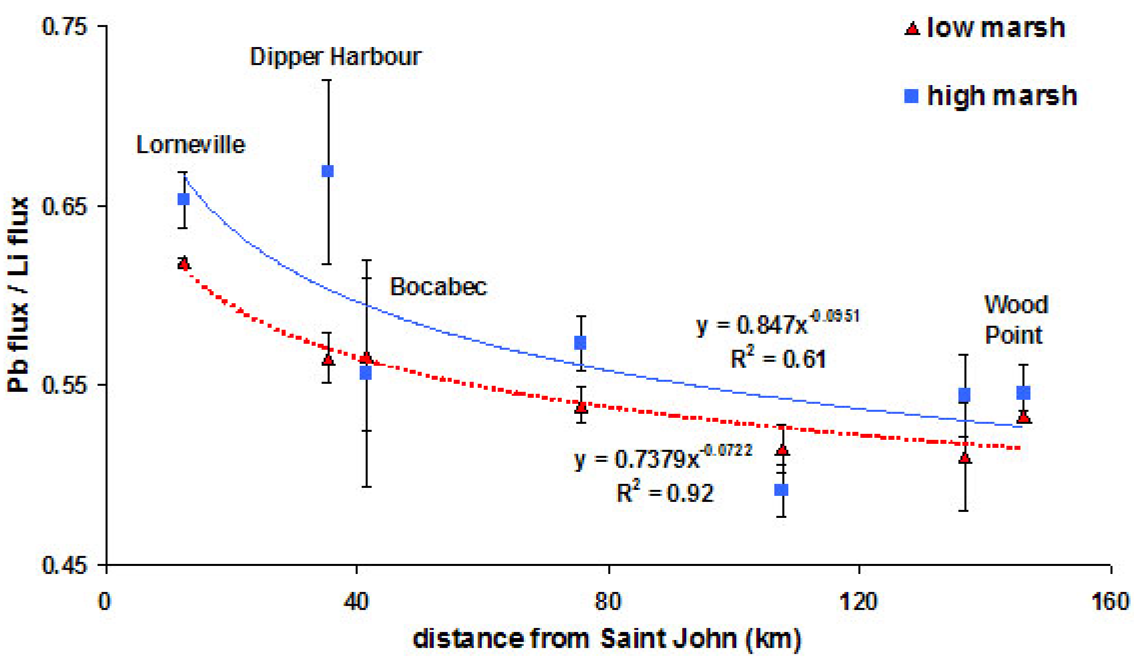


Figure 6. A graph of normalized lead fluxes versus distance from Saint John for each elevation (Error bars represent ± one standard error)



PREVALENCE AND BIOACCUMULATION OF METHYL MERCURY IN THE FOOD WEB OF THE BAY OF FUNDY, GULF OF MAINE

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Mercury enters the east coast marine environment from many sources, most notably from long-range atmospheric transport, land runoff or river discharge, oceanic currents and migrating organisms. As a priority toxic substance, mercury, especially its methylated form, is of concern due to its persistence, high toxicity, known bioaccumulation and biomagnification, and suspected effects on the genetic, developmental and reproduction of aquatic organisms. Despite infamous pollution events of previous decades, such as occurred in Minimata Bay, Japan, where people were poisoned by mercury in shellfish, little is known comprehensively about the fate and effects of mercury in coastal marine ecosystems.

There is evidence in the Maritimes that the Common Loon (*Gavia immer*), which spends its juvenile life in coastal marine waters and subsequently overwinters there as adults, has body mercury burdens well above inland populations. More recently, a joint United States-Canada, Gulf of Maine-Bay of Fundy Mussel Watch Program has reported that greater than 80 percent of the 56 study sites had mercury levels exceeding the US National Status and Trends median values (Chase et al. 2001).

In the present study, total mercury and methyl mercury were measured in the Bay of Fundy and approaches in the following environmental and ecosystem compartments: a) river water (ten of the larger rivers studied at the spring freshet and late summer drought periods); b) seawater of inflowing and outflowing currents (six stations sampled across the mouth of the Bay of Fundy, each at five depths during the spring and fall); c) sediments sampled at various deposition areas in the Bay; d) planktonic organisms collected in nets and fractionated into seven logarithmic size categories from phytoplankton and flagellates (25 to 65um) to macrozooplankton (2 to 4 mm) during spring and summer seasons; e) pelagic organisms collected by a Vass-Tucker trawl and similarly size fractionated from ichthyoplankton and crustaceans (4 to 8 mm) to small fish and shrimp (16 to 32 mm); f) macrophytes such as rockweed and kelp; g) benthic macrofauna such as mussels, lobsters, flatfish, and demersal fish such as cod and haddock; h) pelagic fishes such as herring, mackerel and tuna; and i) marine mammals as the opportunity arose from by-catch of gillnets or shipping accidents.

Our results support the hypothesis that methyl mercury is bioaccumulated in the pelagic food chain. Methyl mercury levels consistently increase from phytoplankton (25 µm; 0.05 ± 0.03 ng/gWet) to zooplankton (500µm; 0.51 ± 0.04 ng/gWet) to macrozooplankton (2.0 mm; 1.9 ± 0.11 ng/gWet) to krill (8.0 mm; 5.7 ± 0.76 ng/gWet) to pelagic fish (herring, 40.2 ± 25.2 ng/gWet) to large pelagic fish (bluefin tuna, 712 ± 140 ng/gWet). This represents a biomagnification of 10^4 from phytoplankton to tuna, or a bioconcentration of 10^7 from unfiltered seawater to tuna.

Atmospheric (0.1 kg/yr) and riverine (185.3 kg/yr) input of methyl mercury into the Bay of Fundy represents approximately 0.003 percent and 6.8 percent, respectively of the total aquatic contribution (oceanic seawater; 2,502 kg/yr). Most of this oceanic input would be flushed out because half of oceanic influx is tidal and exchanged twice a day. It is calculated that 6 kg/year total mercury are deposited within the deep sedimentation basin in the lower Bay off northeastern Grand Manan and 17 kg/year are flushed into the Gulf of Maine with fine particulates. Planktonic organisms represent an additional flux into and out of the Bay of Fundy of 22.1 kg/yr.

This study provides valuable insights into mercury bioaccumulation in a regional coastal ecosystem and provides an assessment of the contribution of the anthropomorphic addition of mercury to a relatively unpolluted east coast bay.

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AN ECOSYSTEM-SCALE MODEL OF MERCURY DYNAMICS IN PASSAMAQUODDY BAY

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High levels of mercury in predatory fish, marine mammals and seabirds are a potential threat to both human and ecological health in the Bay of Fundy. An ecosystem-scale model of mercury dynamics in Passamaquoddy Bay is used to illustrate the linkages that are needed to quantify the risks associated with mercury in the Bay of Fundy, including emissions of mercury from human sources, deposition in coastal marine ecosystems, aquatic cycling and accumulation in organisms. This model illustrates that the slow conversion of "legacy" mercury in depositional sediments of Passamaquoddy Bay to methyl mercury likely slows the temporal response of mercury concentrations in organisms to changes in mercury inputs. However, the quantitative relationship between emissions of mercury, accumulation in fish (the principle avenue of human exposure), and the associated risks to human and ecological health are still subject to considerable scientific uncertainty. A methodology for assessing the risks posed by mercury accumulation in the Bay of Fundy that takes into account some of these uncertainties will be presented using the quantitative framework from the mercury cycling model developed for Passamaquoddy Bay. Alternative risk-management strategies are discussed in the context of information highlighted in the risk assessment, including regulation and phase out of different mercury sources and effective communication of risk through fish consumption advisories.

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CONTAMINANT CONCENTRATIONS AND BIOMARKER CHANGES IN WILD MUSSELS NEAR FINFISH AQUACULTURE FACILITIES AND MUNICIPAL/ INDUSTRIAL ACTIVITIES IN THE LOWER BAY OF FUNDY

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Finfish aquaculture is an expanding industry in the Atlantic Region and a wide variety of chemicals are known to be used (Muise et al. 2000). However, the risk of environmental effects from their use is still unknown. In order to investigate the potential impact of anthropogenic chemical releases, Environment Canada undertook a study involving wild blue mussels in co-operation with two Atlantic Coastal Action Plan (ACAP) groups: the St. Croix Estuary Project (SCEP) and the Clean Annapolis River Project (CARP).

This study attempted to measure contaminant levels, endocrine disrupting potential and mussel leukemia in environmental samples collected near a variety of anthropogenic contaminant sources. Wild blue mussels and sediments were collected from aquaculture areas, municipal wastewater sites, near industrial sites (pulp mill, fish processing plant), and less impacted areas. Field sites were located along the Annapolis Basin in Nova Scotia and in and adjacent to Passamaquoddy Bay in New Brunswick, within the respective locales of the two ACAP groups.

A minimum of 100 mussels (5–6 cm shell length) were collected at each of the three sampling sites for each effluent type tested. At each effluent output, efforts were made to establish a distance gradient of 1,000 m, by collecting mussels at the point source, or 0 m, and 500 m and 1,000 m from the identifiable point of discharge. For the aquaculture sites, 0 m was situated as close as possible to the cages. Length, width and height (mm) of all mussels were measured with Vernier callipers to characterize the size variation in the sample population.

At each sampling site, 20 mussels were randomly chosen and processed for each of the following assays: metal analysis, organic analysis, and reproductive biomarkers (i.e. extractable gonadal proteins, vitellogenin-like proteins in female mussels, gametogenesis activity [aspartate transcarbamoylase activity], coprostanol and cholesterol levels). In addition, 30 mussels were separated at the site, kept submerged in ice-cooled water taken from each site, transported to the laboratory facilities and immediately assessed for leukemia. All mussels were cleaned of external sediment and external growth (algae, other organisms, byssal threads, etc.). At each of the sampling sites for each effluent type tested, sediments were collected with Teflon core tubes and stored frozen until time of the Yeast Estrogen Screen (YES) assay.

Several effect variables were measured throughout the course of this study, including condition index, leukemia and reproductive biomarkers (vitellogenin-like proteins, gametogenesis, coprostanol and cholesterol). Leukemia values at sewage treatment and aquaculture sites in Nova Scotia were significantly elevated above the less impacted sites at each of the activity sites in New Brunswick. Cell counts high enough to be indicative of stress were found in New Brunswick at the aquaculture sites, the sewage treatment plant and the fish processing plant. The highest numbers of individuals with leukemia were found in New Brunswick at the aquaculture sites, the sewage treatment plant, and the pulp mill, and the latter treatment sites were correlated with elevated levels of organic contaminants. Condition indices were highest at the aquaculture sites and were also significantly above the less impacted sites at the sewage treatment plants, ferry, and fish plant. The reproductive biomarkers showed great variability. Vitellin levels were significantly elevated at the New Brunswick sewage treatment plant, and significantly lowered at the remaining treatment sites.

Gametogenesis was also significantly elevated at the New Brunswick sewage treatment plant and variable at the remaining treatment sites. Coprostanol and cholesterol also had variable responses. Both measures were elevated in many cases (including the New Brunswick sewage treatment plant), but not at all of the distances sampled for each of the treatment sites. Overall, there were significant differences between the less impacted sites and the treatment sites for all the reproductive biomarkers measured.

When examining the extent of metal and organic contamination reported in this study, it can be seen that in a few cases the tissue concentrations were below available Critical Body Residues (the threshold concentration at which adverse effects may occur) reported in the primary literature. In the case of copper (Cu), values were two orders of magnitude lower than those previously reported. Thus, it is not surprising that not all response variables examined (condition index, leukemia and reproductive biomarkers) correlated significantly with the metal and organic contaminants analyzed.

There is the potential that other contaminants not analyzed or other chemical parameters (i.e. pH, temperature, dissolved oxygen, etc.), alone or in combination, may be responsible for the elevated adverse effects identified in these samples. Since mussels are an ideal indicator species, further biomarker investigations may be important in determining the environmental quality in specific locations throughout the Bay of Fundy. Further research is necessary, including the analysis of other parameters, in order to better understand the potential cause(s) of the adverse effects identified at the aquaculture sites, sewage treatment plant, fish processing plant, and pulp mill in New Brunswick.

The cumulative evidence indicates that there are physiological effects on mussels that can be attributed to proximity to industrial activities, most notably ferry terminals and fish plants, but also sewage treatment plants and aquaculture sites. There did not seem to be strong evidence of endocrine effects, however, reproductive impairment may be occurring. Although there were elevated concentrations of contaminants, there was no correlation with contaminant concentration and any biological responses.

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CONTAMINANT PARTITIONING AND UPTAKE FOR RISK ASSESSMENT OF TOXICITY WITH *COROPHIUM VOLUTATOR*

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Population expansion in coastal environments leads to the increased discharge of contaminants from raw or treated sewage effluents. These effluents are in some cases combined with road runoff, or the latter can flow directly into waterways according to weather conditions. Chemical contaminants entering with effluents can originate from many sources. For example they can be due to the use of synthetic products, such as pesticides that are sprayed to protect crops; they can also be associated with daily activities, such as the production of PAHs from combustion sources; or they come from the degradation of natural products in digestive systems, such as with the fecal marker coprostanol, derived from cholesterol.

The presence of contaminants in the environment can lead to a variety of biological effects at a population, community or ecosystem level, when it might be too late to reverse the situation. It is generally believed that the detection of toxic effects at a lower level of biological organization, i.e. cellular, tissue or organ, can ultimately prevent the detection of effects at higher levels of organization (Hinton 1994).

One approach to assess the level of environmental contamination is to use sediment quality criteria that represent broad guidelines to classify sediments according to the concentration of priority contaminants (CCME 1999; Chapman et al. 1987). Their limitation is due to the unknown fraction of measured contaminants actually available for uptake and to the presence of more than one chemical or group of contaminants. Amphipods can be used to assess bioavailability, by examining the bioaccumulation of contaminants. It is now accepted that bioavailability will be closely linked to biological effects, if these are due to toxic chemicals, and explains the increasing interest in determining body burdens to assess ecosystem health. Elucidating conditions associated with higher and lower bioavailability helps to interpret environmental risk.

Over the past several years, our group examined the levels, sources and distribution of many polycyclic aromatic hydrocarbons (PAHs) present in Halifax Harbour sediments (Hellou et al. 2000, 2002, 2003a and b, 2004). Earlier studies by Tay et al. (1992) and Cook and Wells (1996) investigated the toxicity of these sediments from different perspectives. Partitioning of these chemicals between water and sediments, relative to uptake by mussels was investigated in the context of predicting changes to be anticipated with the construction of sewage treatment plants. Different aspects of mussels' health, including lipid content and condition indices, were determined for animals collected in the first stage of the study that covered a wide geographical area. These biological effects were determined concomitantly with the chemical investigations. As well, gonad index, sex ratio, vitellogenin, along with other chemicals such as PCBs, alkanes, hopanes, coprostanol and metals were analyzed in some mussels from three sites examined in a following study, or in sediments, to gain a better view of the state of this environment dominated by variable anthropogenic input (Hellou et al. 2002, 2003b).

Since mussels are collected from the shore, they reflect the intertidal conditions of the habitat. Therefore, to determine the risk faced by benthic invertebrates that could be exposed to harbour sediments, laboratory experiments involving *Corophium volutator* were undertaken. The distribution of these amphipods is sensitive to the effects of pollution and this motivated our studies (Esselink et al. 1989). Once again, our interests covered chemical and biological measurements, with PAHs representing our primary targets, while the avoidance/preference response provided a good venue to follow up on a potential association between exposure and effects. The use of the behavioural response to assess contamination has been discussed recently by Weis et al. (2001) and has been used to examine vertical movement, i.e. burrowing in *Corophium volutator.*

For the biological response, the parameters tested included density of the amphipods, length of the experiment, size of the tanks, depth of the sediments, amount of water, percentage of sand, percentage of seaweed, burned wood, coal, used crankcase oil, diesel oil and field contaminated sediments (Hellou et al. Submitted). Spiked sediments can be described as containing a physical or chemical disturbance, where in all cases food was available, since reference sediments collected along with the amphipods were used to prepare the gradient of contaminated sediments. An additional result to the behavioural response obtained for each experiment was percent survival and this helped in interpreting results. Increasing amounts of sand did not affect the survival of the amphipods. However, amounts of ground seaweed, burned wood and coal representing more than 50 percent of the natural habitat of the animals appeared detrimental to the amphipods, i.e. leading to lower survival than observed in reference sediments (<90 percent compared to 90–100 percent in reference sediments). Ground seaweed represented the worst-case scenario (Figure 1). As well, minute amounts, i.e. <0.01 percent, of fresh diesel or crankcase oil, did not represent a good habitat for these benthic amphipods. In comparison to these sediments containing known materials added for a broad view of the amphipods' preferred habitat, amphipods exposed to harbour sediments generally survived in most experiments at levels >80 percent.

Amphipods displayed a preference for reference sediments when sand and ground seaweed represented 10 percent of the sediments and when ground-up burned wood and coal represented 30 percent of the sediments, while the two oils were not avoided by amphipods when representing a proportion of 0.001 percent to one percent of the sediments. In comparison, some sieved Halifax Harbour sediments were avoided when representing 5–40 percent of reference sediments (Figure 2), while other sites were not preferred in a consistent level correlating with exposure.

Three Halifax Harbour sites that were ranked as more impacted at S4 > S10 > S11 for mussels' health, over a period of two years were used in the amphipod study (Hellou et al. 2002). Levels observed for the sum of PAHs in sediments ranked as S11 > S4 > S10. However, site S11 had contaminants that were not as available for uptake by mussels or amphipods as PAH at sites S4 or S10. A subset of two of the 80 PAHs analyzed in these samples, i.e. phenanthrene (PA) and pyrene (PY) is presented in Figure 3. In comparison to the harbour sediments, Bay of Fundy sediments collected at Avonport Beach had only one detectable PAH, i.e. PA, although this compound was more available to amphipods, giving a biota-sediment accumulation factor (BSAF = concentration in animals divided by concentration in sediments, both in dry weight) of one. The BSAF observed for the same compound at S10, S4, and S11 was of 0.5, 0.15 and 0.03, respectively.

Bioavailability of contaminants would be affected by a number of variables, including the source of the contaminants, the physical-chemical properties of each chemical, the age of the material containing PAHs that was deposited in sediments, the grain size of the sediments, and the organic carbon content. This result, along with the earlier tested physical and chemical contaminants, will contribute to understanding and preserving the Bay of Fundy ecosystem.

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Figure 1. Behavioural response of amphipods exposed to ground seaweed, where R represents reference sediments, S represents spiked sediments

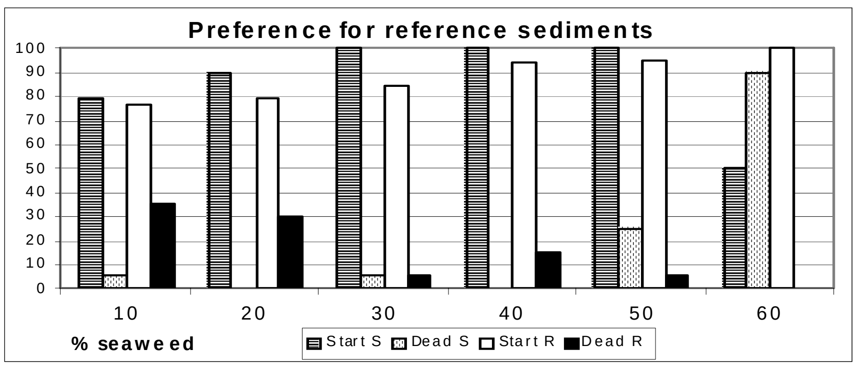


Figure 2. Behavioural response of amphipods exposed to Halifax Harbour sediments, where R represents reference sediments, S represents spiked sediments

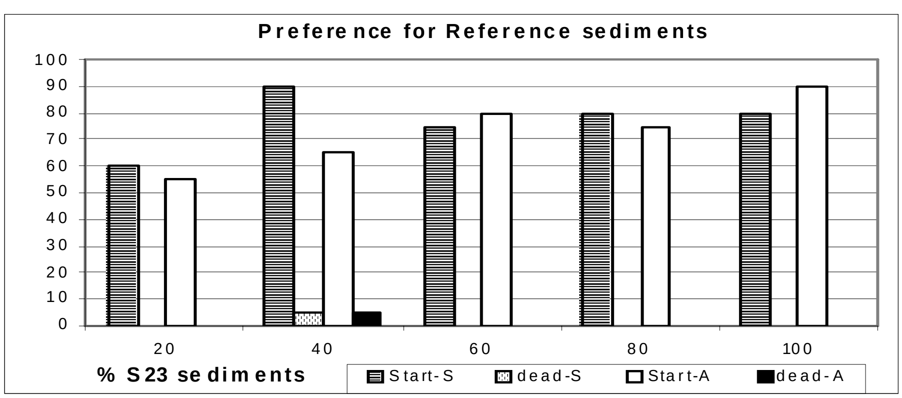
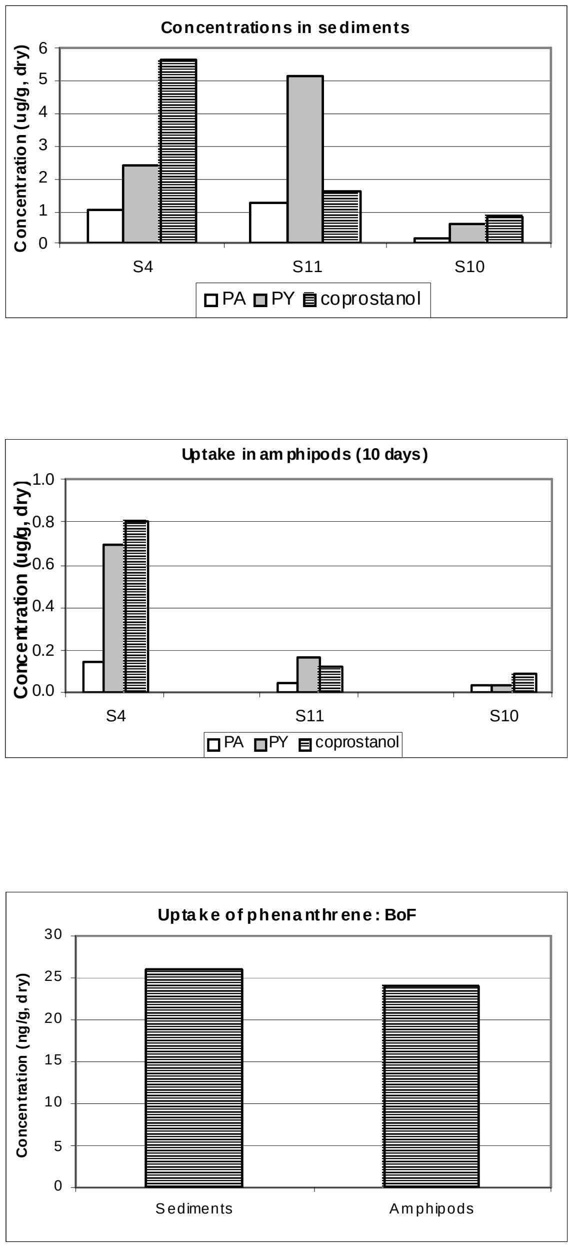


Figure 3. Concentration of selected contaminants in sediments of Halifax Harbour (sites S4, S10 and S11) relative to uptake by amphipods, where PA is phenanthrene and PY is pyrene; while BoF is Bay of Fundy



ENVIRONMENTAL IMPACTS OF BLASTING FOR STONE QUARRIES NEAR THE BAY OF FUNDY

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Abstract

In addition to deteriorating the quality of life of the local residents, there are some major environmental impacts that can be generated by the operation of a stone quarry in the vicinity of the Bay of Fundy. Detonation of explosives near water creates compression waves that produce a rapid rise in the peak pressure and its rapid decay to the ambient pressure. This can damage the swim bladder of fish and damage their eggs/larvae. Large whales orient to objects by passively listening to underwater noise. Their exposure to the intense noise generated by blasting near the shoreline may result in damage to hearing and subsequent death by accidents. Sedimentation resulting from blasting, grinding and washing of the aggregate may cover spawning areas or reduce bottom dwelling life forms that the fish use for food. The explosive residue may pollute the groundwater and may be toxic to aquatic life. Groundwater will be drawn down from upstream of the quarry as a result of excavation with the potential for lowering the water table and drying up the wells in the neighbourhood, as well as reducing the base flow in local streams. If the aggregate produced from the quarry is to be shipped across the Bay of Fundy, the new invasive plants brought in by ballast water may displace existing plant life (such as kelp beds and rockweed) and provide inhospitable environments for critical marine species.

Introduction

The proposed projects for industrial production and shipping of aggregate from stone quarries near the Bay of Fundy shore, especially in southwest Nova Scotia, have emerged only recently. The proposals for quarrying basalt, a common rock found along the North Mountain abutting the Bay, have precipitated the concerns of the community regarding the adverse effects of a quarry on the environment and on the socio-economic well-being of the local inhabitants.

This paper addresses the environmental impact of blasting in stone quarries near the Bay of Fundy. First, an introductory explanation of blasting scheme for quarries is provided. Second, the direct impacts of blasting on fish and fish eggs, the setback distances of a blast from marine life, that are regulated by Fisheries and Oceans Canada (DFO), and the impact of noise on marine mammals are discussed. Finally, additional sources of environmental impacts of blasting for quarries near the ocean are identified and discussed, including blast residue, sedimentation, drawdown of water, and importation of ballast water.

Main Aspects of Blasting in Stone Quarries

Bench Excavation

The drill and blast technique used in quarries (or open-pit mines) involves a sequential excavation of benches (or steps) of the rock. The geometric features (shown in Figure 1) include a grid of drill holes with spacing (S) along the free face (the wall of the bench) and spacing (B) across the wall, height (H) of the bench and corresponding length (L) of the drill hole, and diameter (D) of the drill hole. Each hole can be thought of as having to break its own individual area (AR) which equals BxS as outlined by the dashed lines in the plan view of the bench in Figure 1. The blast design takes into account the type of rock, the ratio of B to D, the type of explosive, the delay interval between successive explosions in the same blast, and the explosive charge weight per delay (Hustrulid 1999).

Ground Vibrations Generated by Blasting

Ground vibrations from blasting are generated by the resulting seismic waves. The primary or compression wave has the highest velocity and arrives first at a point or particle. The next to arrive at the point are the secondary or shear waves. The compression and shear waves are collectively called the body waves. The slowest and last to arrive is the Rayleigh wave, which constitutes the main component of the surface waves (Siskind 2000; Roma 2001).

The velocities of compression and shear waves, *VC* and *VS* respectively, are (Kramer 1996):

$$(VC)^2 = \frac{2G(1+\upsilon)}{\rho(1-2\upsilon)} \qquad (1)$$

$$(VS)^2 = \frac{G}{\rho} \qquad (2)$$

where $G = \dfrac{E}{2(1+\upsilon)}$, E = Young's Modulus, υ = Poisson's Ratio, and ρ = density of the medium.

Measurement of ground vibration at a point (or particle) is generally made in terms of the peak particle velocity, *PPV*.

Guidelines for Use of Explosives

In the guidelines for use of explosives (e.g., Hustrulid 1999; Wright and Hopky 1998), the main variables of interest are the *PPV*, the shock pressure in water (*PW*), the setback distance (*SD*) from the blast to the position of interest, and the explosive charge weight (*W*) per delay. Equations have been developed for inter-relating the main variables. For instance, the following equation (from Wright and Hopky 1998) relates *PPV* to *SD* and *W*, when body waves are considered:

$$PPV = 100\left(\frac{SD}{W^{0.5}}\right)^{-1.6} \qquad (3)$$

where the units of the variables are as follows: *PPV* in cm/sec, *SD* in m, and *W* in kg.

In order to account for soil characteristics (i.e. layering, mechanical properties, surface degradation), more refined models are required to select the relevant values of the constants used in equation (3).

Direct Impacts Of Blasting

Effects on Fish

The compressional seismic waves from the detonation of the explosives produce a high peak pressure (P_{max}) that rapidly decays to below the ambient hydrostatic pressure. This rapid pressure drop induces serious impacts on fish. As discussed by Wright (1982), the primary site of damage in finfish is the swimbladder, the gas-filled organ that permits most pelagic fish to maintain neutral buoyancy. The kidney, spleen, and sinus venosus may also undergo rupture and haemorrhage. Smaller fish are more susceptible to damage than larger fish.

The Canadian Guidelines (Wright and Hopky 1998) require that "no explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (i.e., overpressure) greater than 100 kPa (14.5 psi) in the swimbladder of a fish." The simplified formula for calculating the minimum setback distance (*SD*) of the onshore (in rock) blast from the fish is

$$SD = 5.03(W)^{0.5} \qquad (4)$$

Therefore, a 100 kg charge of explosives detonated in a stone quarry requires a setback of 50.3 m from the fish in order to limit the P_{max} to 100 kPa.

Effects on Fish Eggs

The Canadian Guidelines (Wright and Hopky 1998) state that "vibrations from the detonation of explosives may cause damage to incubating eggs" and that "no explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/sec in a spawning bed during the period of egg incubation".

In reference to the vibrations resulting from the compressional waves, the Guidelines provide the following simplified equation for determining the setback distance, *SD*, from an explosion for a limiting value *PPV* of 1.3 cm/sec:

$$SD = 15.09(W)^{0.5} \quad (5)$$

Therefore, detonation of a 100 kg charge of explosives requires a setback distance of 150.9 m from the fish eggs in order to limit the *PPV* to 1.3 cm/sec.

Significant Increase in Setback Distance Resulting from Rayleigh Waves

As discussed above, the setback distances from the explosives were calculated in reference to compressional (or body) waves as the source of vibrations. However, a blast in a quarry will also generate surface waves (or Rayleigh waves) as illustrated in Figure 2. The amplitude of the vibrations from body waves is inversely proportional to the distance. On the other hand, the amplitude of the vibrations from Rayleigh waves is inversely proportional to the square root of the distance. Therefore, the Rayleigh waves attenuate more slowly than body waves. Figures 3 and 4 (after Roma and Mahtab 2004) depict the significant increase in the setback distance with reference to the limits of P_{max} and *PPV*, respectively.

For example, using a *W* of 100 kg and a P_{max} of 100 kPa in Figure 3, the setback distances for body and Rayleigh waves, are 50 m and 300 m, respectively. For a *PPV* of 1.3 cm/sec, and a *W* of 100 kg, the setback distances associated with body and Rayleigh waves (and shown in Figure 4) are 150 m and 1,460 m, respectively.

Impact of Noise on Marine Mammals

Decibel

As an introduction, it would be useful to define the term "decibel" as a common unit used to express noise, or loudness of sound. Decibel, or dB, is a measure of a single power source with respect to a reference source.

dB = 10[log(sound power/reference power)] (6)

Some examples of the source, loudness, and qualitative nature of loudness are given in Table 1. The level of noise from a given source is a non-linear function of the distance of the observation point from the source. A rule of thumb for noise propagation is to reduce the noise level by 6 dB for each doubling of the distance. For instance, if the level of noise at 25m from a bulldozer is 80 dB, the noise level at 50 m will be 74 dB. To bring the noise level to a (moderate) 50 dB, the required distance would be 800 m.

Masking

Noise generated by blasting of rock and associated activities, such as grinding and shipping of the aggregate, can affect the marine mammals in various ways. Noise can mask communication signals that play a role in social cohesion, group activities, mating, warning, or individual identification. Noise can further interfere with environmental sounds that animals might listen to. Noise also affects the detection of sounds of predators and prey (Erbe and Farmer 2000).

Behavioural Disturbance

Noise has the potential of disrupting normal animal behaviour. Reported animal reactions include a cessation of feeding, resting, socializing, and an onset of alertness or avoidance (Richardson et al. 1995). For many marine mammals, disturbance is known to have occurred at continuous noise levels of about 120 dB. In our opinion, the normal blast per delay in a rock quarry will generate a noise that exceeds 120 dB. If noise scares the animals away from their habitat for an extended period, the effect will have a biological significance (on foraging, mating, or nursing).

Hearing Impairment

Prolonged exposure to continuous noise, such as from shipping and grinding, can also bring about hearing loss. Audiologists call this impairment "threshold shift". On exposure to damaging noise, one's acoustic threshold rises by a few decibels. For a marine mammal, each additional dB can mean a loss of vital information: the call of a calf, a predator, or a prospective mate (NRDC 1999).

Cumulative Effect

Repeated exposures to relatively low levels of noise may have a cumulative effect in inducing permanent hearing loss in mammals (as has been confirmed in humans and other species). Perhaps the most serious impact of noise is the debasement and depletion of habitat, as evidenced by the driving of gray whales, and possibly humpback whales, from traditional waters (NRDC 1999).

Additional Impacts of Quarrying Stone Near the Bay of Fundy

Water Pollution from Explosive Residue

As indicated above and in Figure 1, a pattern of drill holes is used to load and detonate explosives for breaking rock in a quarry. A fraction of the explosive may be left as "explosive residue" in the form of unexploded material after completion of the explosion.

As discussed by Kelleher (2002), there is evidence to support the suggestion that explosive residue is derived from a thin outer layer of the charge. The outer layer in a charged drill hole is the cylindrical surface. (The magnitude of the cylindrical surface for a given bench height is a direct function of the diameter of the drill hole.) As a general rule, the explosive residue will decrease as both the charge size and the velocity of detonation increase. However, in the case of a quarry near the ocean, the charge size per delay will need to be constrained to meet the DFO Guidelines for Peak Particle Velocity. In addition, the practical choice of the explosive for a quarry may not be associated with a high velocity of detonation. Therefore, the small charge (i.e. diameter of the drill hole) and/or the low velocity of detonation will tend to increase the percentage of the explosive residue.

The explosive residue will enter the surface water and groundwater through gravity flow and washing of the aggregate. The pollution potential of the explosive residue will depend on the chemical constituents of the explosive, such as nitrate and fuel oil. The potential hazard will be the contamination of the groundwater, its eventual flow into the Bay of Fundy, and the harmful impact on the marine life.

Sedimentation

Construction activities for a quarry near the Bay of Fundy shore may require clear cutting of the trees from the site, removing top soil, and altering the watercourses. All of these aspects will accelerate erosion, mainly by exposing large areas of soil or hills to faster flow of water during rainstorms. The rock formation along the shore is generally sloping toward the Bay. The silt-laden runoff from the site will end up in the Bay. Figure 5 shows an example of the silt being washed down the stripped hills from a proposed quarry site near the Bay of Fundy. Sedimentation or siltation from a rock quarry will also be generated by blasting, grinding, and transporting of the rock and aggregate.

As indicated in Appendix A of NS DEL (1988), one of the most serious environmental effects of siltation is the destruction of fish and fish habitat. High turbidity may induce physiological stress that makes fish susceptible to infection by disease-causing micro-organisms. High turbidity levels reduce light penetration and photosynthesis, thereby affecting the food chain and dissolved oxygen content. Sedimentation may cover spawning areas or reduce bottom dwelling life forms that the fish use for food.

Drawdown of Groundwater

The quarrying operation will progressively remove one or more benches of rock, most likely advancing from close to the Bay and proceeding away from the Bay. Depending on the cumulative height of the benches, the pit will act as a dug well which will draw down the water from the hills (or land) behind the pit toward the Bay. The extent of drawdown will depend on the rate of advance of the quarry face, level of the water table in reference to elevation of the bottom of the pit, and the hydraulic conductivity of the rock. The rock near the shore is well fractured and has high conductivity, in both horizontal and vertical directions. This conductivity would be enhanced by the effect of blasting.

The drawdown of water will adversely affect the level of water table and the use of aquifers by the neighbours. The wells in the vicinity of the quarry may run dry and the base flow in the regional streams may be reduced. The dust from blasting and grinding as well as the siltation carried by the drainage through the blasted rock will affect the quality of the groundwater.

Impact of Ballast Water

For practical reasons, a large-size stone quarry will need to ship the stone or aggregate using a marine terminal located near the quarry site and on the Bay of Fundy shore. A major concern regarding shipping the product across the Bay and Gulf of Maine would be the new invasive organisms brought by the cargo ships in the ballast water. As stated in the guidelines of Transport Canada (2001), ballast water has been associated with the unintentional introduction of a number of organisms in Canadian waters and several have been extremely harmful to both the ecosystem and the economic well-being of the nation. When a new organism is introduced to an ecosystem, negative and irreversible changes may result, including a change in biodiversity. For example, the imported plants may displace the existing plant life, such as kelp beds and rockweed, and provide inhospitable environments for critical marine species. Chapman et al. (2002) provided a comprehensive example of the introduction of alien marine vegetation and its spread in Atlantic Canada.

Conclusion

The environmental impacts of blasting for a stone quarry near the Bay of Fundy include loss of marine and terrestrial habitat, impairment of water and marine habitat due to siltation from the site, and lowering of groundwater level.

An economically feasible quarry would require shipping of the product (most likely, the aggregate) across the Bay. The traffic of bulk carriers will disrupt the movement pattern of whales. Creation of a marine terminal will jeopardize the safety of small craft that follow the shoreline. The importation of invasive species in ballast water may have a potentially severe impact on the marine life over a wide area.

Regardless of the size of a proposed quarry near the Bay, a detailed environmental assessment report needs to be furnished by the proponent of the quarry project. The federal and provincial governments and the community concerned must examine the report before the proposed project is approved.

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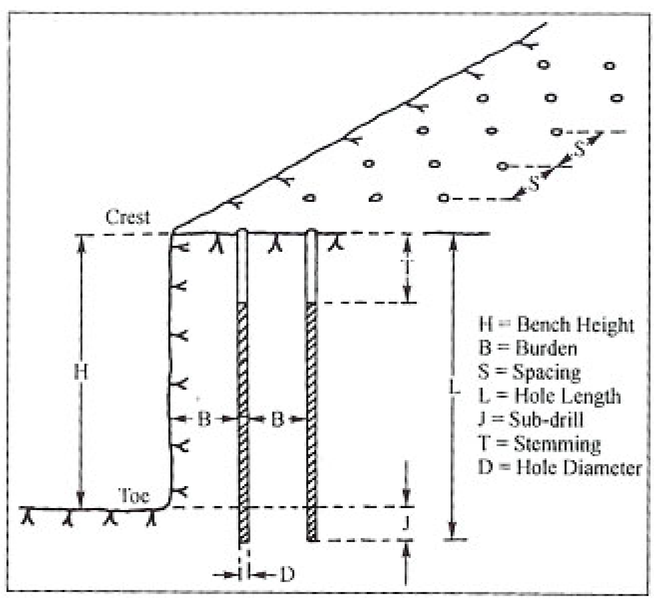
Table 1. Sound loudness (after Lindeburg 1982)

SOURCE	LOUDNESS (dB)	QUALITATIVE NATURE
jet engine or thunder	120	painful
jack hammer (drill)	110	deafening
sheet metal shop	90	very loud
street noise	70	loud
office noise	50	moderate
quiet conversation	30	quiet
none	0	silence

Figure 1. Isometric view of a bench showing blast geometry and a plan view of the bench showing blast layout for one row of holes (after Hustrulid 1999)



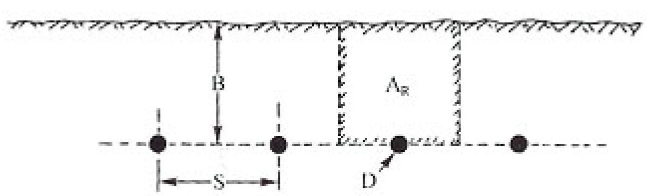


Figure 2. Description of body waves and surface (Rayleigh) waves resulting from blasting near a shoreline (after Roma and Mahtab 2004)

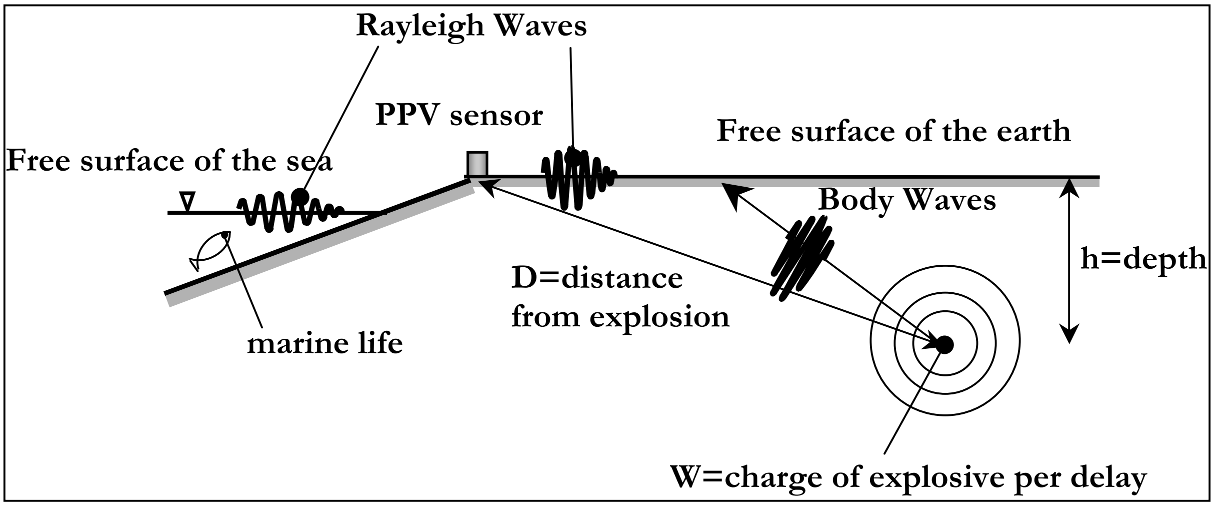


Figure 3. Setback distances for body and Rayleigh waves using the limit P_{max} = 100 kPa for fish habitat (after Roma and Mahtab 2004)

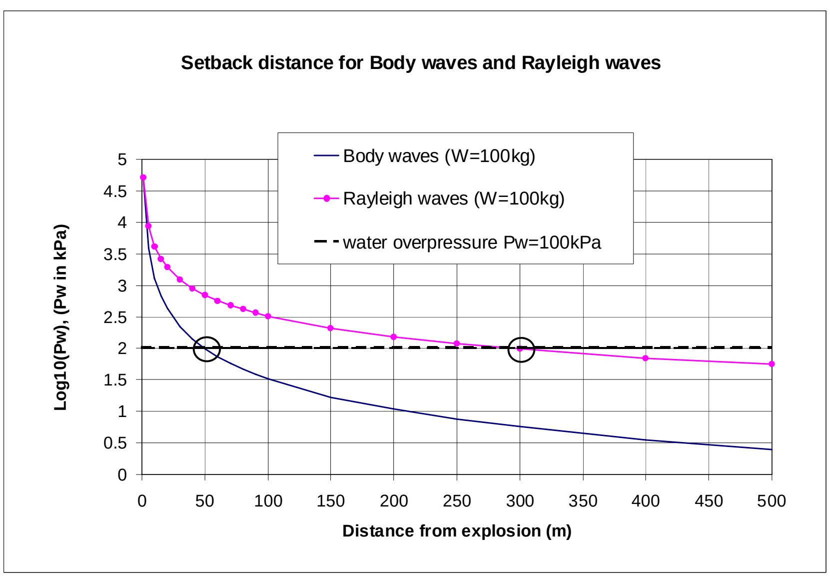


Figure 4. Setback distances for body and Rayleigh waves using the limit *PPV* = 1.3 cm/sec for spawning habitat for fish habitat (after Roma and Mahtab 2004)

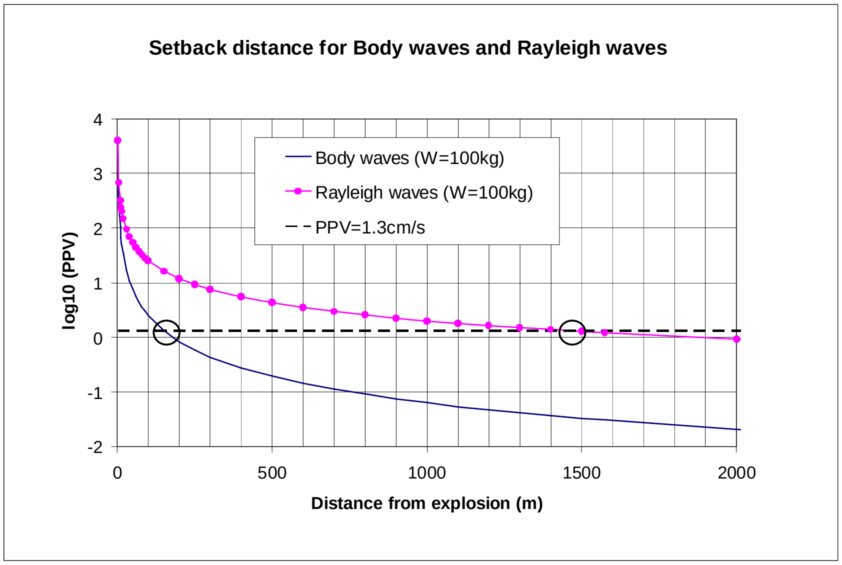


Figure 5. Sediment runoff from stripped hills on a proposed quarry site near the Bay of Fundy

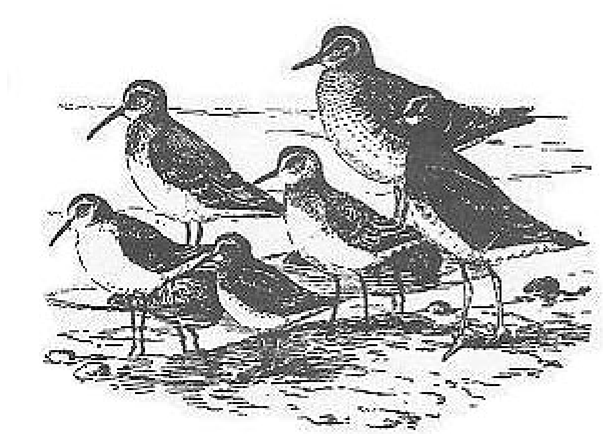
Session Two

ECOLOGY OF SEABIRDS AND SHOREBIRDS

Chairs: Peter Hicklin, Canadian Wildlife Service, Sackville, New Brunswick

and

John Chardine, Canadian Wildlife Service, Sackville, New Brunswick



FEEDING AREAS OF ARCTIC TERNS (*Sterna paradisaea*) AND COMMON TERNS (*Sterna hirundo*) BREEDING ON MACHIAS SEAL ISLAND, NEW BRUNSWICK

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Abstract

Machias Seal Island (MSI) is a 9.5 ha, treeless island located at the mouth of the Bay of Fundy, 20 km south of Grand Manan. It is designated a Canadian Wildlife Service (CWS) Migratory Bird Sanctuary and managed by CWS because it is the breeding grounds of a large number of seabirds, including both arctic and common terns. The Atlantic Cooperative Wildlife Research Network (ACWERN) has been conducting long-term studies on MSI since 1995. One research goal is to assess the ecological differences between Arctic and Common Terns. As a part of this project, we are radio tracking Arctic and Common Terns to determine where they feed around MSI. Preliminary data suggests that common terns feed both inshore and far offshore, whereas arctic terns seem to feed solely offshore. The next step is to relate feeding areas to characteristics of the marine environment, and to investigate whether Arctic and Common Terns which nest together also forage together.

Introduction

Arctic Terns (*Sterna paradisaea*) are seabirds that breed inland and along the coast in northern latitudes of North America, Greenland, Europe, and Asia (Hatch 2002). They often nest sympatrically with Common Terns (*Sterna hirundo*) on offshore islands in the southern portion of their range along the coast of eastern North America (e.g., Machias Seal Island, Seal Island National Wildlife Refuge, Country Island). Common Terns are also found throughout Europe and Asia and, like the Arctic Tern, are considered to be a long-lived species (Nisbet 2002).

Machias Seal Island (MSI) is a 9.5 ha, treeless island located at the mouth of the Bay of Fundy. It is designated a Canadian Wildlife Service (CWS) Migratory Bird Sanctuary and managed by CWS because it is the breeding grounds of a large number of seabirds, including both Arctic and Common Terns, as well as Atlantic Puffins and Razorbills (Devlin and Diamond 2002).

Despite extensive study of the breeding and foraging biology of both Arctic and Common Terns, systematic investigation of their foraging grounds has been limited. Tracking studies of Common Terns have been conducted in the freshwater Great Lakes system (Burness et al. 1994) and in the Wadden Sea, Germany (Becker at al. 1993). There are no published studies of radio-tracked Arctic Terns. These studies have been carried out on tern colonies relatively close to shore, not on colonies of sympatrically nesting Arctic and Common Terns.

Using flight speed and time spent away from the nest, Pearson (1968) calculated that Common Terns on the Farne Islands traveled approximately 21.9 km from the nest. Becker et al. (1993) determined that Common Terns forage close to shore (within 10 km), using coarse calculations based on triangulation that underestimated range due to the spatial limitations of this method. Nisbet (2002) extended this feeding range to within 20 km of the breeding site, and although the birds usually feed closer than this, they may also travel much further to forage. This estimate was made using a combination of radio telemetry data, trip duration estimates, and boat surveys. This fluctuation in range estimates may be a function of either different distances to the feeding grounds at each breeding location, a difference between sampling methods, or perhaps a combination of the two.

Arctic Tern foraging distances from the nest site are poorly documented, but estimates range from less than 10 km (Hatch 2002) to 20.2 km (Pearson 1968). We now have good information on the diet of Arctic and Common Terns nesting on MSI (Devlin and Diamond 2002), but where they feed is still unknown. The next step in understanding the foraging ecology of these terns is to find out where their feeding grounds are and to potentially identify any differences in foraging areas between the two species.

Existing data suggest that Arctic and Common Terns feed on similar prey species (herring, hake, euphausiids, and rockling), but in different proportions (Hall et al. 2000; Diamond and Devlin 2003). Hall et al. (2000) also hypothesize, based on prey diversity studies, that Common Terns prefer to feed in inshore bays, and Arctic Terns mainly forage over open ocean waters and along stony shores.

Objectives

The objectives of this study are to identify the feeding habitat of Arctic and Common Terns breeding on Machias Seal Island, and to compare these findings with those of other tern colonies that are located closer to the mainland and may not have both species nesting together. This will also contribute to one of the larger goals of ACWERN, which is to identify the differences between Arctic and Common Terns that allow them to breed so close to each other.

Predictions

We predict that based on the foraging range estimates of Arctic Terns (Pearson 1968; Hatch 2002) and Common Terns (Pearson 1968; Becker et al. 1993; Nisbet 2002), and the fact that they overlap considerably in prey type (Hall et al. 2000; Diamond and Devlin 2003) these two species may have a large feeding area overlap because MSI is an offshore island (10 km from Maine and 19 km from New Brunswick). However, Common Terns are associated with inland feeding in bays and fresh water more than Arctic Terns (Lemmetyinen 1973; Becker et al. 1997; Hall et al. 2000), so we also hypothesize that Common Terns will be found more often foraging between MSI and the Maine coast, while Arctic Terns will feed farther out at sea.

Methods

Fieldwork was centred on MSI from May–August of 2004. Twenty birds of each species (Arctic and Common Terns) were caught and fitted with a transmitter. All of the tagged birds were mates.

Radio-tagging procedures followed Gaunt and Oring (1997), Canadian Council on Animal Care Guidelines (1993), and Kenward (1988); each bird was fitted with a tail-mounted radio transmitter. The transmitters were attached to tail feathers using cotton thread and waterproof epoxy. This attachment site may minimize obstruction of ground movement by the trailing antenna while still allowing ease of flight. Tracking began no earlier than five days after transmitter attachment to allow the birds to acclimate to the equipment (Ministry of Environment, Lands and Parks Resources, B.C. 1998). Birds were tracked from the air because MSI is too small (9.5 ha) to allow accurate triangulation of birds at sea from land mounted antennas, and the estimated foraging ranges are too large to cover in a boat. Aerial radio-tracking flights extended from Grand Manan Island to approximately 30 km around MSI and began late in incubation (third week of June) using a fixed-wing, twin-engine aircraft mounted with two antennas. The duration of these flights were between 2.5 and 3 hours over a range of times during the day, and were opportunistic depending on weather conditions, which were usually foggy in June and July. A total of six flights were executed. Tracking began around MSI and the sea was explored in a spiral pattern centred around the island.

As each individual was detected, it was scored as either foraging or traveling according to both the characteristics of the signal (in one place and delayed as the bird hits the water while feeding, versus steady and moving away from or towards the island, and not breaking up). Characteristics of the location and the observed foraging flocks were also noted if visibility allowed it. Parameters included number and species of birds in the foraging flock, weather and sea conditions, and time of day. We attempted to find as many of the tagged birds as possible on each flight.

Results and Conclusion

Eighteen Common Tern and five Arctic Tern feeding locations were documented. A low rate of detection of Arctic Tern foraging grounds suggests that perhaps the Arctic Terns are travelling further than the estimated 30 km range. The search area will be increased for the 2005 field season.

Preliminary data shows that Common Terns forage along coastlines, as well as far out at sea, but Arctic Terns appear to stay well offshore. Both Arctic and Common Terns were found very near the nesting site (within 5 km) as well as up to 30 km away. This suggests that these two tern species may show an overlap in foraging niches on offshore feeding grounds, but not inshore areas. This data will be analyzed to relate where the terns are feeding to characteristics of the marine environment, as well as to investigate whether Arctic and Common Terns that nest in the same areas also feed on the same foraging grounds.

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A POSSIBLE REASON FOR THE DISAPPEARANCE OF PHALAROPES FROM AROUND DEER AND CAMPOBELLO ISLANDS: AVAILABILITY OF THEIR FAVOURITE PREY

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Phalaropes are marine shorebirds that spend about nine months of the year at sea feeding on small (ca. < 6 mm) zooplankton at the sea surface (Mercier and Gaskin 1985). From about mid-July to mid-September, the outer Bay of Fundy is an important migratory stop-over area for phalaropes, where the birds feed and gain body mass for their migration south. Over the course of the mid to late 1980s, the number of phalaropes (mainly Red-necked, *Phalaropus lobatus*) using the waters around Deer and Campobello Islands, New Brunswick, declined from 1-2 million to zero. The decline appeared to start in about 1986 and the birds were gone by 1990 (Duncan 1996).

In the early 1980s, the abundant Red-necked Phalaropes around Deer Island fed mainly on the copepod *Calanus finmarchicus* driven to the surface by tidal upwellings around the islands (Mercier and Gaskin 1985). Therefore, a reasonable hypothesis explaining the disappearance of the birds is that their main prey was no longer available to the birds, or was available at much lower levels. Plankton tows were conducted around Deer Island after the phalaropes disappeared but the results of this work appear to be unavailable. I therefore decided to conduct plankton tows around Deer Island in 2002, albeit over ten years after phalaropes were last seen there.

Numbers of phalaropes and their copepod prey were quantified by Mercier and Gaskin in 1980–1982 and their data provide a benchmark against which prey availability can be compared now, in the absence of birds. I used the same methods to sample zooplankton in surface waters around Deer and Campobello Islands. This involved towing a surface plankton net (mouth size 500 mm wide by 200 mm deep; 0.25 mm mesh size) behind and to one side of a small vessel at a speed of 1 ms^{-1} (ca. 2 knots) for 5 minute periods during late August, when the phalaropes were historically at their peak numbers in the area. Samples were stored in glass mason jars and preserved with formalin (4 percent). Zooplankton in the samples were identified and counted by Vivian Bushell of the Unamaki Institute, Cape Breton, NS.

The density of *Calanus finmarchicus* around Deer Island was about ten times lower in 2002 than in the early 1980s. Furthermore, densities of some other copepod species, principally *Acartia* sp. and *Eurytemora* sp., were about twice as high in 2002, suggesting that I was not undersampling copepods due to some methodological reason.

Phalaropes still use the Brier Island area to feed while on migration so I also sampled surface zooplankton there. The copepod species composition of tows I conducted was broadly similar to those conducted in the 1970s (Brown and Gaskin 1988), suggesting that the changes I found around Deer Island had not occurred off Brier Island. I found densities of *Calanus finmarchicus* in areas where birds were feeding off Brier Island to be well above the threshold of $45/m^2$ at the surface (Mercier and Gaskin

1985), below which phalaropes cannot feed profitably. I could not directly compare copepod densities with those found in the 1970s because different nets were used in the two time periods.

I conclude that the most likely cause of the disappearance of phalaropes from the Deer Island area was severely reduced availability of their favourite prey *Calanus finmarchicus* from surface waters during the time phalaropes migrate through the area. The possible reasons for this remain unclear at this time but could involve factors such as local or widespread changes in (1) biological or physical oceanography, (2) *Calanus finmarchicus* consumption by fishes, (3) *Calanus finmarchicu*s phenology, or (4) pollution levels.

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CHANGES IN THE FEEDING OF FOUR ATLANTIC SEABIRDS ON MACHIAS SEAL ISLAND, NEW BRUNSWICK

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Seabirds are long-lived species that are top consumers in the marine ecosystem. They are conspicuous and accessible samplers of the oceanic environment, making them ideal indicator species to assess changes in the marine environment where they spend the bulk of their lives. Seabirds also nest in dense colonies during the breeding season and can be interesting study subjects when exploring scientific questions (e.g., Cairns 1987; Burger and Gochfeld 2002; Diamond and Devlin 2003).

Machias Seal Island (MSI) is a 9.5-hectare island located in the mouth of the Bay of Fundy, 18 km southwest of Grand Manan Island, New Brunswick. During the summer months, the island is the breeding site of several seabird species, four of which have been the focus of a long-term study initiated in 1995 by the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN) at the University of New Brunswick (UNB) in conjunction with the Canadian Wildlife Service (CWS) (Diamond and Devlin 2003). The focal species include two terns, Arctic Terns *Sterna paradisaea* and Common Terns *S. hirundo,* and two alcids, Razorbills *Alca torda* and Atlantic Puffins *Fratercula arctica*.

Arctic Terns and Common Terns are surface-feeding seabirds that feed their chicks on a variety of prey species (Nisbet 2002; Hatch 2002). On MSI, tern chick diets are dominated by schooling fish species and occasional euphausiid shrimp (Charette et al. 2004). Atlantic Puffins and Razorbills are pursuit-divers that forage within the water column and feed chicks primarily demersal schooling fish species (Lowther et al. 2002; Hipfner and Chapdelaine 2003).

The long-term study on Machias Seal Island has now produced ten years of data on the four focal seabird species. Data include chick-feeding prey types and size collected via observation from blinds and data on various reproductive parameters such as clutch size, hatching success, growth rates, and fledging success rates. The feeding data have shown a shift in prey items fed to chicks since 2000. Historically the four species have fed their chicks primarily juvenile Atlantic herring (*Clupea harengus*), but in recent years other species have become the dominant food item, including energetically poor crustaceans (Massias and Becker 1990; C. Maranto, pers.comm.), specifically euphausiids (Charette et al. 2004).

The summer of 2004 stands apart from all previous years of this study, as fish larvae were observed being fed to seabird chicks for the first time since ACWERN started the project in 1995. All four species of seabird delivered fish larvae to chicks, with the larvae composing 17 percent to 25 percent of all identified prey fed to chicks. We have yet to analyze the nutrient and energetic content of fish larvae collected this summer, but the mass of a larval herring we collected were typically an order of magnitude less than the mass of metamorphosed juvenile herring we recovered in the colony. The

Common and Arctic Tern colonies had the lowest productivity recorded to date on MSI in 2004, with adjusted fledging rates of 0.049 and 0.053 respectively. We believe poor feeding and cool, foggy weather contributed to the near failure of both tern colonies.

Herring are fatty, nutrition-rich fish (Massias and Becker 1990). However, past work on the long-term study has shown that seabird productivity varies with percent water/fat content in herring, rather than the proportion of herring in the chick diet (Diamond and Devlin 2003). As more feeding data accumulate since the switch in prey, the amount of juvenile herring in the diet may correlate with reproductive success, unless herring are replaced by energetically-equivalent prey. Seabirds are long-lived species that tend to invest heavily in few offspring (e.g., Weimerskirch 2002) making them potentially vulnerable to prey changes during the brief but crucial breeding season (Monaghan et al. 1989; Harris and Wanless 1990; Danchin 1992).

This possible shift in feeding is of interest to humans from a variety of reasons. Atlantic herring supports a weir fishery in New Brunswick that catches approximately 26,000 tonnes of herring annually, making it a commercially valuable species (Power et al. 2003). Previous research conducted during this long-term study has shown that the amount of herring delivered to Arctic Tern chicks in the 1990s on MSI predicts the size of herring weir catches on nearby Grand Manan Island two years later (Amey 1998; Amey et al. 2003).

Long-term studies of seabirds are essential for understanding aspects of the marine ecosystem. The research conducted in Machias Seal Island has already helped us to understand the four focal seabird species and how they relate to other species of the marine environment. The seabird feeding data from the past ten years show a shift from mostly herring to other prey over the past four years; however, little is known about the extent of this variation and what factors may have influenced this change. This study will address feeding variation and overlap between seabirds over summers and within breeding seasons. The resulting information will elucidate aspects of niche theory and increase our understanding of the complex relationships that seabirds have with the marine environment and with each other.

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FACTORS AFFECTING MOVEMENT OF SEMIPALMATED SANDPIPERS (*Calidris pusilla*) MIGRATING THROUGH THE UPPER BAY OF FUNDY

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Introduction

The upper Bay of Fundy is a key migratory stopover point for Semipalmated Sandpipers (*Calidris pusilla*), a small shorebird which breeds in the Arctic and winters in northern South America. One to two million birds—between 40 percent and 75 percent of the world's population—visit local mudflats annually, the majority from late July to late August (Hicklin 1987; Mawhinney et al. 1993). Many migrating shorebird species tend to concentrate in large numbers on a restricted number of sites, making them very vulnerable to habitat loss (Morrison et al. 1994). The Western Hemisphere Shorebird Reserve Network has designated the Bay of Fundy as a site of critical importance for these birds (Shepherd and Boates 1999). This mass migration also represents a major attraction for New Brunswick and Nova Scotia tourists interested in wildlife.

During their stay in the Bay of Fundy, sandpipers nearly double their weight in preparation for migration to their South American wintering grounds by feeding almost exclusively on mud shrimp (*Corophium volutator*), the most abundant macroinvertebrate on mudflats in the area (Hicklin and Smith 1984). Semipalmated Sandpipers forage on exposed mudflats during low tide and return to communal roost sites to rest during high tide. Throughout their approximately two-week stay in the Bay of Fundy region, it is not clear how these birds select foraging habitat, or whether they stay on a single mudflat or use multiple mudflats.

The selection and use of a foraging site should be based on perceived predation risk, food abundance and availability (Lima and Dill 1990; Elchuk and Wiebe 2002). Populations of Peregrine Falcons (*Falco peregrinus*) and Merlins (*Falco columbarius*), the main shorebird predators in the Bay of Fundy, have recently increased due to the banning of DDT use in North America and raptor reintroduction programs (Noble and Elliot 1990). This has resulted in increased predation risks for shorebirds in the Bay of Fundy area, and is likely altering the sandpipers' choice of foraging areas. Historical evidence prior to the raptor increase suggests that individual Semipalmated Sandpipers restricted feeding to single mudflats (P. Hicklin, pers. comm.); however, mudflat use by shorebirds appears to have changed in recent years (Hamilton et al. 2003). This may be related to changes in feeding habitat, as indicated by loss of mud shrimp from some mudflats (Hamilton et al. 2003), the recovery of predator populations in the area, or other factors.

** First Place Student Paper award winner

Given the crucial importance of the region to this species, and the global population decline of Semipalmated Sandpipers (Morrison et al. 1994), it is critical from a conservation standpoint that we understand factors influencing shorebird movements and habitat use. Such knowledge will also help to predict future responses of shorebirds to human-induced changes in the ecosystem, such as the damming of tidal rivers and the subsequent removal of these barriers. For example, if we find that birds are able to use multiple mudflats, they may be less vulnerable to changes in their habitat than if they remain on one mudflat throughout their stay. This issue is very relevant to New Brunswick as the province is currently debating the removal of the Petitcodiac Causeway in Riverview, which may alter surrounding mudflats.

Specific objectives of this project include:

1. Quantify individual shorebird movements around the upper Bay of Fundy using radio-telemetry.
2. Identify factors that contribute to foraging site selection and individual bird movements during the migration stopover.

Methods and Preliminary Results

Objective 1: Quantifying movements based on radio-tracking individual birds

In early August, during the peak migration period, 20 sandpipers each from Shepody Bay and the Minas Basin were captured using pull traps (following the technique of Peter Hicklin, CWS) and fitted with radio transmitters. Healthy birds with low body weights (indicating recent arrival) were selected. Radio transmitters were attached to an area of clipped feathers on the lower back of the birds using a light coating of waterproof epoxy adhesive (Warnock and Warnock 1993).

Tagged birds were tracked using a high-winged monoplane with H-style antennas mounted to the plane’s struts (Kenward 1987). Flights followed the coastline along both Shepody Bay and the Minas Basin in attempts to locate all tagged birds. Birds were also tracked from ground at communal roost sites. Once a tagged bird was detected, the GPS location was noted. Of the 19 birds tagged in Johnson’s Mills (Shepody Bay), 60 percent were not detected at any other mudflat. Only 16 percent were located across the Bay foraging on Daniels Flat. In the Minas Basin, more movement was detected with 30 percent of the birds located on one mudflat, while 50 percent were found on three or more different flats.

Objective 2: Factors affecting movement and foraging site selection

Prey abundance and size distribution were quantified by sampling *Corophium* on mudflats in the region. Stratified random sampling of sediments (21 samples per mudflat) was carried out along three transects on each of these selected flats in late July and again in mid-August. Sediment samples were sieved through a 0.25-mm sieve (Crewe et al. 2001) and all *Corophium* were retained and preserved in ethanol. At a later date, samples will be sorted and measured in the lab, and the number of *Corophium*/m^2 will be determined. This will facilitate accurate assessment of the prey base at each mudflat for birds observed during the study.

Predation threats to the sandpipers were assessed through behavioural observations of shorebirds and predators at selected mudflats. Predator observations were conducted at both high and low tide. Predation risk was quantified by recording the number of predators on each mudflat, number of attacks observed, outcome of attack, and response of sandpipers to predators. A two-way ANOVA found more attacks occurred at high tide than low tide ($p = 0.02$). No significant difference was found between predation rates in Minas Basin and Shepody Bay.

The effects of landscape on bird movements will also be assessed. Detailed maps of the area will be used to determine the following metrics: 1) proximity to roost sites to foraging areas, 2) nearest neighbour distance (km) will be measured from the perimeter of one mudflat to the perimeter of the nearest mudflat, and 3) mean patch size will be the mean area (ha) of the individual mudflats.

Conclusion

The upper Bay of Fundy is both a rich and diverse wildlife habitat and an important ecotourism site for Atlantic Canada. This research will offer the first solid information on shorebird movements during their migration stopover in this area, especially since the recovery of their predators. This new knowledge on foraging site selection and shorebird movements will lead to suggestions on how to best conserve this crucial habitat and ensure that the world's largest population of Semipalmated Sandpipers will continue to return to the Bay of Fundy for years to come.

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RETURNING VISITORS: SEMIPALMATED SANDPIPERS IN SHEPODY BAY

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Over 13 field seasons between 1981 and 2004 inclusive, a total of 35,583 Semipalmated Sandpipers were captured and banded along the shore of Grande Anse in Johnson's Mills, New Brunswick (Table 1, Figure 1). In 1981 and 1982, the birds were captured using mist nets but after (and including) 1986, we used the Fundy Pull Trap to capture all birds (see Hicklin et al. 1989). Consequently, in the course of this study, we recaptured many birds previously banded by us at Johnson's Mills and the band numbers of the recaptured birds were recorded. The numbers of sandpipers recaptured throughout this period are shown graphically in Figure 2. These data indicate that most of the recaptured banded sandpipers were taken within the first three years of banding and the majority of these were recaptured during the year they were banded; the longest interval prior to recapture was 14 years after the bird was initially banded (Figure 2).

Upon the initial analysis of this data, it was surprising to discover how many birds banded on the same day were recaptured together again on the same day, either in the same or a different year. These birds recaptured on the same (exact) days occurred in pairs, triplets and quintuplets (groups of two, three and five birds); the time between banding and recapture varied between 1 and 728 days (Table 2). For those groups of birds banded and recaptured in the same year (i.e. the same late summer/ fall season), the time between captures ranged between 1 and 20 days for mean between-capture intervals of 9.1 (groups of two), 8.8 (groups of three) and 5.0 days (one group of five birds) (Table 2). For similar groupings captured in different years, the mean time intervals between captures were 411 (groups of two) and 380 days (one group of three birds) (see Table 2). Overall, 88 Semipalmated Sandpipers captured together (in various groupings) on the same day were recaptured together (in various groupings) in either the same or later years, but again on precisely the same day. The majority of within year recaptures occurred in 1988 when we captured the most birds (nearly 10,000) during that season (Figure 3). In order to represent large flocks of sandpipers rather than individual birds, larger groupings of birds captured and recaptured within the same 48-hour periods over all seasons showed the same pattern (Figure 4). Over the 13-year period at Johnson's Mills, groups of 2, 3, 4, 5, 6 and 10 birds were recaptured together, within and between years (Figures 3 and 4), over time intervals ranging between 1 and 2,169 days, inclusive (Table 3).

These results indicate that the large flocks of Semipalmated Sandpipers that migrate annually to and through the Bay of Fundy during southward migration do not represent random assemblages of birds but possibly consist of well-structured groups of returning visitors. Whether these birds are genetically related and stop over at the same sites every year during migration and use the same breeding and wintering areas in the western hemisphere comprise testable hypotheses for future field studies.

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Table 1. Numbers of Semipalmated Sandpipers captured at Johnson's Mills, NB (1981–2004) (n= 35,583 birds)

Year	Banded & measured	Banded only	Banded & weighed only
1981	1,239	-	-
1982	1,795	-	-
1986	2,438	-	-
1987	1,624	4,805	-
1988	-	9,738	-
1989	304	903	781
1997	1,800	-	-
1998	1,604	-	-
1999	1,600	-	-
2000	932	-	313
2001	1,916	-	-
2002	1,937	-	-
2003	1,069	-	-
2004	785	-	-
14 yrs	19,043	15,446	1,094

Table 2. Semipalmated Sandpipers banded on the exact same day and re-captured together on the exact same day over 13 banding seasons at Johnson's Mills, NB (1981–2003) (n=88)

Group Size	*Mean days (±SD) within season*	*Mean days (±SD) later seasons**	*Overall Mean days (±SD)*	*Range*
pairs	9.1 (±8.9) (n=20)	411.4 (±128.8) (n=8)	124 (±196.5) (n=28)	1 - 728 days
triplets	8.8 (±6.0) (n=8)	380 (n=1)	45 (±117.5) (n=9)	1 - 380 days
quintuplets	5 (n=1)	-	5 (n=1)	-

*excluding the seasons when birds were banded

Table 3. Semipalmated Sandpipers banded on almost the same date (over a 48-hour period) and re-captured together on almost the same date (over a 48-hour period), across 13 banding seasons at Johnson's Mills, NB (1981–2003) (n=247)

Days Between Banding and Re-capture

Group Size	Mean days (±SD) within season	Mean days (±SD) later seasons*	Overall Mean days (±SD)	Range
pairs	10.7 (±9.1) (n=22)	647.6 (±439.8) (n=18)	297.3 (±432.8) (n=40)	1 – 2169 days
triplets	9.4 (±4.7) (n=9)	430.7 (±144.6) (n=17)	284.9 (±234.9) (n=26)	1 – 748 days
quadruplets	8.2 (±9.1) (n=7)	365 (n=2)	87.5 (±157.6) (n=9)	1 – 365 days
quintuplets	15.6 (±8.1) (n=3)	-	15.6 (±8.1) (n=3)	1 – 23 days
sextuplets	10.8 (±13.5) (n=3)	-	10.8 (±13.5) (n=3)	1 – 26 days
group of ten	8.3 (±4.7) (n=2)	-	8.3 (±4.7) (n=2)	5 – 12 days

*excluding the seasons when birds were banded

Figure 1. Location of banding station and sampling transects in Shepody Bay, Bay of Fundy

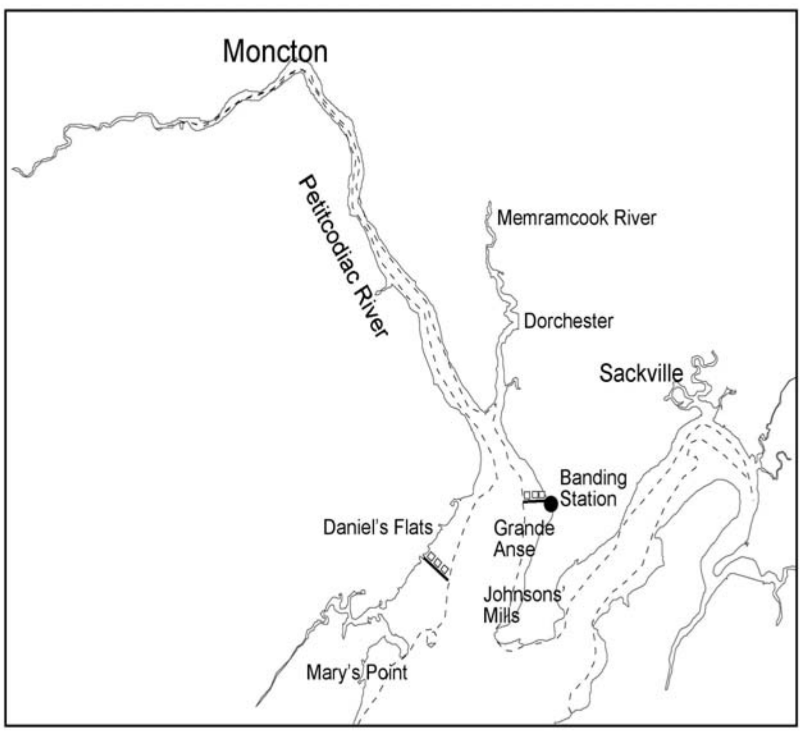


Figure 2. Semipalmated Sandpipers re-captured at Johnson's Mills, NB (1981–2003) (n=454)

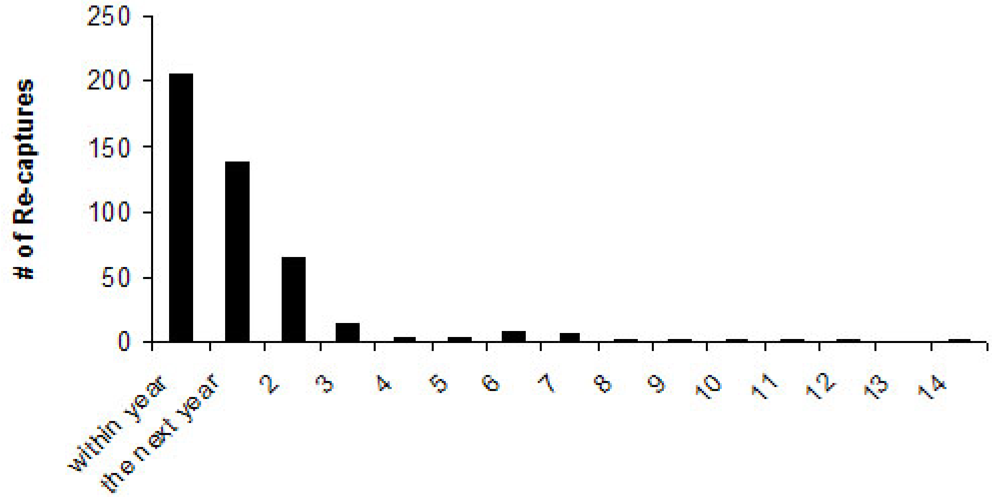


Figure 3. Re-captures of grouped Semipalmated Sandpipers banded and re-captured on the same days (within and between years) at Johnson's Mills, NB, Bay of Fundy (1981–2003)

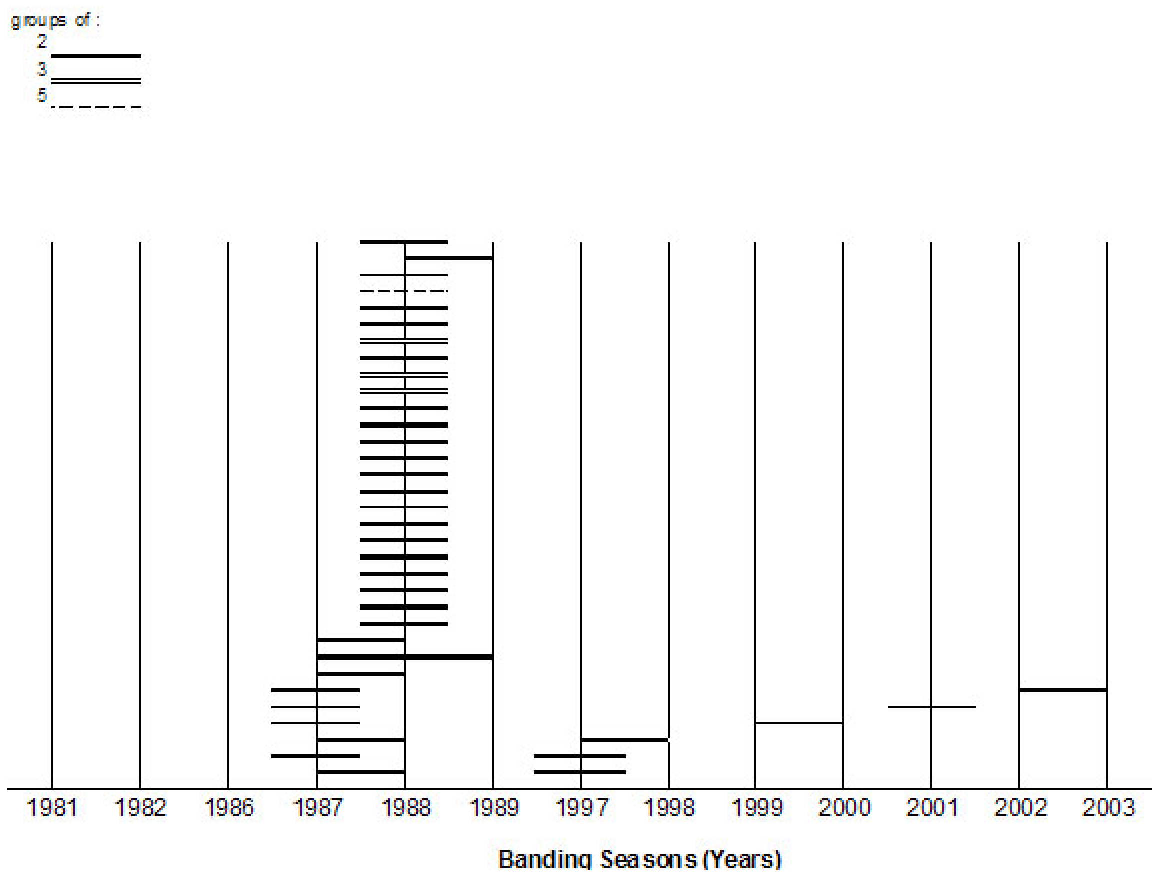
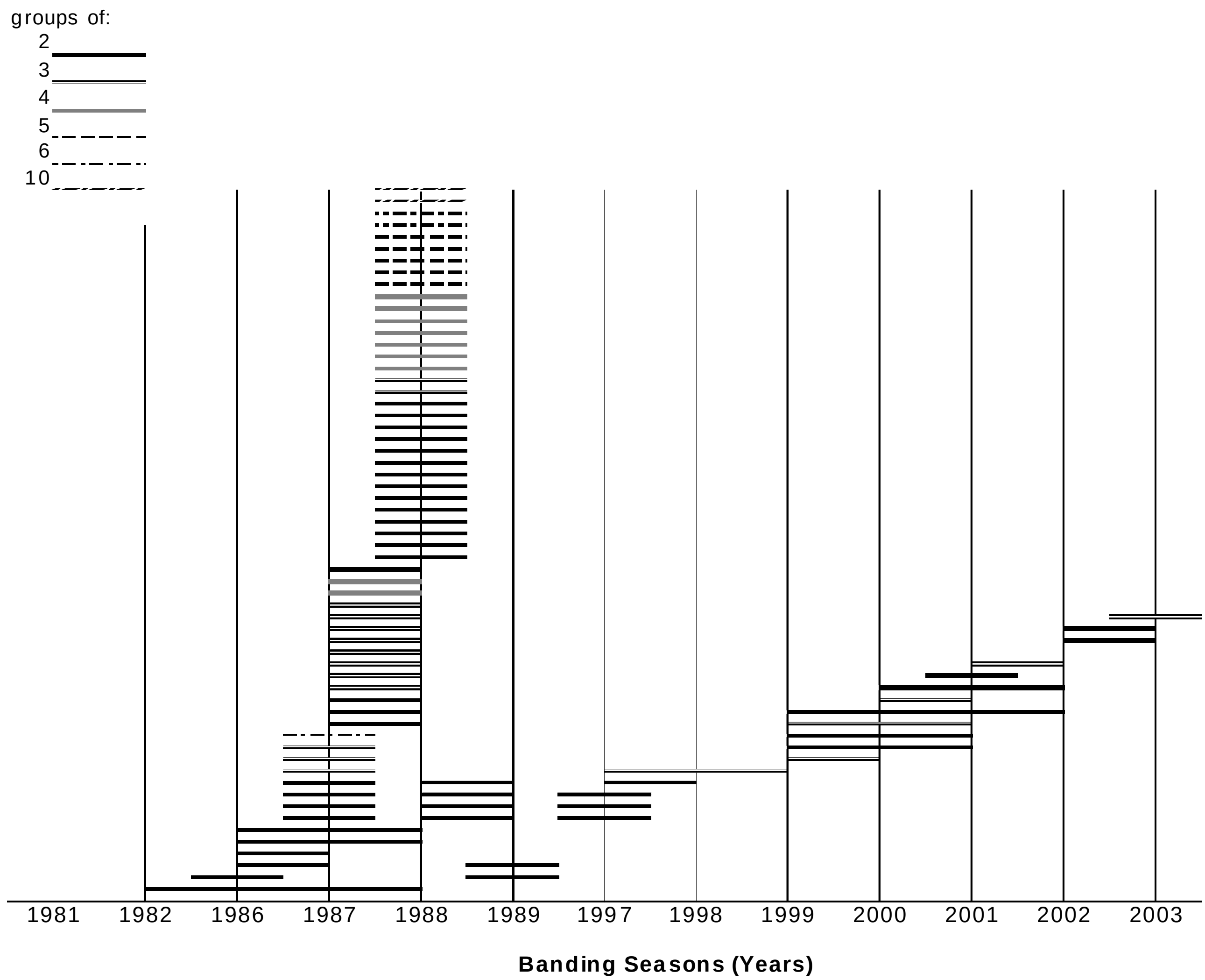


Figure 4. Re-captures of grouped Semipalmated Sandpipers banded and re-captured within 48 hours of each other (within and between years) at Johnson's Mills, NB, Bay of Fundy (1981–2003)



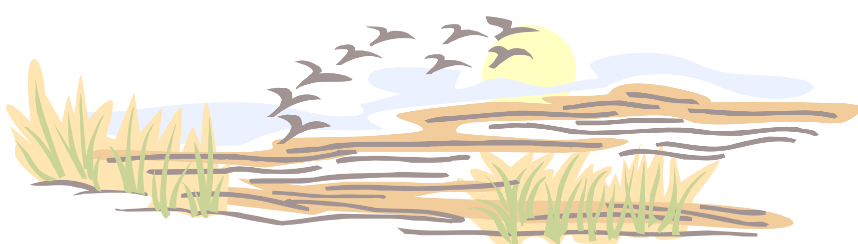
Session Three

COASTAL DEVELOPMENT AND SEDIMENT FLUX

Chairs: Mike Brylinsky, Acadia Centre for Estuarine Research, Acadia University, Wolfville, Nova Scotia

and

Hank Kolstee, Nova Scotia Department of Agriculture and Fisheries, Truro, Nova Scotia



WHAT IS "*NATURAL*" IN THE BAY OF FUNDY?

Hank Kolstee

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Numerous changes take place in the Bay of Fundy on a daily and annual basis. Change is always occurring—low tide, high tide, mudflats, gravel bars, grassy salt marshes, high marsh whose vegetation almost resembles upland vegetation. Within this context I restrict my comments to silt movement at several locations within the Bay.

What prompted me to talk about this is the fact that over the last several years I have heard a lot of comments regarding the mudflats in the Windsor, Nova Scotia area, near the Avon River Causeway. The general comments being "look at all the silt build up because of the causeway". There is no doubt that the causeway had an effect on where the silt is deposited, which by the way is still changing and may continue to change forever.

However, the main point is that two other very distinct areas that have mudflat build up over the last 30 years are not at all associated with the causeway. Amherst Point is actually an area that is eroding at a fairly rapid rate, while the area adjacent to it has built up to the extent that over 50 acres/hectares are now covered in grass. Why has this occurred? The flow patterns would not suggest obvious reasons for the change. What will happen here over the next 20 years? Will we have a point that will be known as Lower Maccan Point?

At Old Barns, considerable amounts of silt moved in a relatively short period of time. The large aboiteau was built at its present location in 1957 and was rebuilt in 1996. During this time no adverse effects on the operation of the aboiteau were noticed, although silt has built up to a considerable extent. In the late 1990s, with some very dry summers resulting in very low runoff, the aboiteau was at one point completely blocked and this caused some flooding in low lying areas of the marsh. Subsequently the gates were propped slightly open so that a small amount of tidal water could flow upstream. This served to allow enough water to flow back and forth to keep the aboiteau open. This poorly draining system stayed in place until 2001 when rapid erosion (rate of 5 ft/day) occurred. At this time the aboiteau outlet channel started to drain into the main river channel again and the aboiteau operation greatly improved.

For the 56-day period in 2001 when erosion rate was measured, an average of six yds^3 of material was removed every minute of every day. Where did this material move to? No major silt bars were noted, apart from the usual seasonal build ups that occur. Could this be a usual occurrence that happens somewhere in the system every year and was only taken note of because it so adversely affected our aboiteau structure?

Considering the mudflat at the causeway, it should be noted that mudflats previously existed at the place where the causeway is now situated. The shape of the mudflat changed but the general location was the same. There were also mudflats above where the causeway now exists. Actually, flow deflectors were constructed at one time in an attempt to keep the Windsor Wharf area free from mud. This only met with limited success. The people responsible for the causeway construction expected that mud would build up against the causeway within several years. In fact, a channel adjacent to the causeway stayed open until the mid-1980s, and is still in the process of being filled to the height of the remaining mudflats.

The channel adjacent to the causeway would partially fill each summer, but generally the next spring it was back to previous years size. One year it did not flush out in the winter, and the following summer the silt built up to such an extent that it has not opened up again.

What determines where the channels and silt bars are located? My theory is that tidal ice deposits in the winter determines where the channel will be located. Large amounts of tidal ice move during peak high tides and get deposited; with the right weather conditions this ice gets frozen at a location and prevents water from going through that channel. The mudflats are more easily moved than the large chunks of ice. This makes it extremely difficult to determine where the next build up or erosion will occur. Nature has a way of determining its own direction and in some cases there is little man can do, especially as it relates to water and silt movement in the Bay of Fundy.

Observations at site NS15, Isgonish River, show how silt builds up in the channel. The difference in the river bottom elevation is about three meters between May and August. This occurs every year, although the actual amount of deposit varies each year depending on rainfall amounts. In 2004, build up was only two meters.

Outlet channels can also change over a very short time frame as seen at VDJ Marsh NS-12. Over winter the channel changed from a problem channel because of a now direct route to the main channel. Change is indeed natural in the Bay of Fundy.

SEDIMENT MOVEMENT IN THE SALMON RIVER ESTUARY, TRURO, NOVA SCOTIA

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Abstract

This research in the upper reaches of the Bay of Fundy examined the sediment changes occurring over two years in a 4.8 km section of the Salmon River Estuary of the Cobequid Bay, at Truro, Nova Scotia. Using water samples collected at the surface during slack tide, the sediment concentration from the water surface downward to a maximum depth of 2.4 m along the estuary is characterized. Particle size analysis by the hydrometer method is used to determine particle size changes within areas of the estuary during the season. The migration of the estuary bedload landward into the system was measured from three bridges crossing the estuary, as well as the tidal range at the seaward end of the study, all based on geodetic elevation. This allowed comparison of the tidal heights, the estuary infilling and water column depths to each other. Results indicated that the estuary is significantly infilled with sediment over the summer, restricting the estuary channels, and that this sediment remains until winter hydrological conditions prevail.

Introduction

The town of Truro is one of five designated Flood Risk Areas under the Canada-Nova Scotia Flood Damage Reduction Program undertaken in the 1980s by federal and provincial governments (Service Nova Scotia and Municipal Relations 2000) and is the only such designated area located on the Bay of Fundy. Therefore, evidence of any estuary discharge channel restriction and its duration may have some influence on this designation.

The purpose of this study is the characterization of the intertidal sedimentary environment of the Salmon River Estuary, showing that the tidal intrusions of the silt over the summer months significantly restricts the estuary channel cross-sectional areas and the suspended sediment concentration changes both temporally and spatially.

Methods

The study sites were at four locations 141 m, 2,502 m, 4,542 m and 4,819 m upstream from the lower boundary of the study area during the summer months. Measurements were made of: (i) sediment concentrations in the water column within specific ranges of depth from the water surface, (ii) particle size distribution of the collected suspended material at the four locations, (iii) the net deposition of sediment at 0 m, 4,542 m and 4,819 m, (iv) tidal peak ranges at 0 m, the lower boundary of the study area and, (v) electrical conductivity (EC).

The sampling of the water column was conducted during each monthly high tide series, from June to November 2000 and 2001, from the water surface downward. The sampler was designed to open when the tidal peak caused a float to trip, allowing water into the 50 mL sample vials equally spaced at 0.61 m along the sampling platforms. If the tidal influx was lower or higher than predicted from the Saint John tidal charts, then the sample collected would be within the 0.61 m spacing.

The sediment concentration in the samples was measured by a gravimetric method and the particle sizes of the suspended sediment were determined by a modified procedure used by NSAC Soil Analytical Laboratory (Brewster 2001). Only complete sample sets of the water column profile from individual sampling platforms were selected for particle size analyses.

Measurement of the tidal high water elevations were made by a Sonic Ranging Sensor (Campbell Scientific 1994) and was referenced to geodetic elevation, allowing the comparison of the tide height to any point within the estuary and elevations of deposited sediment. The tides were measured in 15 minute intervals in 2000 and in one minute intervals in 2001, allowing a profile of the incoming tide and tidal bore to be compiled.

Results

The study used a definition of fluid mud as being greater than of 20 g L^{-1} (Guan et al. 1998) and less than 250 g L^{-1} (LeNormant 2000). Eighty-one percent and 88 percent of all sediment concentrations collected in 2000 and 2001, respectively, were greater than 20 g L^{-1}. Between 20 and 24 percent of the sediment concentrations were greater than 250 g L^{-1} in 2000 and 2001, and according to LeNorment (2000), that makes the mud act as a viscous fluid. Mean sediment concentrations increased downward from the surface, indicating possible sediment size stratification within the water column.

Examination of the suspended sediment revealed that at mid-estuary very fine sand was the dominant particle size and at the upper reaches of the estuary it was silt. The competence of the tide was such that the majority of the sediment sample concentrations were well sorted and skewed in the negative direction, indicating a predominance of fines.

Converting changes between each successive cross-section measurement from the three bridges crossing the estuary to a percentage of the total channel area showed the dynamic nature of the erosional and depositional environments at these three sites. The measurements, before and after a monthly spring tidal event, showed the estuary channels at the start of the season had sediment deposits occupying a small portion of the discharge channel area and were steadily infilled as the summer progressed. The maximum channel area occupied by the sediment deposits annually were as high as 48 percent, 35 percent, and 45 percent in 2000 and 48 percent, 47 percent, and 62 percent in 2001 for the 102 Highway Bridge, North River Bridge and the Park Street Bridge, respectively, indicating a tidal pulsing of sediment into the estuary.

Typically, at each sampler location, the higher mean salt concentrations occurred vertically at the 0 m and 0.6 m depths, declining as the sample depth increased. The estuary had a higher salt content at the seaward end of the study area to mid-estuary, diminishing in the landward direction. The salt concentrations followed the tidal cycle; when the successive tidal height was higher the salt concentrations rose, and fell when the successive tide was lower. Only when a rain event greater than 29 mm occurred did the salt concentration again fall dramatically.

The tidal measurements of the Salmon River Estuary were found to be highly correlated to the predicted Saint John tidal highs (Minister of Supplies and Services Canada 2000 and 2001) and were higher than the predicted tidal highs by 0.76 m and 0.72 m in 2000 and 2001, respectively. Examination of tidal curves show that the flood tide was the dominant sediment transport mechanism during the study years. The 2001 minute analysis of the tidal profile revealed that tidal resonance started at tides above 8.70 m geodetic elevation. The mean calculated tidal velocity is 0.99 km h^{-1} ± 0.23 km h^{-1}. The bore mean speed recorded was 7.75 m s^{-1} ± 0.27 m s^{-1} and the mean tidal bore height was 0.21 ± 0.17 m.

Conclusion

The Salmon River Estuary is a flood tide dominated estuary with stratified suspended sediment concentrations exceeding 20 g L^{-1}. The sediment deposit accumulations during the summer restrict the discharge area of the estuary channels. The deposits of sediment remain until freeze-up and may play a part in the reoccurring winter floods prevalent within this section of estuary.

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THE EFFECTS OF LARGE-SCALE BARRIERS IN RIVERS OF THE BAY OF FUNDY: OBSERVATIONS FROM THE PETITCODIAC RIVER, NEW BRUNSWICK

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Industrial and municipal developments have led to changes in the natural processes and health of several rivers discharging into the Bay of Fundy. Perhaps the most noticeable of these alterations has been the construction of barriers that impede tidal flow. One example is the Petitcodiac River, New Brunswick, where the hydrological and geological characteristics of the river were changed dramatically by the construction of a causeway in 1968. Following construction, the channel downstream of the causeway quickly filled with sediment, reducing the cross sectional area by as much as 90 percent. In 2002 and 2003 the Science Branch of Fisheries and Oceans Canada carried out a field study to evaluate the present sedimentary and hydrologic conditions in the tidal reaches of the Petitcodiac River. In this study it was observed that the operation of the causeway gates influenced the river flow up to 5 km downstream. In addition, salinity and temperature effects could be seen up to 34 km downstream of the causeway. Both flow conditions and the magnitude and extent of the saltwater intrusion depended upon causeway gate operations. The hydrodynamics of the estuary are further complicated by the high concentration of suspended sediments found below the causeway. Hindered settling and the creation of fluid mud layers characterize these sediment suspensions. Both these phenomena can have significant effects on the hydrodynamics of the river flow.

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THE EFFECTS OF TIDAL BARRIERS IN HIGH ENERGY ENVIRONMENTS: CONSIDERATION OF LARGER SPACE AND TIME SCALES

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Throughout history, anthropogenic modifications have caused extensive changes in the hydrological and geological characteristics of tidal rivers in many parts of the world. These changes often extend over larger space and time scales than are immediately apparent. The impacted systems may not reach equilibrium for many decades, if at all. In addition, the spatial extent or full implications of the impacts may not be appreciated. Some local examples of tidal river modification are the causeways constructed in the late 1960s in the Petitcodiac River, New Brunswick and the Avon River, Nova Scotia. In both of these estuaries, the causeway construction resulted in rapid sediment accumulation on the downstream side of the barriers. The operation of gate structures to prevent the intrusion of salt water above the barriers has also had a severe impact on fish passage and navigation. In the Petitcodiac River, there is evidence that the system has not yet reached equilibrium, more than three decades after causeway completion. Other evidence seems to indicate that the sediment distribution nearly 34 km from the causeway was changed by causeway construction. Reduced flushing and tidal exchange in the upper reaches of the river may also result in reduced dilution of effluent from the city of Moncton.

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THE AVON CAUSEWAY: IMPLICATIONS OF THE CAUSEWAY REMOVAL

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The removal of the Windsor Causeway at Windsor, Nova Scotia, were it to occur, will have an impact on a number of conditions that exist in the area of the causeway. I will briefly discuss seven items that need to be considered. There may be others, but these are the most obvious.

Loss of Agricultural Land

If the causeway is removed, a certain amount of agricultural land will be lost. At the present time the causeway protects 1,400 hectares of agricultural land. If none of this land is protected with dykes and if the causeway is removed, it would eliminate the majority of farms in the Martock-Falmouth area. Some farms have as much as 95 percent of their land as dykeland. Dykeland is some of the best agricultural land in Nova Scotia. The freshwater lake in this area, Lake Pesaquid, adds to the value of this farmland as it is a good source of water for irrigation.

Rebuilding dykes would still involve loss of land since space is required for dykes to be constructed on, as well as between the dyke and river's edge in order to excavate material for the construction of dykes. A minimum of 150 hectares would be lost. In addition, 25 kilometers of dyke would need to be constructed along with 33 aboiteaux; this amounts to a minimum cost of 3 to 4 million dollars.

Changes in Flooding Potential

At the present time, with the causeway in place, Lake Pesaquid acts as a storage area during rainfall events. If heavy rains are forecast, the lake level is sometimes lowered to provide additional storage. The normal lake level is 3.0 meters. A normal high tide can reach an elevation of 7.9 meters. Dykeland levels are at about 6 meters. Therefore, approximately 3 meters of water can be stored in the headpond before any significant flooding occurs. At the present time, since there are no dykes above the causeway, a water rise of another meter could occur before major roads become inundated, although agricultural land would flood. Some houses have been built at the dykeland level, and these would become subject to flooding with the removal of the causeway. Changes have taken place in the watershed since the causeway was built. Clear cutting has increased considerably, resulting in increased rates of runoff. This could make flooding considerably worse than prior to the causeway construction.

If the causeway were removed and no dykes replaced, extensive flooding would occur on every high tide cycle of the month, including the inundation of houses that have been built at marsh level. If dykes were rebuilt, flooding would not be as severe, but extensive flooding would still occur, since the only storage area would be the dykeland behind the dykes, as the river would fill up with salt water. This would impact a number of major traffic routes in the area. Would this be an inconvenience? I will leave that to the people who travel these roads to decide.

How is the Town of Windsor to be Protected?

Since the causeway has been constructed, several developments have taken place along the waterfront of Windsor. These buildings and town infrastructure would be subject to daily tidal flooding with the removal of the causeway. To make matters worse, this is not simply clean water but water laden with silt. A decision would have to be made as to whether to remove all the buildings that are below high tide elevation or to attempt to waterproof these structures. Apart from high tides, you also have to consider what happens when high tide occurs at the same time as high runoff from rainfall events. This could cause flooding well beyond areas where tidal waters normally reach.

Changes to Recreational Value of the Now Existing Lake

At the present time the town of Windsor and the surrounding area have a lake that is used extensively for recreation. This would disappear if the causeway was removed and you would see instead the type of mudflats and channels that now occur downstream of the causeway. Again the local people will have to choose the type of surroundings they want. Also Ski Martock, a nearby downhill ski operation, draws all their water from Pesaquid Lake for snow making. They would have to find an alternate source at considerable expense.

Changes in Fish Passage

With the causeway in place there is limited opportunity for fish passage. The fish can only pass through the gates for relatively short periods of time. This occurs when the gates are opened and the tide and lake levels are nearly at the same elevations. This same condition occurs again when the gates are closed on the rising tide. If the causeway was removed, the fish would have unlimited passage. At the present time, if the lake is kept at normal operating levels, the most opportunity would occur if the gates are opened on each tide cycle thus giving four time periods a day when fish could pass through the opening. If runoff is very low and the gates are not opened, no passage for fish exists. The only other time when fish passage is available is during spring maintenance when the lake level is lowered and the tide gate is kept open during low tide and natural flows occur. How much extra fishing potential is present now when the lake exists for most of the year is a question that remains unanswered.

Changes to Existing Riverbanks

At the present time, the area above the causeway has a freshwater environment. The river banks have stabilized with grass growing on them and in many places bushes are starting to grow. Removing the causeway would kill the existing vegetation and it would be a number of years before salt tolerant vegetation would start to grow again. What type of river bank is preferable?

Cost of Causeway Removal and Construction of Bridges

It required a million tonnes of rock to construct the causeway. If all this rock were removed, what would be the cost? Five to six million dollars? Actual costs would depend on where the rock could be hauled to. Suggestions have also been made that only part of the causeway needs to be removed. If that occurred, removal costs would be lower but, mudflats would then exist within a short period of time both below and above the remains of the causeway. Would this be desirable? The Nova Scotia Departments of Transportation and Public Works have estimated that a replacement bridge for the causeway would cost between 50 to 100 million dollars, depending on how much of the causeway was removed. One then has to look at how much it would cost to provide a railroad bridge. No doubt this cost would be quite significant. Who would pay for this railway bridge? I am sure Windsor-West Hants Railway would not.

The road bridge between Falmouth and Windsor, a short distance above the causeway, would also need significant changes. The bridge length would need to be lengthened considerably and some of the causeway removed, again at a considerable cost.

Conclusion

It can be seen from the foregoing that several issues have to be addressed before considering the removal of the Windsor causeway. Like most things there are two sides to the story. One has to weigh the pros and cons and come up with a logical decision based on facts.

CROSSING AVON: ENVIRONMENTAL IMPLICATIONS OF TWINNING HIGHWAY 101

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Current plans for twinning Highway 101 in Nova Scotia call for an expansion of the causeway at Windsor to accommodate either two or four additional lanes. Because of infrastructure and property issues, the expansion would likely occur on the seaward side of the causeway over a mudflat-salt marsh complex that has evolved since the causeway was constructed over three decades ago. Recent research has shown that the salt marsh is extremely productive and is expanding at an unprecedented rate. As a consequence, productive mudflats inhabited by invertebrates that supported important fish and bird species are being converted to marsh, and migratory birds are moving to other foraging sites. The implications to the mudflats of expanding the causeway will be discussed.

Note: ACER has prepared two recent technical reports on this topic.

Session Four

SUSTAINABLE USE AND MANAGEMENT OF THE BAY OF FUNDY

Chairs: Dave Duggan, Fisheries and Oceans Canada, Halifax, Nova Scotia

and

Barry Jones, Gryffyn Coastal Management, Fredericton, New Brunswick

COMMUNITY-BASED CO-MANAGEMENT OF SCOTIA-FUNDY GROUNDFISH: TOWARD SUSTAINABLE FISHERIES AND SUSTAINABLE COMMUNITIES

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Abstract

Historically, Atlantic Canada's fishing economy is reliant on groundfish. Nonetheless, there has been a demonstrated lack of success in groundfish management, due in no small part to a history of multiple conflicting management objectives, which include economic, conservation, and employment goals. In addition, fishing communities' goals for and existing interactions with the resource, as well as the effects of policy on human communities, have largely been ignored.

In 1996, an experimental community-based co-management (CBCM) system, developed in conjunction with fishermen and Fisheries and Oceans Canada (DFO), was introduced in Scotia-Fundy's under-45 foot, fixed-gear, inshore fleet. The fleet (2,500 licences, about 850 of which are active) was divided into eleven county-based community groups. Within each community, management boards are responsible for the distribution of catch allocations and for the development of management plans that suit the needs of their community. These communities are now responsible for managing remaining stocks in a manner that ensures conservation of groundfish, of their own livelihoods, and of the integrity of their communities.

This paper assesses the relative success of CBCM management boards, in terms of meeting conservation, economic, and social goals, and in terms being robust and enduring institutions. The Fundy Fixed Gear Council is examined in more depth, to assess the rules they have created and why, as well as how those rules interact with social norms and with other layers of management. Implications for resource management and for community-based management, in Atlantic Canada and in general, are also explored.

Emergence of Community-based Co-management

The Scotia-Fundy inshore groundfish fishery is a multi-species fishery characterized by high diversity of boat sizes and types, as well as a diversity of community and habitat level ecological interactions (DFO 2002) (Figure 1). While many fishermen now concentrate on invertebrate fisheries, Atlantic Canada is historically reliant on groundfish. Meanwhile, there has been a demonstrated lack of success in groundfish management, due in no small part to a history of multiple conflicting management objectives, which include economic, conservation, and employment goals (Fanning 1999). The under-45 foot, fixed-gear (FG) (hand-line, long-line and gillnet) fleet has approximately 2,500 licenced boats, over 850 of which are active (DFO 2002).

The Haché report (1989) warned that overcapacity in the inshore FG fleet remained an unaddressed problem, as the rest of the industry was converting to Enterprise Allocations and Individual Transferable Quotas (ITQ) in an effort-limiting 'rationalization' attempt. In 1996, after two years of conflict and mediation, an experimental community-based co-management (CBCM) system, developed in conjunction with fishers by DFO, was formally introduced in the Scotia-Fundy inshore FG groundfishery. The fleet was ultimately divided into ten community groups based on geographic location (see Figure 2), and each community was given a share of the sector's Total Allowable Catch (TAC) of cod, haddock and pollock, based on the sum of the individual catch histories for the years 1986-1991. Within the communities, management boards are now responsible for the distribution of catch allocations and for the development of management plans. Due to the history and importance of fishing in Atlantic Canadian communities, social concerns are important to inshore sector management, and communities now grapple with certain novel questions: Should fishing benefit individuals, or should it benefit communities as a whole? Should fishing be a safety net for those with limited employment options in rural communities (Fanning 1999)?

An Analysis of CBCM: Rationale and Research Questions

Drawing on the tradition of common property management of common pool resources, the evolution of CBCM may represent an innovative approach to fisheries management that lets organizations develop rules that reflect their community's ecological and social context (Fanning 1999). This study compares the management institutions established for the governance of CBCM to determine what rules have been created and why, to assess their relative success, and to place CBCM in the context of common pool resource literature and of Canadian fisheries management policy. A qualitative approach was employed to assess the management boards, in terms of meeting conservation, economic, and social goals, and of fostering institutional robustness, and to attempt to generalize about the effectiveness and benefits of community-based co-management as it is practiced in Atlantic Canada. All ten boards were involved in a preliminary round of study, while a second round provided in-depth analysis of three management boards, the Fundy Fixed Gear Council (FFGC), Eastern Nova Scotia 4X (ENS 4X, including Sambro) and Shelburne B, which were selected for a diversity of management approaches and location (Figure 2). The FFGC is examined in depth in this paper and presented along with results of the first round of study.

Evaluation Criteria

Institutions consist of the set of rules that determines, among others, who can make decisions, which actions are allowed or disallowed, which procedures are followed, and which payoffs are assigned (Ostrom 1990). To endure, an institution must be robust to change and to stress placed upon it by the human community and by the resource itself. Consequently, institutional functioning can be looked at as an umbrella that encompasses ecological, economic and social aspects of management. To evaluate a co-management institution for the management of a common pool resource, the criteria considered by different authors (Pinkerton 1989; Ostrom 1990; Berkes et al. 2001) were reviewed and synthesized. When considered in sum, their approaches address not only what criteria assist co-management institutions to emerge and endure, but what conditions should be present in the resource and in the community. To determine if an institution is ‘successful’, one must consider the context, including the goals—as well as the subjective experiences and perceptions—of the parties involved, in this case, of the managers who form the management board and DFO. Whether CBCM in general, and FFGC in particular, possess these criteria is discussed below.

Results

An Institutional Look at CBCM Management Boards

Description of the Fixed Fishing Gear Council

The FFGC manages 228 licences from the Yarmouth-Digby county line in Nova Scotia to the New Brunswick border, and has been allocated about ten percent (depending on species) of Scotia-Fundy groundfish quota. According to one board member, approximately 80 of those licences are active, but only 30 target cod, haddock and pollock (the remainder fish halibut and dogfish). A majority of the active licences are in the Digby Neck area. The FFGC consists of up to nine members: three from each of two local fishermen’s associations, and three seats are reserved for non-fishing members of the community (although those have not been filled in the past few years.) Three gear type subcommittees each consist of one member from each port. As the FFGC further divides its allocation into a share for each gear type, each subcommittee brings its allocation plan to the FFGC for approval, and the FFGC plan is then submitted to DFO for approval. As with all management boards, fishermen must sign a contract with their board before they are granted conditions to fish (although fishermen can opt for DFO-managed ‘Group X’ if they choose not to belong to a management board; eight fishermen did so last year). Decisions made by the FFGC must be unanimous. Through the Council, resource users have the opportunity to participate in rule making (Ostrom 1990). The group of resource users is then clearly defined, which Ostrom (1990) identifies as important; meanwhile, fishermen are not only geographically dispersed, but use a diversity of gear types and have diverse histories in the fishery. Also problematic according to Ostrom (1990) is that by the nature of the resource, its boundaries cannot be clearly defined.

Whose fish is it? Underlying beliefs revealed in allocation decisions

Ostrom (1990) found that appropriation rules must be relevant to local conditions. Managers from all communities grapple with allocating quota, as those decisions often reflect communities’ fundamental values. One manager from FFGC asked, “Are all entitled to same time at sea, same income, same amount of fish? ... If you have a very good aggressive fisherman should he kind of pull back to let the guy who just wants to tinker around a bit till he gets his fair share as well?” In terms of allocation decisions at FFGC, the Council does not consider an individual’s catch history or fishing activity, as “each person is treated equally. It don’t matter whether ... they’ve been at it every year”. Most fishermen (depending on gear type) who want to fish the community’s allocation are given an equal share, which reflects a relatively egalitarian approach, as compared with that of some other communities.

Management capacity (or lack thereof)

Fishermen witnessed dramatic changes in their fishery even before the inception of CBCM, but CBCM brought a radical change in their role in the fishery: *fishermen must now assume a management role where none was required before*. This new challenge has been addressed in different communities with varying success. At the FFGC, only 20 of 103 fishermen (invited) attended an annual general meeting. One manager argued that most have lucrative lobster licences and accordingly are not concerned with groundfish. "A lot of them have many opinions on how the fishery should be run on the end of the wharf" but are not willing to express those in meetings or to take a role in management. This leaves decision making to a few locally important people and makes communication more difficult with those who choose not to participate. While Pinkerton (1989: 29) identified an "energy core" of dedicated individuals as important in co-management, this represents a critical lack of management capacity for DFO. One official suggested that the boards need to communicate better and to work on getting more people involved. Meanwhile, lack of participation in management is a common problem across all communities, and the FFGC works to overcome this problem. Among others, the Council is engaged in building capacity by developing various projects, seeking funding and creating the Marine Resource Centre.

The role of DFO

In some communities, managers express the sentiment that CBCM is simply an exercise in downloading by a cash-strapped DFO. On FFGC, the attitude was: "Well, if they're going to give up an inch of management authority, well, we should take an inch, and even if we don't have the money to do it, the wherewithal, the knowledge, we should." In fact, some feel that DFO 'did them a favour' by allowing CBCM to evolve and by not providing any support. Across all communities, almost every study participant maintained that if fishermen or managers attempt to involve DFO officials in a dispute, DFO will refer them back to their management board. Accordingly, "there is no going to DFO because they didn't care ... so fishermen realized that they had to work together. They couldn't go to big brother DFO to bail them out, or they couldn't go to their local MP, or follow some political lead or whatever, they knew that the only way they were going to fishing was to go through the MB [Management Board]."

Property rights

Another threat to CBCM is that while communities have access and management rights, they do not have full property rights over the resource. The TAC (total allowable catch) is set by DFO, and the formula for quota sharing between communities is also done by DFO. Fishermen have been involved in those processes, but as DFO is constitutionally obliged to conserve and to manage ocean fisheries, it has the last word on management decisions. DFO has expressed the intention to work with resource users in management (see Atlantic Fisheries Policy Review and the *Oceans Act*), in order to reduce costs through reduced management (and enforcement) expenses, and to involve those who have the knowledge and the interest to protect the resource. However participants in CBCM remain wary, as they feel that "every fishery except for lobster and this little bit of groundfish quota has essentially followed the course that was set out 20 years ago, which has put the actual quota access in a few private hands." Authors such as Ostrom (1990) and Pinkerton (1989) emphasize the importance of a legal framework that supports institutions and their decisions. In CBCM, resource managers feel insecure not only about whether their decisions will be supported, but whether the management system will be allowed to continue to exist. Civil contracts between fishermen and management boards are one way to establish a MB's legal authority, and to create legal support for the MB-fisherman relationship. Yet higher-level policy and administrative support is still lacking, and while the relationship between the MB and fishermen may be secure, the relationship between the MB and DFO remains tenuous.

Some members of at least one community feel that they would benefit from moving toward a formalized ITQ (individual transferable quota) system, which would grant a form of property rights to the few who possess sufficient catch history. Presently, more than one community internally allocates their quota like an IQ by assigning seasonal limits to fishermen, in some cases based on catch history. Some managers have expressed concern over this development as ITQs can lead to quota concentration and can eliminate people from the fishery. Even DFO does not appear to support the move. In 2004, the FFGC gillnetters have "gone past the norm" by dividing their quota equally amongst themselves and fishing a seasonal limit. One manager insisted that this "still isn't turned into an IQ ... because it's still handed out to their group by DFO as a total amount of quota, a community group quota, and it's just that's how the community or their members have decided to deal with their quota."

Li (2002) criticizes community-based resource management literature for assuming that communities have a heterogeneous interest in their resource, and that resource users will behave in a manner that is divorced from rational self-interest. The conflict over ITQs reveals that different interests and goals do exist in the communities: some stand to gain, where many others might lose substantially. At the outset of CBCM, communities were allocated quota based on collective catch history of each individual, not of the community, and that might exacerbate (or be the root of) this problem. In many communities, individuals feel as though they contributed more to their communities' total allocation and now receive only an equal share.

Social/Community

Compliance in the fishery

CBCM appears to have increased compliance in the fishery by fostering a sense of ownership over the shared resource (Berkes and Farvar 1989). One board member explains, "with DFO running the show" people wanted to "stick it to government. Now this is the fishermen's plan." Under CBCM, fishermen "weren't cheating DFO, they were cheating their neighbour. It was not somebody far away or some other fishermen's organization or government telling them what to do, it was their plan, they owned it and they were making it work." Peer pressure also appears to play a role in constraining cheating behaviour, because "when you don't comply with DFO, nobody knows who you are—with CBM, everybody knows."

Infractions do continue to exist in the fishery. However, in every community, conflict-resolution mechanisms exist, as do accountable monitoring and graduated sanctions, which according to Ostrom (1990) are crucial for success of a common pool resource institution. While only DFO can annul a fisherman's licence, the ultimate sanction in CBCM is removal from the management board: a participant from FFGC stated that "threatening somebody with removal from the MB [is] a very serious threat ... we [have] every right to demand compliance. And to enforce that." The Infractions Committee of FFGC is anonymous, so that "you go out to a dance or something and there's buddy right there beside you – I'm sure individuals don't want him to know that, you know, I'm responsible for kicking you out of the fishery for two years."

Economic

Latent fishing capacity

Many claim that CBCM allows people to keep fishing, which might meet a community's implicit goal of maintaining employment in the fishery, while perhaps not meeting DFO's goal of "efficiency" and capacity reduction. There remains much latent capacity in the groundfishery in the form of inactive licences. The importance of the groundfishery in terms of fishing activity and income varies among communities, but it has been dramatically reduced as participants leave the groundfishery for the lucrative lobster fishery. Two opposing views are expressed regarding whether fishermen would reactivate groundfish licences if the lobster fishery were to decline: "Quotas are so low, availability is so low, rules are so strict, why would they want to get in?" (southwest New Brunswick); alternately, "If lobster fishery goes down, 200 + licences [might want] back in – that could be devastating" (FFGC).

Addressing economic issues

For FFGC, employment insurance (EI) is an important part of their industry: "It's a do or die thing. If [some fishermen] don't get their unemployment then they'd never survive." The Council addresses this by incorporating qualifying for EI into their allocation decision: "That's why we try to stretch [our]" allocation. Strategies adopted by FFGC to raise funds for management include discussing forming a marketing cooperative for handline fish and collecting back dues as a way to make money for the Council.

Conservation

Although there is disagreement about whether fish stocks are rebuilding under CBCM, the sentiment that "community-based management would be great if there were enough fish" (FFGC) was repeatedly expressed during the first round of interviews. Berkes et al. (2001) and others contend that communities themselves have the best knowledge of the resource. Board members frequently accuse DFO of mismanagement and of bad science, and blame draggers and other types of fishing for the extremely low quotas they are allocated today. Managers feel that DFO chose to download management responsibility and expense only once the resource was decimated. Today, the impacts CBCM, or the decisions of FFGC, have on fish stock health remains unclear. However, it is clear that the communities all feel that they were treated unfairly in the initial allocation of quota, and that they continue to be marginalized.

Implications for Community-based Management

FFGC Conclusion and Policy Implications

According to one local expert, CBCM has "taken root in a place like [Digby county] ... it is part of the community here, it's the way the fishery's worked, there's a very broad social consensus around that." There appears to be the social will and self-driven capacity building necessary to create a successful co-management institution under the conditions that exist in and around Digby County. Meanwhile, FFGC managers still struggle with defining "What is community-based management? Is it what's good for the fisherman or what's good for the community?" They express wariness at involving non-fishing community members in technical management decisions, but recognize that their decisions may impact on the greater community. FFGC is also considering an ecosystem-based approach: "All we're doing is DFO's dumping a few fish on the table here, we're fighting over it, and we go out and catch 'em. That's it. We've got to get more people involved. And it has to be more than just groundfish ... these community quotas ... they're groundfish quotas and that community-based management actually should be multi-species and ecosystem based". In this regard FFGC is ahead of DFO and Canadian fisheries policy, and in fact has made proposals to DFO to move toward ecosystem-based management.

Conclusion

This discussion has shown that CBCM, and the community management boards, possess many of the literature-described characteristics, and appears to be meeting many community and DFO goals. The questions posed by Fanning in her 1999 review of CBCM remain relevant and largely unanswered: Should fishing benefit individuals or communities as a whole? Should fishing be a safety net for those with limited employment options? The CCBM management boards struggle with these questions in their allocation decisions in the context of an overall management system that appears destined to concentrate quota and wealth and to decimate coastal communities. CBCM needs to have its role defined and cemented in Canadian fisheries and oceans policy. This unique policy 'experiment' should articulate for itself a clear mission statement, and some clear goals, since direction is lacking from the laissez-faire attitude of DFO. DFO needs to determine where CBCM fits within its mandate, and how to provide the conditions for enduring success: legal backing, organizational support where appropriate, and support for movements toward ecosystem-based management and other initiatives.

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Figure 1. The Scotia-Fundy Sector, Maritimes Region extends from Cape North, NS, to the Canada-United States border.

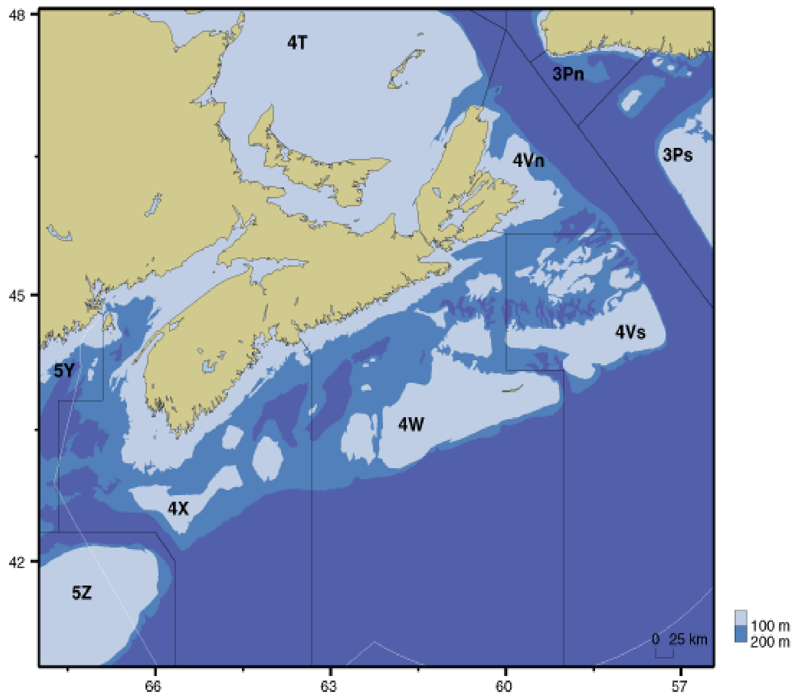
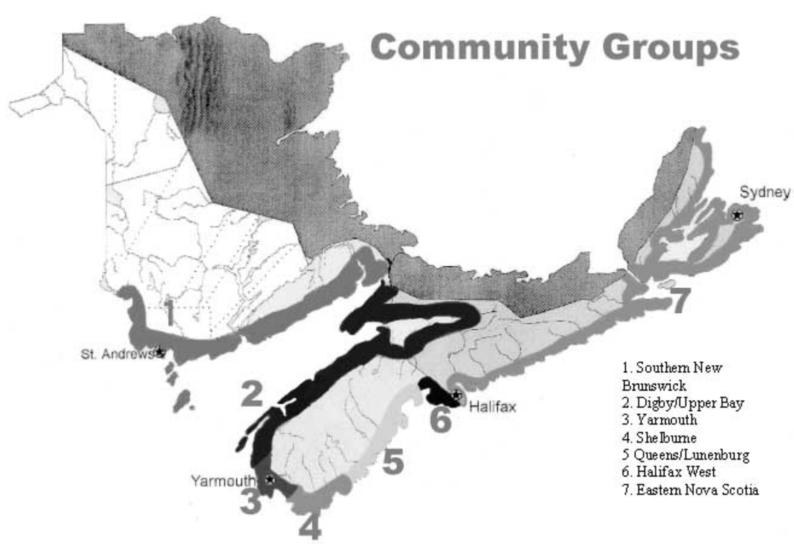


Figure 2. Location of community groups for CBCM in Scotia-Fundy. Shelburne (area 4) is governed by 2 management boards (Shelburne A and B), while Eastern Nova Scotia is governed by one for 4X, one for 4vSW, and one for Cape Breton, for a total of 10.



WORKING WITH MINAS BASIN WATERSHED COMMUNITY GROUPS

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As Minas Basin Working Group Coordinator I will speak about my experiences working with community groups in the Minas Basin Watershed Area. The Minas Basin Working Group (MBWG) is one of the working groups of the Bay of Fundy Ecosystem Partnership. One of the MBWG's objectives is to develop an Integrated Management Plan for the Minas Basin Watershed. In previous years, forums were held to identify issues and to begin networking with all the community groups. In the summer of 2003, I was hired as a coordinator for six months to work with community groups within the watershed to help them develop action and work plans.

As coordinator I made presentations to 22 community groups, arranged a website location where community groups could post their meeting information, collected and then compiled in a final report the mission and mandate statements of community groups, and updated the database of contact information on the community groups in the Minas Basin Watershed Area. The methods that were successful when working with community groups will be discussed.

"THE CAMEL PRINCIPLE": TOOLS FOR PARTNERSHIP BUILDING

Stephen Hawboldt

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The Clean Annapolis River Project (CARP) is a community organization formed in 1990 to work with communities and organizations to promote awareness about, and to foster the conservation, restoration and sustainable use of the freshwater and marine ecosystems of the Annapolis River and its watershed. Since its formation and subsequent invitation in 1991 to become part of Environment Canada's Atlantic Coastal Action Program, CARP has launched a series of community-based programs aimed at achieving its mandate. The cornerstone of these programs is a multi-partnership approach that involves all orders of government, the private sector, academia, international agencies and the general public. "The Camel Principle" is one of several tools that CARP has utilized to build these wide-ranging partnerships. This principle uses Aesop's fable of the gradual intrusion of a camel into its owner's tent as an analogy for the step-by-step approach needed to gain the trust, support and participation of all the stakeholders in a project. The hope is that other organizations might be able to adapt these tools to better achieve their respective mandates.

DEFINING THE ROLE OF THE COASTAL PLANNER IN NOVA SCOTIA

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Abstract

Coastal planners occupy a unique niche within the profession of planning. In contemporary Nova Scotian coastal planning, the potential for successful coastal planning is only slightly recognized. This study adds a new perspective to the field of planning by defining the purpose of the coastal planner and the core elements of effective coastal planning practice in Nova Scotia.

This study analyzes and highlights tasks, roles and requirements of the coastal planner to show how coastal planners differ from traditional land-use planners and/or coastal managers. By using an analysis of different types of planners' roles, work places, methodologies and related planning theories, this study shows how the different roles assumed by practicing planners can significantly shape the planning process and subsequently, the outcomes of planning. Finally, a modelling approach is used to present a legislative and management framework needed for effective coastal planning in Nova Scotia.

Introduction

Land-use planners participate in many activities that determine the use of land within a community, province or region. They routinely work on scenarios that directly affect the health and stability of natural coastal features and processes. Land-use planners, who have the responsibility to make land-use recommendations, are also capable of suggesting solutions for various land-based issues or problems. However, current attempts at land-use planning are falling short of addressing the myriad of issues, problems and opportunities in coastal areas. This study argues that the potential of land-use planning in coastal areas, especially in Nova Scotia, is not fully recognized.

Currently, many of the detrimental effects of land-based activities affecting coastal areas are addressed through the relatively new field of coastal management. Practitioners of coastal management (coastal managers) usually involve a diverse group of scientists, resource managers and public administrators who work collaboratively to develop "management plans". Such management plans work similarly to land-use plans; however, these "plans" often lack the planning "tools and techniques" required to fully achieve the desired outcomes of the management plan.

Compared to the practices of land-use planning in coastal areas and coastal zone management, coastal planning is much less developed, especially in Nova Scotia. The idea of coastal planning as a distinct practice of planning is a relatively new concept, as is its nature as a hybrid of other approaches (DFO 1997: 31). Without the recent exploration of the ideas of "sustainability" or "integrated management" or in a more strictly planning sense "environmental" or "social" planning, the concept of contemporary coastal planning would be incomplete (Glass 1973: 45). Advances in environmental and social thought have allowed for the proliferation of theories that can apply to, and improve, coastal planning.

This lack of understanding, regarding both how coastal planning functions and the role of the coastal planner themselves, is detrimental to planning practice. What results in Nova Scotian coastal planning is a scenario whereby the potential for successful coastal planning is only slightly touched upon. Hence the main research question: what is necessary for effective coastal planning in Nova Scotia?

Methodology

This study explored the field of coastal planning as a means of finding the most suitable and functional role for the coastal planner under the Nova Scotia system of land-use planning, coastal management and governance. The three main phases of this study were:

Step I: Exploring the role of the coastal planner

Coastal planning is often assumed to fit within the field of coastal zone management. This is a valid assumption, yet one that is not entirely correct. Many of the tasks, desired outcomes, projects and efforts of coastal planning and coastal zone management are similar but may be approached sometimes quite differently. Furthermore, land-use planning in a coastal area is also similar, yet fundamentally different from coastal planning. Once these two fields (land use planning and coastal zone management) are discussed and compared, the differences become clear.

The introductory task for this study was to explore the role of the coastal planner in Nova Scotia. Using a content analysis of both i) relevant literature related to this topic, as well as ii) discussion results from a series of coastal planning and management workshops, conferences and meetings, this study developed a summary model of the efforts of the three main practitioners in Nova Scotian coastal planning and management – the land-use planner in coastal areas, the coastal planner and the coastal manager. This compare-and-contrast method produced a robust explanation of the differences and similarities between the three types of practitioners and subsequently, clarifies the role and function of a Nova Scotian coastal planner.

Step II: Establishing a need for the coastal planner

Step I discussed the difference between land-use planners, coastal managers and coastal planners; however, Step II further defines the coastal planner by elaborating on the earlier focus of the plann*er* to discuss the process of plann*ing*.

Beyond the field of land-use planning, there is a certain confusion regarding the contribution of the land-use planner to Nova Scotian coastal management. For example, although coastal communities or areas could have a stated need for coastal planning, this need might not be addressed through contemporary land-use planning. The land-use planner and coastal planner would create different planning approaches and subsequently produce different planning outcomes.

For this study, the variables content, context, role and theoretical approach were applied to a framework of the planning process to display, first, the difference between the many types and streams of planners, and second, the need to have a particular type of planner to achieve a particular outcome or objective.

Step III: Recommendations for effective coastal planning in Nova Scotia

The next phase for this study suggested improvements in the legislative framework that governs planning in Nova Scotia. The field of coastal planning is complex and multifaceted. Coastal planning requires different approaches depending on the community or area in question. Suggestions for improving coastal planning start with recommendations for addressing the difficulties that exist specifically within the current government structures.

This approach required the compilation of the current models of coastal planning and management in Nova Scotia. In addition, hypothetical examples of probable scenarios for improved coastal planning and management were also collected. This approach yields two main benefits: first, highlighting various models provides an accurate comparison of coastal planning and management strategies, and second, problems that impede successful coastal planning become evident. New models for effective coastal planning and management in Nova Scotia can then utilize the positive aspects of the existing models while avoiding elements that hinder the planning process and outcomes.

Summary

The most important finding was that effective government-based, coastal planning in Nova Scotia is not functionally possible under the current legislative (i.e. governance) and management framework. The planning process is hindered by a chronic lack of coordination between planning practitioners, lack of decision-making power at the local level, and reduced or minimal resources (people, time and funds). Essential elements of the planning practice (jurisdiction, guiding principles, and legislative power) are needed and as a result, the potential role of the Nova Scotia coastal planner is undescribed and underutilized.

Creating a framework for coastal planning in Nova Scotia required observation of the current coastal planning and management system. Emphasizing the positives and consciously avoiding the negatives produced a series of recommendations for Nova Scotia coastal planning:

- Creation of a comprehensive coastal policy for Nova Scotia and formal recognition of it by the provincial government;
- Creation of a Nova Scotia coastal planning secretariat to consider, coordinate and organize provincial coastal planning efforts;
- Creation of a new statement of provincial interest regarding coastal planning;
- Review of recommendations from existing documents and projects related to coastal planning.

Unfortunately, no specific provincial body is entrusted to do coastal planning, let alone act on such recommendations. Until provisions are made to address any of these recommendations, there should be no assumption that the field of planning, under the current Nova Scotia governmental framework, is adequate to address the multitude of coastal issues and problems that continue to hinder coastal communities in the province.

In summary, the field of planning in Canada has developed to the point where coastal planning can now be considered a recognized discipline. However, if that discipline is to have any merit, then planning and management structures must adapt to the current challenges of coastal planning. These challenges lie within the institutions that create and control the legislative authorities and responsibilities over Nova Scotian coastal areas. Although the role of the coastal planner is now defined, it has yet to be established in Nova Scotia. Moving beyond theory and establishing the jurisdictional umbrella and the role for the coastal planner in Nova Scotia should be the next task in this process. The paradox is that coastal planning is still very much reactive. A planner cannot plan for yesterday. Until the coastal planner is viewed as a forward thinking practitioner who can achieve the needed outcomes of coastal planning and management, the practice of coastal planning and coastal planners themselves in Nova Scotia will remain underutilized.

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DECISION MAKING UNDER UNCERTAINTY: A LOGICAL (RATIONAL) APPROACH

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One of the more fundamental challenges facing all forms of resource management is how science is to have an input into the making of management (policy) decisions. Traditionally, decision making has been based on a model's prediction, a prediction that, while remaining inaccurate (uncertain), is still able to indicate the scale of a decision-making approach that is needed for a satisfactory result. This data-driven approach to management can be represented by the following schema:

data-> model-> prediction-> policy

Under this schema it is necessary to collect the data (facts) as accurately (and perhaps as much) as possible in order to reduce (contain) an inherent uncertainty in the system.

But how does an accurate prediction (a prediction built from accurate data) help us? Can it tell us what will happen? Can it tell us what we should do? How absurd! What happens depends on what we do. And what we do reflects our values. A policy, like a goal (such a sustainability), is what the economist refers to as a normative law or norm. Since norms are made by our decisions, they reflect our values and we have to take full responsibility for them—norms (goals, objectives, policies) cannot be predicted from the facts. This paper explores the possibility of replacing a factual based view of decision making with a rational and logical one. Instead of asking (a) "How do we collect data as accurately as possible?", this approach asks (b) "How do we base management decisions on arguments that are sound and rational?" Once question (a) is replaced with question (b), a paradigm shift becomes unavoidable. Under a management paradigm based on sound arguments, management decisions are no longer based on what is expected to happen in positive terms, but are guided by a negative view of scientific advice that explains to the decision-takers what policies (decisions) should not be taken.

Examples are:

a) You cannot obtain a sustainable fishery (goal) without containing excessive fishing effort (policy);
b) You cannot maintain full employment for the fishermen (social objective) and still maintain a sustainable fishery (societal goal);
c) You cannot contain excessive fishing effort (objective) without reducing the catchability of the fisherman's gear (policy) or the length of the fishing season (policy); and
d) You cannot put in place policies supporting the goal of a sustainable fishery without enduring criticism from the interested parties (concomitant effect).

Session Five

SCIENCE, MAPPING AND INFORMATION MANAGEMENT

Chairs: Maxine Westhead, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

and

Kathryn Parlee, C-CIARN Coastal Zone, Natural Resources Canada, Dartmouth, Nova Scotia

RESOLVING THE WORLD'S LARGEST TIDES

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Abstract

For several decades, a controversy has existed as to whether or not Ungava Bay has tides equal to, or greater than, those of the Bay of Fundy. Traditionally, it has long been held that the "World's Largest Tides" occur at Burntcoat Head, Nova Scotia, situated at the head of Minas Basin in the Bay of Fundy. Recently, the Canadian Hydrographic Service has completed the analysis of new tidal observations collected at Gauge Point in Leaf Basin, Ungava Bay, Quebec. These data are compared with analysis of new and old data from Burntcoat Head and Cobequid Bay, Bay of Fundy.

Introduction

Oceanic tides are harmonic oscillations in the sea surface caused by the gravitational attraction between the sun, earth and moon (Forrester 1983). These oscillations are modulated by:

- The relative alignment of the Sun, Earth and Moon
  - full and new moons produce maximum or "spring" tides.
  - "destructive" misalignment occurs at quarter moons, producing minimal or "neap" tides.
  - the spring/neap pattern repeats twice a month.
- The distance of Moon from Earth
  - the lunar gravitational pull is enhanced during the nearest approach (perigee) of the Moon in its elliptical lunar orbit, and is minimized during the farthest approach (apogee)
- The distance of Earth from Sun
  - a similar variation occurs at the aphelion and perihelion of the solar orbit, however it is much less than the lunar effect due to the greater distance of the solar orbit.
- Solar/lunar declination
  - the declination of the Moon, when above or below, the plane of the Earth's equator causes unequal daily tides. When the Moon is on the equator, daily heights tend to be equal.
- The precession of the lunar-ecliptic planes over an 18.6 year cycle.

– the multi-year variation caused by this precession in annual tidal extremes is typically less than 0.1 or 0.2 m, but can exceed 0.5 m in areas of extreme tides.

Locator Maps

Interest in areas of large tides (with their associated large currents) has always existed. Reasons include tidal power, tourism, difficulties for navigation, and the extensive inter-tidal zone containing rich habitat, as well as the scheduling of a myriad of day-to-day coastal zone activities.

Historical Review

Bay of Fundy (Figure 1):

- measured more frequently, but only for very short periods (a few months at best).
- very inadequate observations in most places.
- a minimum of 200 days of observations is required to estimate accurate extreme tidal ranges.
- long-term observations in Saint John, New Brunswick, indicates that the tides there are getting larger by as much as a few decimeters per century. This is compatible with geologic evidence that Fundy tides have grown from normal coastal ranges to their present size in very recent millennia and are continuing to do so (Amos et al. in prep).

Ungava Bay (Figure 2):

- observations in early 1950s indicated very large tides (i.e. greater than 50 ft).
- data was extremely poor and unsubstantiated.
- data was too sparse for proper harmonic analysis.

For years, many people have held that the tides in Leaf Basin were equivalent to (or even greater than) the record tides at the head of Minas Basin. This controversy has been fueled by media interest every few years, and has remained a controversy due to the simple fact that no measurements were ever made at either site after the debate erupted. Since 1998, both sites have obtained new observations using modern instrumentation.

Methodology

Selection criteria for determining the “Largest Tidal Range”:

- only pure tidal motion was considered (over a 19-year period).
- i.e. no barometric, wind or other *non-tidal* influences were considered.
- chose the maximum “*high to adjacent low* tide”.

Note: Using the historic highest minus lowest water level thresholds yields the *extreme water level range*, and using highest minus lowest predicted tidal levels yields the *extreme tidal range* (i.e. highs and lows may occur on different days). This study was seeking the largest single tidal high to adjacent low events.

Instrumentation

Both sites were gauged with submersible Aanderaa Water Level Recorders. These instruments use highly accurate sensors to measure total hydrostatic pressures (occillating quartz crystals) and water temperatures, which are recorded at regular intervals. The pressures are converted to equivalent water level heights after applying factors for water temperature, salinity and local gravity. This equipment gives an excellent measure of the tidal contribution to change in water level height. With care, measurements to within centimeters are possible in areas of large tides.

Results

Figure 3 shows superimposed tidal predictions from both sites for 1998. This year experienced the Highest and Lowest Astronomic Tide (i.e. HAT and LAT) during the 18.6 year precession of the lunar/ecliptic planes. From the predictions, it is apparent that on the average, Minas Basin experiences higher tidal ranges, but that during extreme conditions, both sites are comparable.

Burntcoat Head, Minas Basin:

- 16.3 m range recorded in November 1998
- highest predicted extreme **17.0 m (± 0.4 m)**
- lunar forcing appears a dominant resonance feature

Leaf Basin (Lac aux Feuilles), Ungava Bay:

- 16.2 m range recorded on March, 2002
- highest predicted extreme **16.8 m (± 0.4 m)**
- lunar forcing was less, and solar forcing was more pronounced than in Minas Basin

Conclusion

- Both sites have measured tides larger than anywhere in the world
- Extreme values are only estimates!
- Neither site *has ever been measured* during extreme highest tides (occurs next in 2014)
- This controversy was mainly a tourism issue, i.e. all about “bragging rights”

- Further resolution will require very expensive field surveys and, regardless of findings, the truth may never be totally "accepted".

The results obtained from analysis of the data in Ungava Bay indicate a maximum predicted tidal range to be 16.8 meters over the 19-year period from 1998 to 2016. The maximum predicted range in Minas Basin was 17.0 meters for the same period. The estimate of accuracy at both sites was determined to be ± 0.4 meters (95 percent confidence). As both computations essentially agree within the limits of the error boundaries, the contest was concluded to be a draw. Both sites now share the official accolade of "World's Largest Tides".

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Figure 1. Minas Basin, Bay of Fundy

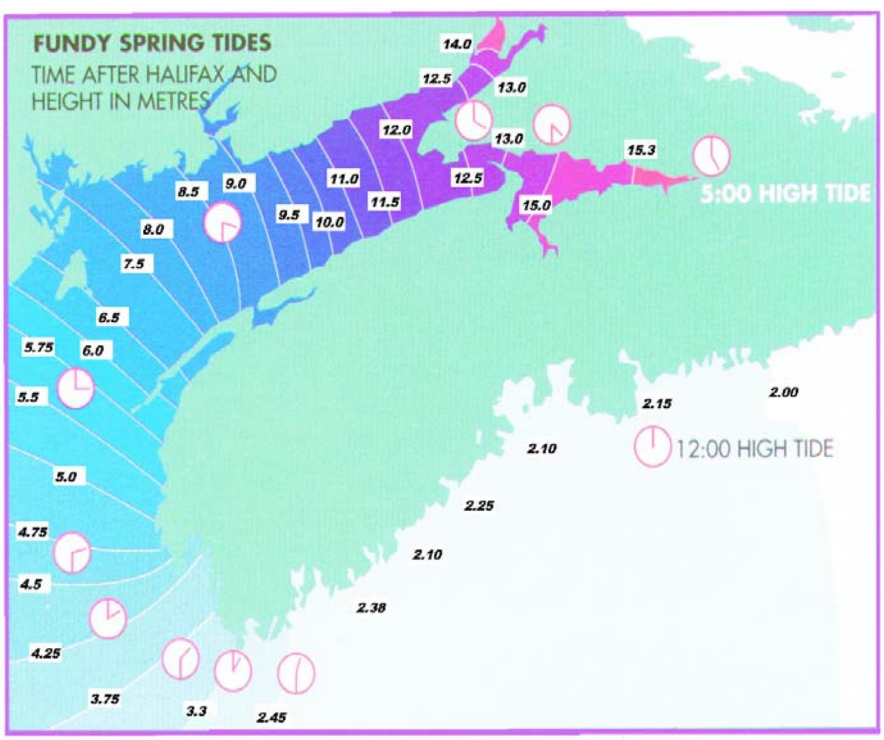
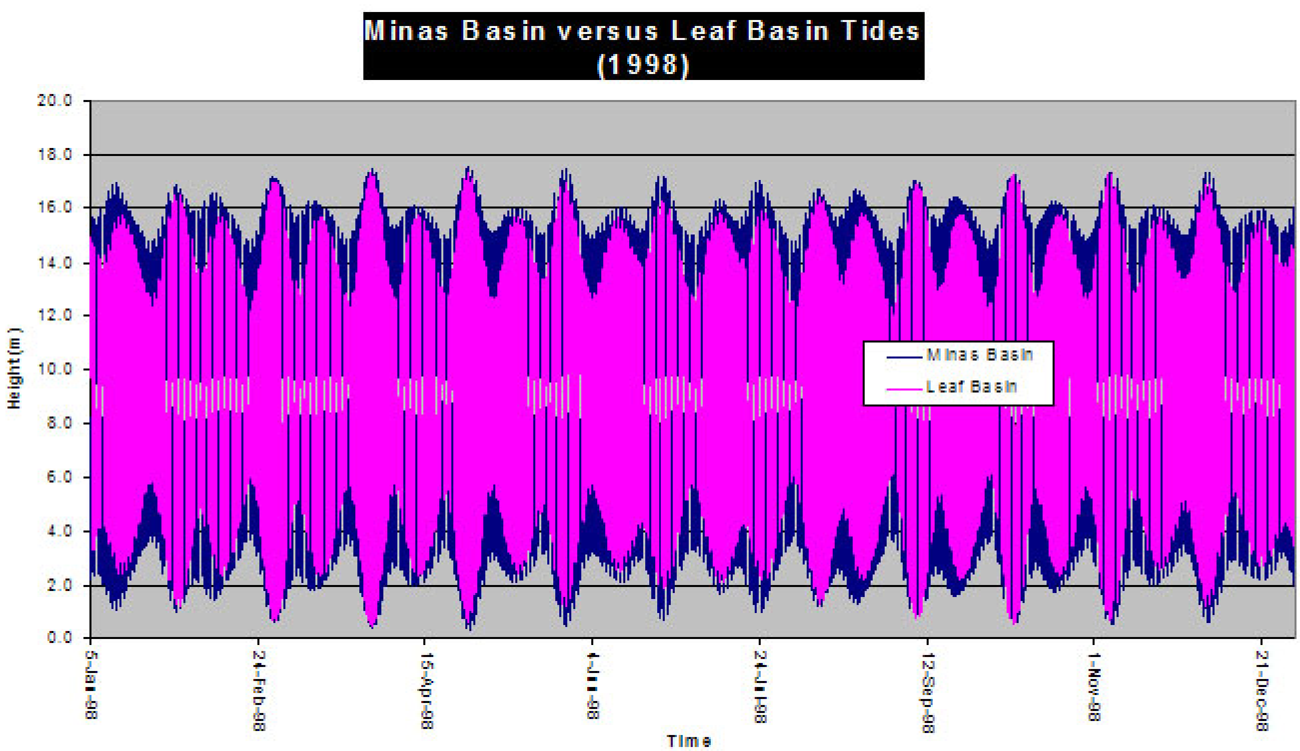


Figure 2. Leaf Basin, Ungava Bay

Figure 3. Annual predictions during period of highest/lowest astronomic tides



THE NEXT 400 YEARS: KNOWLEDGE GAPS AND RESEARCH PRIORITIES FOR ADAPTING TO CLIMATE CHANGE IN THE BAY OF FUNDY

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The Bay of Fundy region has seen significant environmental change over the last 400 years, much of it human induced. The next 400 years promise to be far more dramatic as climate change may be the driving factor behind widespread physical and ecological stresses on the bay. How (and if) we adapt to these changes may depend on decisions we make in the near future regarding research priorities, planning strategies and development priorities.

The Canadian Climate Impacts and Adaptation Research Network (C-CIARN) is a national network that facilitates the generation of new climate change knowledge by linking researchers with decision-makers to address key issues. The network consists of six regional offices and seven sectoral offices. The regions cover geographically significant issues, while the sectors focus on areas of broad national interest such as fresh water, the coastal zone, fisheries, landscape hazards, and more.

Over the past three years, C-CIARN regions and sectors have been consulting with researchers, practitioners and decision-makers to identify key climate change impacts, knowledge gaps and research needs that will assist in the development of appropriate adaptation measures. A series of national and regional workshops have identified issues, outlined current adaptation strategies and discussed research projects and case studies that address climate change impacts relevant to the Bay of Fundy region. Topics have included impacts from increased air temperatures, changes in precipitation, sea-level rise, reduction in sea-ice cover, and changes in storm frequency and intensity on communities, infrastructure, environment, health, and natural resources. A workshop held in April 2003 focused specifically on the vulnerability of the Bay of Fundy coasts to climate change and provided an opportunity for participants to discuss issues and identify knowledge gaps and information needs of particular concern for the region. C-CIARN has used these knowledge gaps to develop a framework for a climate change research agenda relevant to the Bay of Fundy.

ENVIRONMENT CANADA'S EMERGENCIES MAPPING PROGRAM: AN INTERNET APPROACH TO ENVIRONMENTAL MAPPING

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Abstract

During emergencies, the ready availability of information on the location and vulnerability of resources at risk is crucial to a successful response and in preventing or minimizing further environmental impacts.

Environment Canada–Atlantic Region has developed over a number of years a computer-based geographic information system (GIS) mapping system for managing and analyzing environmental information. This stand-alone, user-friendly mapping application has recently moved to the Web, allowing broader access by federal, provincial and industry partners in the spill response field. Enhancements have been made that facilitate better coordination and exchange of data among partners. It incorporates a unique shoreline classification system that can be viewed in concert with biological, human use and logistical data. It includes a spill logging function to manage situation reports, maps, resource summaries, photographs and trajectory model outputs. The system allows thematic layers to be displayed on either topographic maps or hydrographic charts and possesses links to other sites that allow real-time display of weather and ocean current data useful in a response. With an open architecture concept the Web mapping system is readily modified; partners are able to digitize on-line and to update their own databases shared on the system. Mapped data for the northeastern United States are also included in the package to facilitate joint response to trans-boundary pollution incidents.

Although this paper will highlight the unique features of the Web mapping application for planning and responding to environmental emergencies, other partners are using the system for conducting environmental assessments, inland management projects, or planning for nuclear emergencies around the globe.

Introduction

In the early 1990s, the government of Canada undertook a nation-wide review of its capacity for responding to environmental incidents. This review gave the government an opportunity to assess, but also create, a national committee that would provide information on biological/human-use resource information and protection priorities during environmental incidents. In order to achieve this goal, a national committee was formed to discuss and to implement a computerized sensitivity mapping application. Environment Canada–Atlantic Region was tasked to lead this project and was assigned the responsibility to gather and to manage appropriate data sets from various agencies while providing the standards and frameworks that would lead to the implementation of a National Sensitivity Mapping

Program. In subsequent years, a lack of funding and resources allocated for this initiative has forced each region to manage and develop their own system. Fortunately, the Atlantic Region remained determined to achieve the development of a state-of-the-art mapping application by focusing on data collection and the creation of a unique computer interface that would be used by environmental responders across the Atlantic region. To date, the Atlantic Region Sensitivity Mapping Program is the most comprehensive, up-to-date and complete information system with more than 120 different layers of information. With its user-friendly interface, minimal training is required in order to operate the system (see Figure 1).

A team of two persons was necessary to develop, create and maintain the mapping application. Efforts were first placed on collecting and acquiring various data sets from a wide range of government and private organizations. Once all of this information was collected, it was necessary to structure all the layers of information to fit the mapping system. The stand-alone system in use in the Atlantic Region has evolved to a point where no more structuring is necessary; a new interface has been developed using an “open architecture” technology. As soon as a layer of information becomes available for update, the database is copied to a specific location on the hard drive and automatically integrated in the mapping application.

In early 2002, Environment Canada–Atlantic Region launched a unique Web mapping system featuring all the concepts of the original stand-alone version, taking advantage of new Web programming technologies.

The objectives of developing and maintaining the best possible sensitivity mapping system is to provide planners and managers with the full range of information that they require as part of pre-spill activities as well as resource protection recommendations at the time of a spill. The data and information are based on consistent sets of terms and definitions that describe the shore-zone character, the objectives and strategies for a specific response, and the methods by which those objectives may be achieved. The data are linked with other resource information in a GIS-based system.

Standard or accepted terms and definitions and shoreline segmentation procedures are already in place for describing the shore-zone character and shore zone oiling conditions. In this program, a set of standardized objectives and strategy statements have been developed that can be entered easily into a database; these provide a better level of consistency than do phrases or sentences constructed by different recorders or evaluators. The suggested protection and treatment objectives and strategies are intended for consideration by the spill response management team.

The actual type and volume of spilled oil, plus local environmental conditions, and local priorities would be brought to bear on the decision process at the time of a spill. The suggested objectives and strategies provide a starting point and a framework for decision-makers and planning and operations managers to discuss objectives and priorities. The concept of management by objectives provides a framework for decision-makers to set the goals of an operation at both the regional and a segment by-segment level (Percy et al. 1997).

The pre-spill database is integrated with the actual Sensitivity Mapping Program, which is capable of displaying natural, cultural and man-made features vulnerable to oil spills. The computerized mapping system facilitates quick access and management of multiple data sets. A user-friendly interface allows queries and statistical analysis of data and display of graphical outputs. The system provides both planning and response tools; information can be accessed or modified using a laptop computer and real-time spill information or trajectory model outputs incorporated using a spill/incident log function (Figure 2).

A hard copy atlas is also available for the Atlantic Region. Made using 11x17 paper format, it includes a thematic layer showing the coastal geomorphology (mid/upper intertidal zone) and the most up-to-date human-use and biological information. A series of large maps (36x54 inches) has also been produced. The maps are very useful when planning response for large areas or for media briefings during incidents.

Partnerships

Following the *Exxon Valdez* spill in Alaska, the government of Canada realized the need for having a system where sensitivity data could be accessible for planning and response purposes. The Green Plan of the early 1990s provided initial funding to develop, create and maintain a sensitivity mapping system to support environmental responders during marine spill incidents. Because of its mandate, Environment Canada has environmental emergencies officers who are on duty on a 24/7 basis. Therefore, available information must be accessible quickly in order to mitigate potential impacts on marine and coastal resources.

Partnerships are crucial in order for environmental emergency responders to locate, identify and protect sensitive resources present at a spill site, especially for the first few hours/days of an incident. Environment Canada involves other federal, provincial, municipal agencies, private industry, and local communities through the Regional Environmental Emergencies Team (REET) to ensure environmental data are accessible. Most of the organizations involved during a spill incident are part of REET.

Many organizations are using the Atlantic Region mapping system. Among them are the Eastern Canada Response Corporation (Atlantic Division), Fisheries and Oceans Canada (Scotia-Fundy Region), Environment Canada's Shellfish Sanitation Program, and Environment Canada's Office of Enforcement. Other groups that have expressed interest in using the system include the Ship Source Pollution Fund (SSOPF), Health Canada–Nuclear Emergency Response Division, the response organization ALERT (Atlantic Emergency Response Team), and the government of New Brunswick.

Geographic Application

The main coastal areas covered by the Atlantic Region Sensitivity Mapping Program encompass the four Atlantic Provinces: New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador. Approximately 12,500 unique shoreline segments covering more than 40,000 kilometers of coastline have been identified in Atlantic Canada. Labrador is the only area not presently covered by the shoreline classification. However, growing federal interest and activities in Labrador will likely require the completion of the pre-spill database for this area in the near future. Portions of the province of Quebec have been included in the mapping system, including Chaleur Bay (north shore) and Magdalen Islands, since these areas would likely be impacted by spills in the Atlantic Region or require joint response. For potential trans-boundary spill incidents in the Gulf of Maine and Bay of Fundy, all digital maps for the entire State of Maine have also been added to the mapping program. Despite the coastal applications of the mapping system, it also has the flexibility to cover the inland part of the Atlantic Provinces. Environmental data has been collected for the State of Maine and New Brunswick border. The Atlantic Region Sensitivity Mapping Program in conjunction with the Maine Department of Environmental Protection have agreed to exchange cross-border information on coastal areas that can be used for planning and response during marine incidents that could impact both countries. As the information becomes available for inland areas, the mapping system will integrate the information in a format that is compatible with the existing data sets.

Shoreline Classification and Pre-Spill Database

The objective of the pre-spill database is to collate data and information that would be required and used by the spill response management team in the development of planning, priority and operations decisions. This database plays a fundamental role in the definition of resource protection priorities, and constitutes an introduction to the Shoreline Clean-up and Assessment Techniques (SCAT) process. The database involves an initial segmentation of the shoreline and data templates then are completed for each segment. This process involves the use of various tools such as low-altitude videotape survey data, aerial photography, and pre-existing mapping material to define sections of shoreline that have a uniform alongshore character. In Atlantic Canada, each segment has a unique two-letter prefix code followed by a sequential number (Figure 3). The two-letter prefix is unique to one coastal area in Atlantic Canada that makes each code different (e.g., Halifax Harbour has the following segment codes: HX-01 to HX-75).

The description of the shore zone and the development of appropriate response strategies are presented in a systematic format based on four distinct templates: 1) Shore Zone Character, 2) Shoreline Protection, 3) Shoreline Treatment, and 4) Summary of Response and Requirements. These templates contain a total of 143 different attributes that are unique for each shoreline segment. The Shore Zone Character template describes information such as shoreline material/type, nearshore environment, longshore current, oil traps, and potential behaviour, and resources at risk.

The shoreline material/type is further subdivided into five distinct categories: lower inter-tidal material, lower inter-tidal form, shoreline type (area located between the high and low tide mark), backshore material, and backshore form (Figure 4).

The Shoreline Protection and Treatment/Cleanup templates offer a variety of shoreline data, including treatment and protection methods, objectives, strategies, and operational considerations. The last template is known as Summary of Response Requirements. It is a summary of the protection and treatment templates and includes a response priority code (L = low, M = medium. H = high, VH = very high). The response priority code is defined based on the information available at the time of collection of the pre-spill database. Although it is a starting point in defining priorities, Environment Canada's Sensitivity Mapping Program is now in the process of incorporating other data sets in order to define a response priority code that will better reflect the actual resource inventory for a specific shoreline segment.

These templates use a knowledge-based concept, as data and recommendations are entered, in part, from knowledge and experience rather than from an objective analysis. Owens and Dewis (1995) describe the templates in more detail. The shoreline protection and treatment or cleanup techniques that are recommended for each segment are derived from the Environment Canada Field Guide for the Protection and Cleanup of Oiled Shorelines (Owens 1996).

The shoreline type is a description of that area of the shore zone where oil is most likely to be stranded, and the coastal character is described since this is the area in which backshore operations will stage and deploy resources. The description also includes identification of features that are likely to affect the behaviour of persistent oil, such as along-shore traps, potential boulder, or riprap reservoirs.

Areas outside Canada where the same shoreline classification approach has been applied include Hawaii (Honolulu-Waikiki), Russia (Sakhalin Island), and Alaska (Port Valdez). A number of countries have shown keen interest in the Atlantic Region Sensitivity Mapping Program, including Bangladesh, Brazil, Spain, Israel, Chile, France and New Zealand.

Sensitivity Web Mapping System

All computerized Web mapping systems require base-map layers. In the past, Environment Canada has purchased National Topograhic Data Base (NTDB) topographic digital maps from the Natural Resources Canada Centre in Sherbrooke, Québec. Three different scale were purchased: 1:50,000, 1:250,000 and 1:1,000,000. All are used to represent specific information sets.

As mentioned earlier in this document, the shoreline classification along with the pre-spill database, constitutes one of the most important components in the Web mapping system (Figure 5). It relates the physical aspect of the shoreline and provides useful information on protection and clean-up methods. For each individual segment, a shoreline video is available. By selecting a shoreline segment, it is possible to view the video for that specific portion of coastline. The shoreline videos generated for the Atlantic region comes from the Geological Survey of Canada. In addition, the Web mapping system allows the display of various databases such as birds, fish, shellfish, aquaculture sites, parks, and archaeological sites. With all the information available, the Web mapping system is able to provide a detailed report for any given area.

The user has the option of defining a buffer zone that can be used to determine the sensitive resources within an area, to calculate features such as length of shoreline or area affected, or to display data in a graphical form. The information can be displayed in the form of bar graphs or pie charts, and a detailed written report on the affected resources may also be generated. The report contains information on various species or human-use resources, their sensitivity to oil spills, and their seasonal vulnerability. A complete database of photographs related to sensitive birds, fish, shellfish, vegetation, and human use structures such as aerial photographs of small craft harbour can also be viewed or printed. In addition to the Natural Resources digital base maps, the system can also display information on digital hydrographic charts or digital elevation models.

The Atlantic Web Mapping application uses the latest technologies to facilitate and enhance its various mapping applications. Designed using a MapInfo® Corporation technology called MapXtreme®, it brings a new dimension to how people create, edit and manage geographical information. Portions of the Web mapping uses Scalable Vector Graphics (SVG) technology which is a new graphics file format and Web development language based on XML. SVG enables Web developers and designers to create dynamically generated, high-quality graphics from real-time data, with precise structural and visual control. With this new tool, users can now create and edit geographical information on-line, modify a database, and share information with other people with the use of only a Web browser. The architecture of this interactive mapping application provides many advantages:

- Very user friendly (Web interface);
- All data resides on the server (maps and databases);
- All of the processing work is done on the server that returns information to clients through their browsers (MS Internet Explorer, Netscape). There is no need to have a powerful workstation to run the application;
- No software is required on the client side (only browser, IE or Netscape);
- Data updates are easy since only the copy of the data (on the server) needs to be changed;
- The structure of the system allows easy addition of resource information to the application;
- Links to other sites (EC) or other organizations can be easily be implemented;
- Password protected for enhanced security;
- Ability to share your own database with whoever you want.

The Web Mapping application is located at http://www.e-map.gc.ca.

Summary

The Atlantic Region Sensitivity Web Mapping Program's main focus is to provide Environment Canada and its partners with a widely accessible mapping tool for emergency planning and response applications. The Web mapping, with its real-time capabilities, will certainly bring a new dimension to responding to environmental emergencies. Consistency is also crucial if personnel are to be brought in from different regions during a drill or spill, as they are immediately comfortable with the application, process and terminology. The same sets of standard terms and conditions are applied to pre-spill data base development, sensitivity and pre-spill mapping, SCAT data generation, and the response management decision process. Although the use of standard terms and definitions is essential for the description of oiled shorelines, the value of standardization extends into the decision process with regard to shoreline protection and treatment recommendations. This concept is very powerful, as it provides a consistent terminology through the entire range of pre-spill planning and response activities.

Web-based sensitivity mapping often has been viewed as an isolated activity in spill planning. Although the identification of resources at risk is a study that can stand alone, the application of that information into the response decision process involves a broader perspective. The integrated approach for spill response in Canada uses sensitivity information as one part of a larger body of relevant information that can, and should be, used by the decision team in the formulation of an appropriate response. For example, the pre-spill database includes information for each shoreline segment that describes potential oil traps or oil behaviour considerations, possible operational constraints, as well as the resources that are at risk.

Future developments for Environment Canada's mapping program include the integration of the Shoreline Clean-up Assessment Techniques form into a handheld device such as Pocket PC. The portable application called *Pocket SCAT* would allow field users to remotely enter coastal information in order to assess the oiling condition of a given stretch of coast. MapX Mobile is used to link the Atlantic Region mapping system to the field unit. With communication devices such as cellular or satellite phones, information gathered during a field trip can be transferred without having to connect to a land-line (Figures 6 and 7).

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Owens, E. H. 1996. *Field Guide for the Protection and Cleanup of Oiled Shorelines* (2nd Edition). Environment Canada, Atlantic Region, Dartmouth, NS.

Percy, R. J., R. S. Leblanc, and E. H. Owens. 1997. *An Integrated Approach to Shoreline Mapping for Spill Response Planning in Canada*. Proceedings 20th Arctic and Marine Oil Spill Programme (AMOP) Technical Seminar, Environment Canada, Edmonton, AB.

Figure 1. Screen shot of the stand-alone mapping system

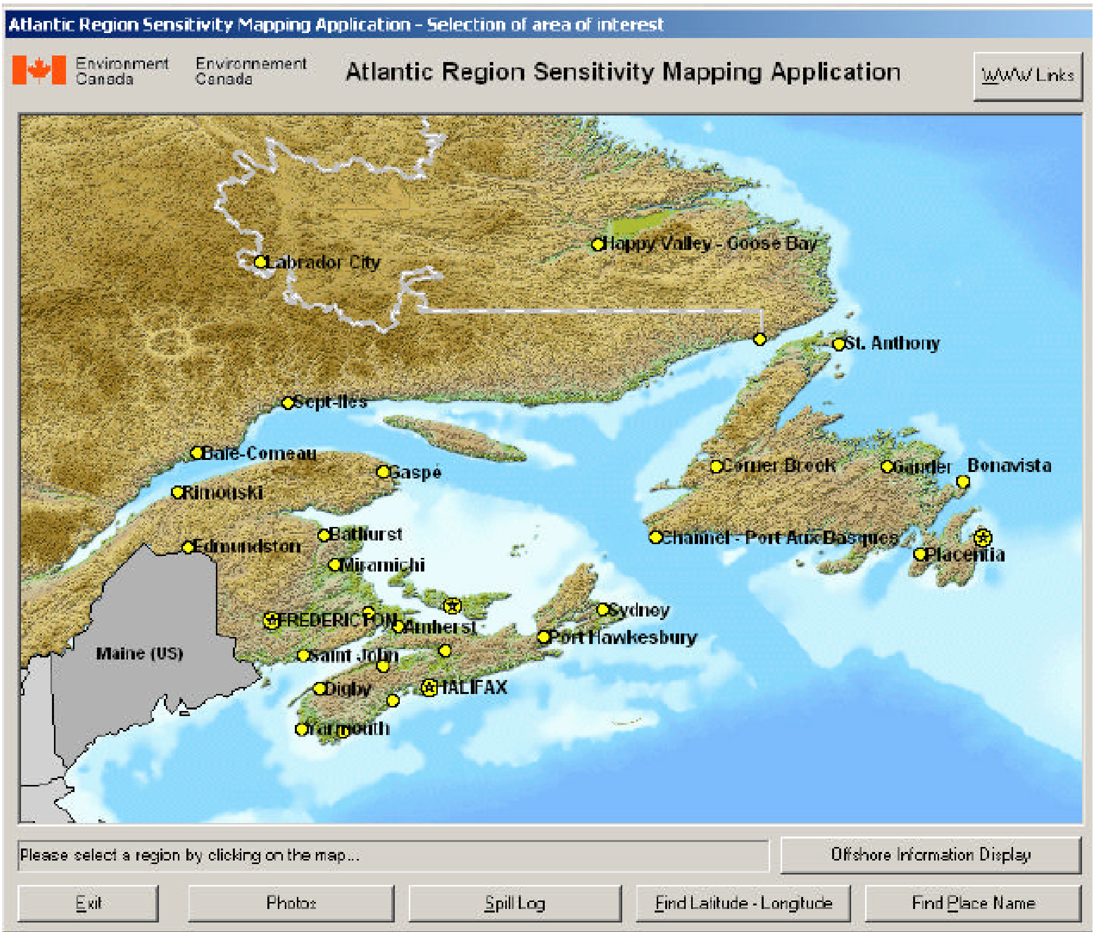


Figure 2. Spill/Incident Log function stores information produced during an incident; also useful for retrieving information on previous incidents

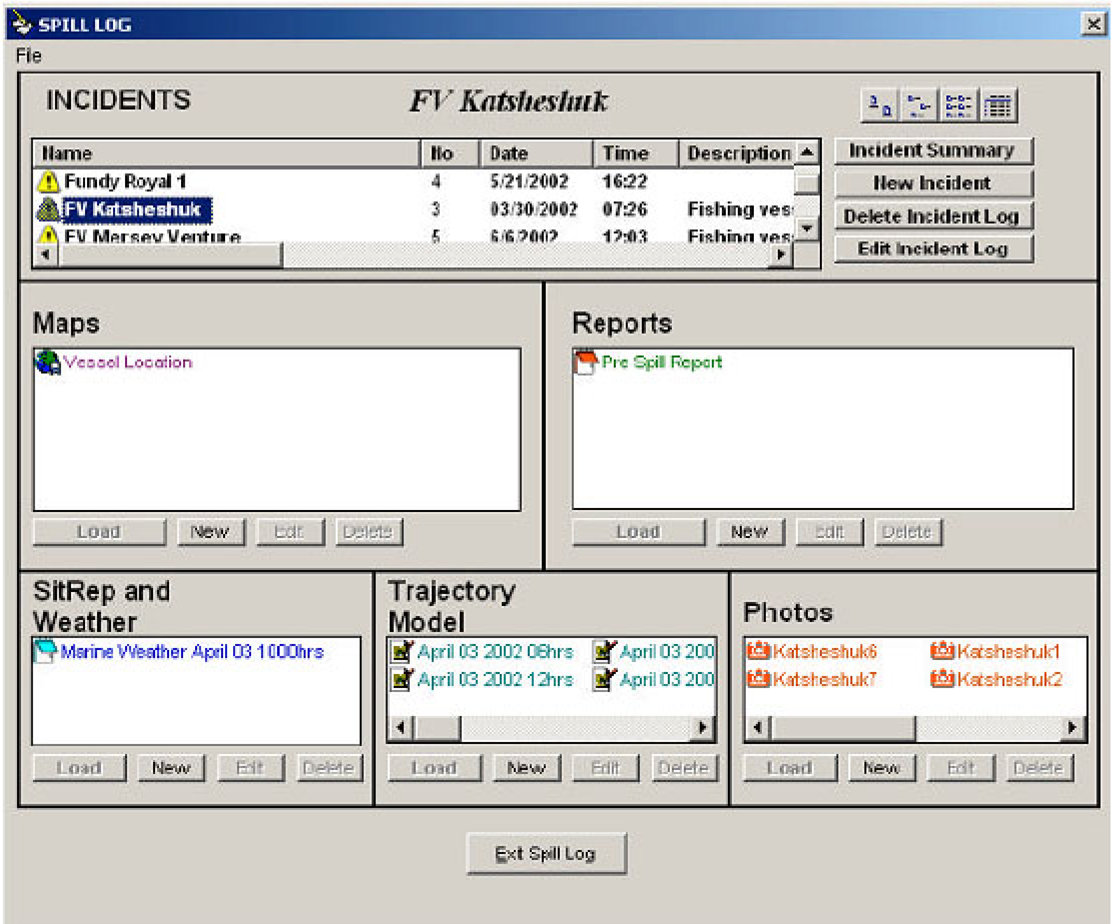


Figure 3. An example of the shoreline segmentation of the Northwest Arm area, Halifax, NS

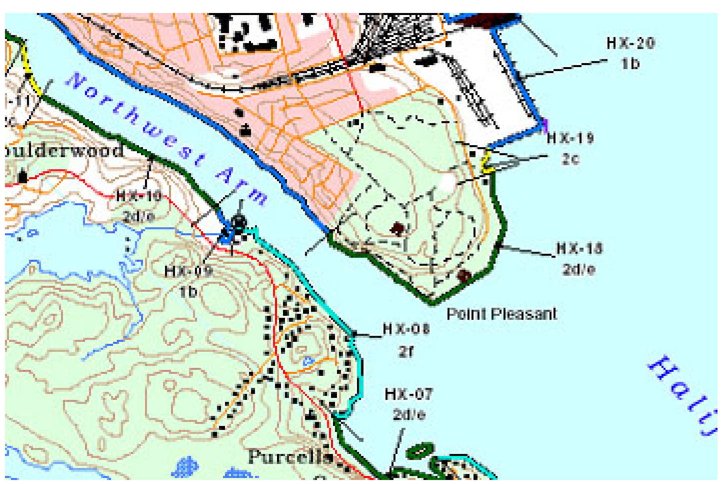


Figure 4. Shore Zone Character template for a given segment of shoreline

Shore Zone Character

Environment Canada Environnement Canada

Other Shoreline info on this segment:

Shoreline Protection | Shoreline Treatment | Summary of Response Requirements

REGION: NFL-4 | SEGMENT: MW-07

SHORELINE MATERIAL/TYPE:

Lower ITZ material:	sand				
Lower ITZ type:	beach	Permanent inlet:		Cyclical inlet:	
		Inlet location changes:		Inlet shape changes:	
Shoreline type:	pebble-cobble beach				
Backshore material:	mixed coarse-no sand	Inlet width:		Number of channels:	
Backshore type:	platform				

Primary resources: BIO/ECO: capelin spawning beach

Secondary resources: recreational beach (moderate use)

NEARSHORE ENVIRONMENT:

TIDAL RANGE: Mean tide: 1.4 (m) Large tide: 2.1 (m)

Open, exposed coast: No Segment Length: 1499 m

Predominant longshore current/drift direction:

OIL TRAPS AND POTENTIAL BEHAVIOUR:

Natural alongshore barrier (e.g headland)	No	Sand-burial potential	Yes
Man-made alongshore barrier (e.g wharf)	No	Pebble/cobble - penetration potential	Yes
Bay or re-entrant	No	Riprap or boulder - reservoir potential	No
Tidal inlet or channel	No	Overwash potential into lagoon/marsh	No
Tidal lagoon or estuary	No	Marsh meadow oiling potential during high-water levels	No

RESOURCES AT RISK:

Amphibians (n)	No	Agricultural (n)	No
Birds (shore birds, ducks)	No	Crustaceans/Mollusks	No
Harbour/Marina	No	Fish (nearshore only)	Yes
Recreation	Yes	Flora/Plant communities	No
Residential	No	Mammals	No
Commercial or Industrial	No		

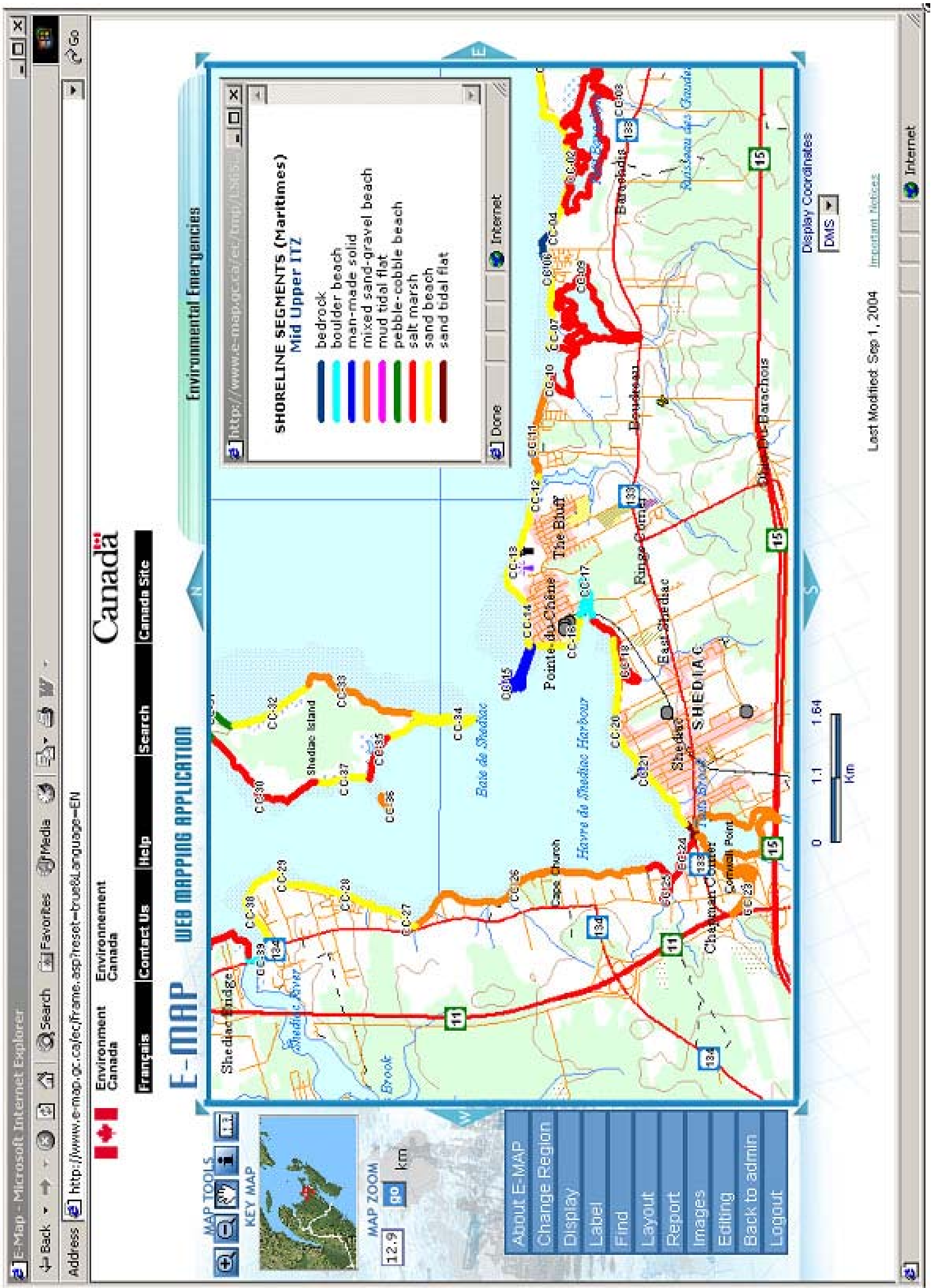


Figure 5. View of the Web mapping system showing a thematic layer for the shoreline classification (coastal geomorphology)

Figure 6. Shoreline Clean-Up Assessment Technique forms transmitted from the field to a given operation centre, saving time and effort while improving response and decision-making process

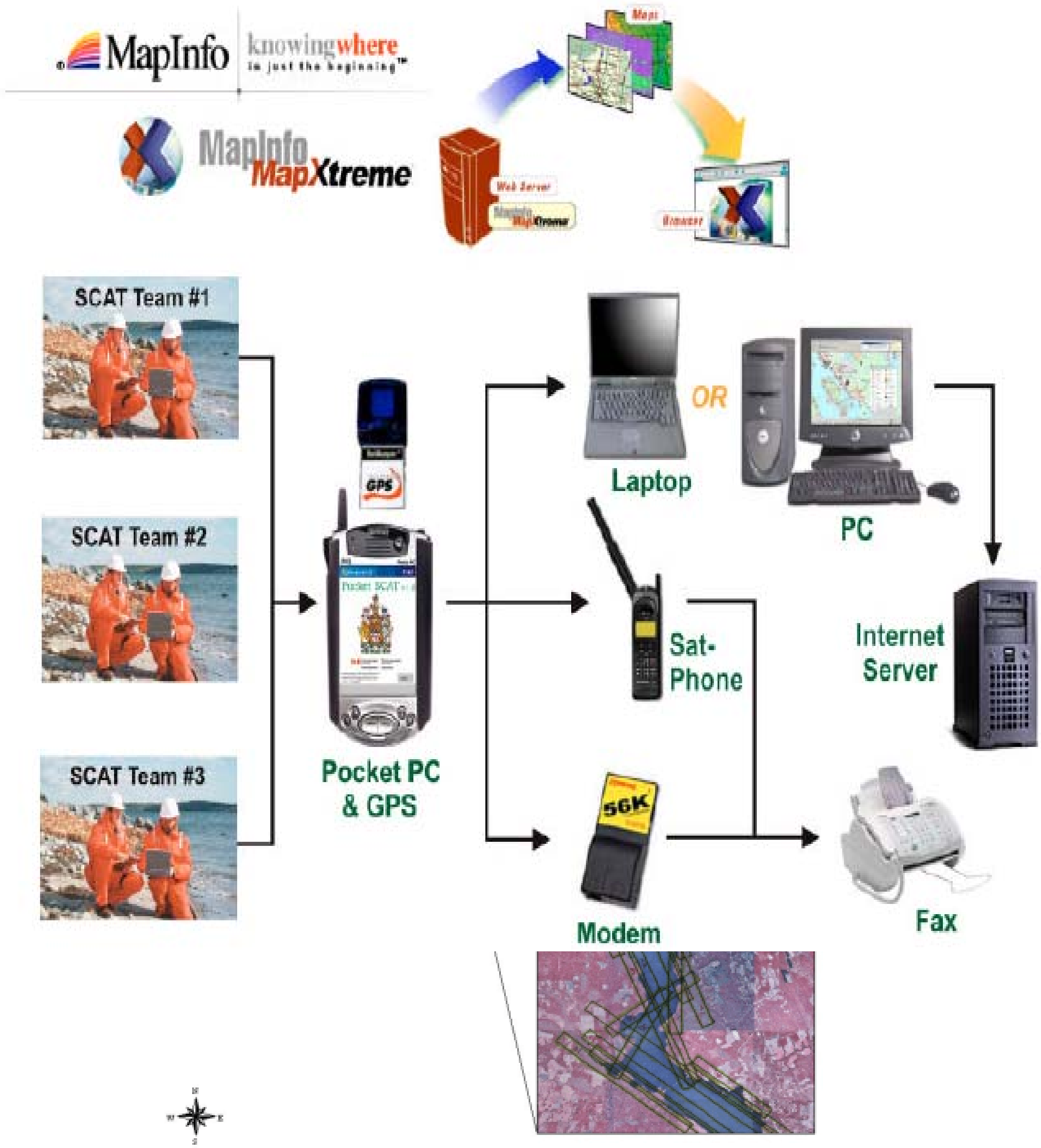
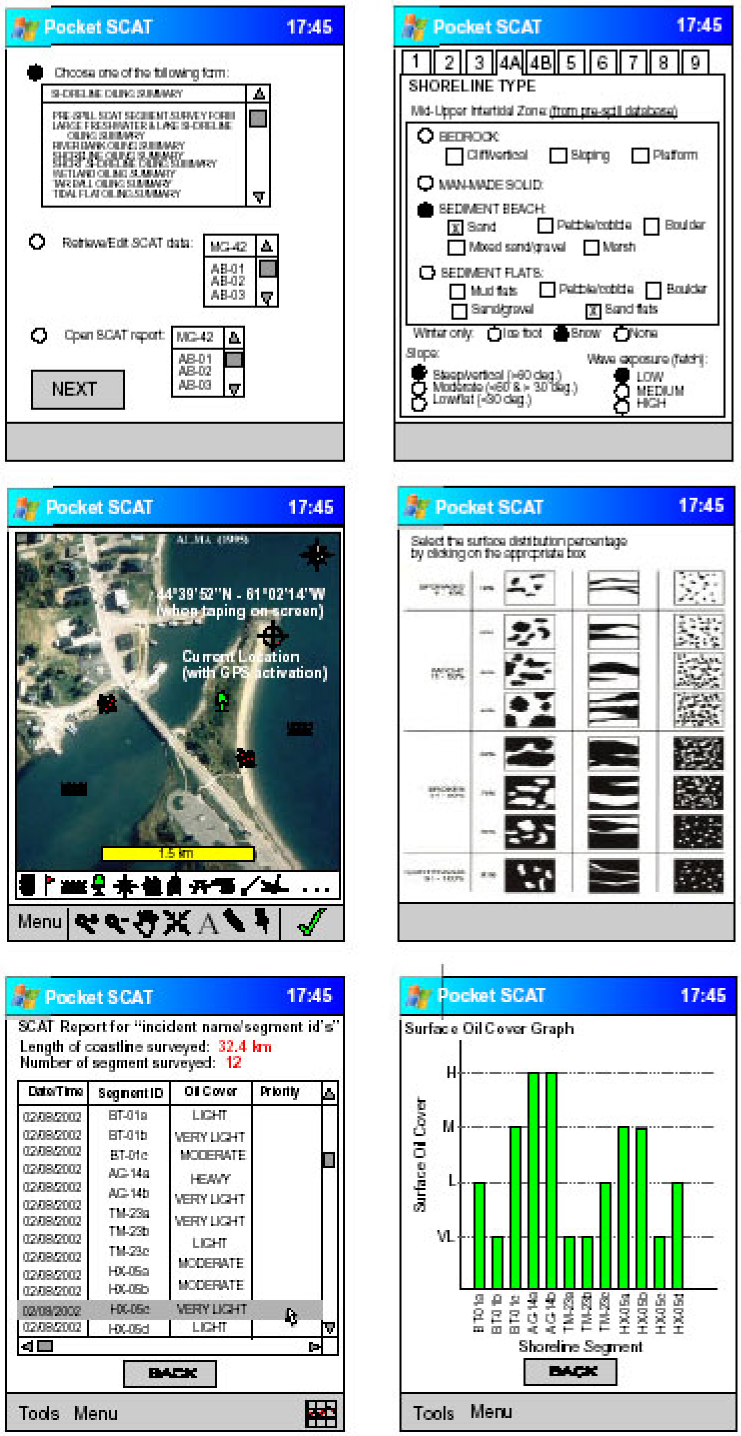


Figure 7. Screen shots from the upcoming Pocket SCAT application for Pocket PC and handheld devices



HYPERSPECTRAL IMAGING FOR MAPPING SEAGRASS DISTRIBUTION IN FLORIDA

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Abstract

Seagrass beds are shallow soft-sediments habitats typically found along the shores of bays and estuaries throughout most of the world. The extremely high primary and secondary productivities associated with these habitats make seagrasses an extremely important component for the stability of coastal marine ecosystems. Although we recognize that there is an accelerating loss of seagrass habitats and associated species of ecological and economic values, we know very little about the rate at which the global extent of seagrass beds recedes. Our inability to quantify this rate is directly related to the lack of adequate procedures for accurately detecting and mapping changes in the distribution of benthic vegetated habitats over large (tens to hundreds of km) domains. One of the most promising (and increasingly used) technologies to map benthic components is the Compact Airborne Spectrographic Imager (*CASI*). This hyperspectral sensor is highly efficient in detecting subtle changes in reflectance over narrow wavelength bands with an unprecedented high spatial resolution. Although not originally designed for marine detection and mapping purposes, the *CASI* system has proven itself to be a very powerful tool for water-related studies. In the work leading to this paper, the *CASI* was used to measure the extent of seagrass beds in the St. Johns River system in Florida. The positive results emerging from that study will be discussed in this paper, with a view to providing an overview of the feasibility of using hyperspectral technology for detecting and mapping seagrass beds in dark, nutrient-laden waters.

Introduction

The St. Johns River is a major river system in the northeastern portion of the State of Florida. There is considerable human habitation along this river, and in general the river has high utilization for both commercial and recreational purposes. The St. Johns River Water Management District (SJRWMD) is a state-level organization that was created to have authority over the river and its usage. One of the major variables that the SJRWMD monitors closely is the amount and location of underwater vegetation that occurs in the river. In the past, surveys were conducted using surface vessels to prepare detailed mapping. On some occasions aerial photography was used to assist in this mapping.

Over the past number of years, progress in, and greater availability of, remote sensing technologies have increased the ability to study spatial and temporal patterns over larger areas than is possible by other means (Lillesand et al. 2004). One of the more promising technologies to map shallow water habitat is airborne hyperspectral surveys, in particular the *CASI* hyperspectral system. *CASI* is easily deployed on light aircraft and can provide both high spatial and spectral resolutions. The sensor is capable of recording radiance in as many as 96 bands simultaneously.

In early 2003, HDI was approached by the SJRWMD about the possibility of conducting a hyperspectral survey of the river for the purposes of detecting and mapping the seagrass beds. SJRWMD were interested in using a hyperspectral survey because of the very dark nature (average secci depth of 1.5 m) of the river waters. The ability of hyperspectral imagers to penetrate water was of major interest to them. An agreement was reached to conduct this survey, with the survey taking place in September 2003.

Methodology Overview

Study Sites

This project was carried out in the late summer, early fall period of 2003. The study area was a large portion of the St. Johns River, Florida (Figure 1). This area was chosen because of the human population living along the river having a direct effect on water quality and therefore on marine vegetation in the river, and the need by the SJRWMD to monitor this activity.

Preliminary Information

SJRWMD staff have closely studied this area for a number of years. Previous surveys had been conducted and maps produced showing areas of submerged seagrasses. These maps were used to help define the overall area to be covered by the *CASI* airborne hyperspectral survey.

The *CASI* system was installed on a Cessna 182 aircraft belonging to U.S. Imaging Ltd., based in Ormond Beach, Florida. A series of flight lines, covering all land/water interfaces along the river, were prepared and in early September 2003 a series of flights were conducted and *CASI* data collected over all flight lines. While September was not the optimum month for data collection based on sky and water conditions, budgetary and other constraints meant that the survey had to take place when it did.

Ground Data

HDI deployed two hand-held radiometers during the *CASI* data collection phase of the project. The two ground teams travelled extensively by boat along the St. Johns River collecting spectral samples of a variety of vegetation. This spectral data was then compiled into a report for subsequent use by the remote sensing specialists conducting the data analysis portion of the project.

Summary

We present a methodology for using airborne hyperspectral surveys to map synoptically the extent of shallow water seagrass communities in optically dark, freshwater rivers in Florida. While this project focused on Florida river waters, the methodology is easily transferable to other optically dark waters.

References

Lillesand, T. M., R. W. Kiefer, and J. W. Chipman. 2004. *Remote Sensing and Image Interpretation*. John Wiley & Sons, New York, NY.

Figure 1. *CASI* data acquisition

THE POTENTIAL FOR A DIGITAL GEOLIBRARY FOR THE GULF OF MAINE REGION

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Abstract

The concept of a geolibrary has become well established in the field of digital library research, and refers to a digital collection of materials of any type that have a spatial element accessed and/or used within a distributed digital environment. Geolibraries exist for California and for the Georgia Basin Region on the west coast, and there are research projects underway in the Baltics as well as individual nations within the European Union. From a scientific standpoint, a digital geolibrary has already been established for geoscientific information in the form of the Marine Realms Information Bank (MRIB) created at the US Geological Survey Field Office in Woods Hole, Massachusetts. MRIB is an excellent first step towards a larger, broadly-based geolibrary that would hold information produced in, or about, the Gulf of Maine, including the Bay of Fundy. For any such activity to be successful, several local activities must take place, and there must be broad-based activities with regard to: creating metadata, developing a shared gazetteer which takes into account language issues, licencing, formats, standard geocoding, and accurate data that can be merged seamlessly. There are many opportunities for such a digital geolibrary to grow. This paper will explore these as well as review many of the issues that need to be addressed in order for the research to be translated into practice. Most importantly, this paper highlights the critical need for broad-based support and involvement of stakeholders, as well as the need for stable funding resources and a distributed technical infrastructure.

Introduction

As part of our 'radical' move towards a more integrated on-line society (Castells 1996; Brown and Duguid 2000), we are seeing new structures and cultural institutions forming – or is that re-forming? We are also seeing new views of information management, access and distribution. One such change is the move towards more digital libraries being available. Digital libraries have become commonplace, both in practice and from the more technical, philosophical and organizational perspectives. Within the literature – library and otherwise – there is a growing acceptance of library frameworks being mirrored in a digital realm (Beard 1995; Geodata Alliance 2000; Onsrud 1998a). In fact, digital libraries have become viewed as more than just library-run or -controlled infrastructures. The best digital libraries are those that are invisible to the user and that do not seem to be owned by one agency or group (Borgman 2003; Boxall 2003; OECD 2003).

This paper seeks to briefly review the issues and trends associated with digital libraries that pertain to types of communities and needs we see in our region. Unfortunately, time and space do not permit a more thorough examination of each issue, but they are presented in such a way to open up the discussion, and the references listed provide ample material for personal exploration. Some issues are more interrelated than others, and some can be more easily 'conquered'. The underlying construct that the issues come under is the geolibrary.

The What and Why

Within the digital library realm there exists a specialized form of the library, or better yet, a specialized way of organizing and acquiring information – geographically (Goodchild 1998; Mapping Science Committee 1999). One of the most intuitive ways of organizing, searching and retrieving information is based upon the map. People (expert or novice) may sometimes be willing to learn a particular taxonomy or database structure in order to obtain the right useable information. Managing, searching for and acquiring information (be it data or more refined knowledge), however, may best be served within a geographic framework, a method with less of a learning curve (Borgman et al. 2000; Reid et al. 2004).

If, for example, one wanted to find all the information dealing with the Annapolis River, then a map or gazetteer search would be easier (Frew et al. 1996; Lam et al. 2002). Once a person has all the information on that area, a more refined search can be conducted (journal articles, raw data, images, movies, texts, etc.). Perhaps another delimiter in this method would be 'date', which makes for a possibly more accurate 'hit' result. Of course, these are not the only ways to refine a search – type/ genre of material sought would be an excellent candidate (Borgman 1997; Saarenmaa 1999). These tools or procedures have been around before the advent of digital libraries, but a move to more digital structures has other implications and areas of concern, such as copyright, archiving and standards – all areas of experience in analogue library infrastructures, yet areas that are now problematic because of digital technologies and work patterns (Buttenfield 1996).

The premise in this discussion is:

> Digital libraries are organizations that provide the resources, including the specialized staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily and economically available for use by a defined community or set of communities. (from the Digital Library Federation)

The emphasis herein should be on "collections of digital works", on structuring their management, archiving, and making available to "defined community or set of users".

In the context of the Gulf of Maine, we may want to add that:

> Anything related to Gulf of Maine (GoM) and Bay of Fundy (BoF) that is location specific or topical within all locations possible, whose value and utility is

acquired with the goal of *making all information about, created in or relevant to the GoM watershed* available.

Developments in data management (from creation to disposition)—or how can a digital library becomes a reality—have exploded in terms of concern to most enterprises today, from business to academia to government, to non-profits and non-governmental organizations. There have been many projects that have ‘pushed’ the available digital library technology to new limits. There have also been concurrent efforts, with measured success, in the creation and implementation of geolibraries (Borgman et al. 2000; Jankowska and Jankowski 2000; Moon 2002; Talwar et al. 2003). Major libraries—even in the future—will see some elements of service and collections remaining, changing and growing, but the need for collaboration to keep these essentially non-digital aspects of libraries is vital.

Equally central to this idea of a digital geolibrary is the notion of the public good. At one time, this was viewed as a stumbling block, with only a few jurisdictions making information available at or below distribution costs. This has become (thankfully) an idea and practice accepted in most jurisdictions. In a sense, the idea that full cost-recovery is the only option has been broken. There is now an acceptance that it is vital to community health and participation that basic data be made equally available to all (Onsrud 1998b; Sears 2001). This has created an opportunity for digital geolibrary projects to capitalize on new access models. Those successful digital library projects have one thing in common—preferential licences and financing.

There still remains the need to maintain databases, archive information and data, distribute updates, and to staff agencies at both the creation and receiving sides. Most problematic is that there remain few metrics regarding the cost burdens on the ‘buyer side’. Interesting is the fact that as more and more data is made available, the more support there is for making sure data creation and maintenance is viewed as a core function of (government) producers. Libraries have experience in this area as they have been, and remain, neutral funding and operational entities—or better put, the last to be considered when funding increases are available, and the first on the list when cuts are made. Furthermore, as we shall see later, archiving is an issue that has yet to be fully appreciated or dealt with, at least from the archivist view, and in terms of maintaining databases they have yet to be fully exploited.

Nature of Information Exchange Changing

In terms of scholarly publishing, or any publishing for that matter, we are seeing new forms growing out of changing attitudes towards how information is distributed or created. We now see peer-reviewed works on-line; born, edited, managed, published and used in a totally digital environment. We see, from the archival access view, the creation of Open Archive Initiatives (OAI) (Cole 2003; Steinmetz et al. 2002) based upon standards for description and distribution, which also change the nature of information management.

We are seeing more emphasis (or is that acceptance) on interdisciplinary work—this is of great importance to community efforts such as those we see around the Gulf of Maine and Bay of Fundy. One perspective, scientific or otherwise, is not viewed positively, and this is true for other areas, scholarly or not (Boudreau 1999; Carver 2003). The very nature of how we communicate and work together, across disciplines or areas of interest, has altered to the point that boundaries are fuzzy and thinking in terms of 'silos' is not accepted as part of a wider initiative in society; we see more 'human' efforts towards social and environmental sustainability (Geodata Alliance 2000; Schroeder 1997, 2003).

Standards

Of all the issues that have received greatest attention is metadata. Ironically, with all the good standards out there, there still exists a great need to see those standards followed. We have all seen such things as XML/MGL, AACR2, Dublin Core, FGDC, ISO 19115:2003, and other forms to create a broad range of possible standards. On a positive note is the fact that each standards-creating organization is seeking ways to allow for the interoperability between standards (Evans 1999). From a library perspective (and using the library standards AACR2/3 and z39.50) there is every opportunity to ensure that materials added into any geolibrary will be described and accessible as well as possible. But a note of importance needs to be raised. Libraries are *the* institutions where metadata has always been of concern, from the days of card catalogues to the digital library interfaces. Having librarians at the fore in terms of creating geolibraries is not a bad thing at all, and it has been recognized as such for some time.

Interoperability (from a library viewpoint) is now not so much an issue of 'idea' as it is a problem of implementation. From the digital library view, interoperability is easier to deal with than ever before. Part of this is the enforcement of standards for data description; the other is due to inter-networking standards, such as z39.50a and OGC. One issue that has 'popped up' is the question of the ontology of database, especially the ontology of fields or even more, the ontology of regions (just how do we parse out that which we define spatially, but is not shared). There remains much work to be done, but the general trends point to more and more success stories for digital libraries—especially geolibraries. But there are other questions such as language, focus, type of material and reliability of source. These are areas where research and testing are needed, but the mere fact that we can now see them as valid areas of enquiry bodes well for the geolibrary projects.

Archiving – Persistent Information Exchange

Of all the areas receiving the least attention is that of archiving information generated in or about this region. Another view of sustainable development is that any development must be sustained beyond the researcher, funding and even the agency. When systems change, migration are the key element. Who wants to re-catalogue millions of items? Some of the most basic operations are the emulation of technologies used to create or 'read' information, the migration of information from one source or digital language to another, and redundancy, which is the need to make certain there are multiple archives to prevent loss of information and to reduce some of the costs (one site could be responsible for researchers and developing emulation techniques, while the other focusses on migration practices).

There have been numerous studies regarding the process of archiving digital data, including geospatial (Moon 2002). These works have proposed solutions of migrating data from one system to another, emulating the programs and software, and promoting a redundancy factor in the system (Beagrie 2003; Buneman et al. 2004; Muir 2004).

Ironically, this creates one of the paradoxes of digital libraries—things need to be centralized in order to allow for decentralized access. For example, standards will always be set up 'centrally', while information will be stored more locally. The scale of 'local storage' is the real question, and it impacts project planning because funding requirements will vary greatly depending upon geographic and topic coverage—economies of scale play a role in defining structure and project funding. But, at the end of the day, less is being done on the archival side of the equation (this is true in print as it is in digital); we assume someone is saving it, when in fact it is being widely lost. Most of the problem rests with the confusion between archiving our data on our PCs or servers, to last a decade or two, with preserving the information that involves many other functions than just keeping the data filed.

Geolibraries in Practice

The first geolibrary, the Alexandria Digital Geolibrary (ADL), arose out of a National Science Foundation (NSF) project at the University of California, Santa Barbara. This project sought to bring together as many resources as possible that had geographic footprints—any information 'form' (text, video, art, etc.) that could be 'placed' in a geography. ADL was followed by ADEPT—the Alexandria Digital Earth Prototype—which saw the application of ADL into the classroom (and the name also arose out of the Digital Earth concept and project focus; see Borgman et al. 2000; Frew et al. 1996).

ADEPT has been a success, as was ADL, in terms of pushing the envelope for digital libraries. ADEPT and ADL have now become components of the California Digital Library, a project seeking to bring together all information about California, or used by researchers in California, into one 'location'. These projects have led the way, but they are not the only success stories that allow a GoM geolibrary an opportunity to develop.

Two efforts in the Gulf of Maine that have had some great success from a geolibrary perspective have been the Gulf of Maine Biogeographical Information System (GoMBIS) (Tsontos and Kiefer 2001) and the Marine Realms Information Bank (MRIB) which was deliberately called a geolibrary in the same context as ADL (see Boxall 2004; Schroeder 2003). The MRIB was established by the USGS field office in Woods Hole; it sought to bring together the information researchers needed that dealt with the coastal and marine programs in the region from a geoscience, internal use viewpoint (although others were not excluded).

In Canada, the Georgia Basin Futures Project and Georgia Basin Digital Library (GBFP/GBDL was funded under the GEOIDE program) was the first real effort in Canada to build a digital geolibrary that supported community development and participation. At the present time, and thankfully, there is much conversation taking place between the GBFP and participants in the Gulf of Maine seeking to replicate that success (Journeay et al. [n.d.]; Talwar et al. 2003) through another effort—New Directions.

New Directions Downeast – Another Step Forward

These efforts to establish a working digital infrastructure within the Gulf of Maine and Bay of Fundy are not new exercises in establishing the foundations for a digital library. In fact, there have been many versions and iterations of projects that have sought to acquire, manage and distribute information—especially that which can be georeferenced—around the region (ACZISC 2004; Kiefer et al. 2001; Tsontos and Keifer 2000, 2003). These have mirrored more philosophical discussions that have given rise to excellent rationales for such 'networks' (Evans and Cavanagh 1998, 1999; Farrey et al. 1998; Schroeder et al. 2001).

One of the more interesting efforts to come out of previous discussions regarding a geolibrary for the Gulf of Maine has been the New Directions Down East (NDDE) dialogue. NDDE is a program out of the Colorado School of Mines that seeks to 'sponsor' open discussions that focus on connections between the earth sciences and humanities (Schroeder 1997, 2003). Also, this has some strong collaborative connections to the Georgia Basin projects (Journeay et al. 2003).

What is interesting to note is that the NDDE has created an additional avenue for exploring the basis for digital library projects that "may" be developed. It is as much about opening up communication lines among different disciplines as it is about technological structures. There is also an element of empowerment and a Public Participatory Geographic Information System (PPGIS) underlying the view or framework for discussion (Harris and Weiner 1996, 1998).

Funding

Of course, no project can take shape without funding. In this case there will be a need for sustained funding, as there is a need for post-funding permanency and redundancy; digital archives funding sources and partners; libraries as permanent institutions; government and universities (see the California Digital Library for example; Lopez and Larsgaard 1998). There are many sources or possible partners, such as the Social Sciences and Humanities Research Council (SSHRC), the National Science and Engineering Research Council (NSERC), the National Science Foundation (NSF), GeoConnections, and possibly the Gulf of Maine Council on the Marine Environment. And there are institutions beyond government (focus on 'institutions') such as libraries and archives, universities, and others. Let us not forget that in the search for permanency the oldest surviving cultural information institution is the library (the largest having been Alexandria 300BCE and others 1300-1200BCE—the originals were also considered archives). But this is not meant to be a library building exercise, but a community building and supportive enterprise. The role of cultural institutions is to make certain the information is available to all and for all time. And, based upon work in the Netherlands and the United Kingdom, there are roles for the private sector, but that is a topic deserving of its own exploration.

In order to be successful, we will have to reach out to other partners, funding agencies, and 'similar' efforts around our shared geography. For example, the Gulf of Maine Ocean Observing System (GoMOOS) and the Gulf of Maine Mapping Initiative (GMMI) are efforts where data created about the GoM can be brought together with other databases and form seamless systems of information resources. We also have to talk to our federal, provincial, municipal, state, and county partners, not to mention the not-for-profit groups and universities or colleges (Widoff 1996). And let us not forget broader Atlantic efforts like the Coastal and Ocean Information Network (COIN) and the Atlantic Coastal Zone Information Steering Committee (ACZISC). In fact, there is a plethora of partners and groups that need to be 'at the table' if any Geolibrary project is to succeed (also given the number of data producers at various levels) (Percy et al. 1997).

Moonshot – Digital Earth

So, what about digital Earth (DE)? DE is a global scale geolibrary, but it must be based upon regional or local scale projects that are standards-based up to the point where bringing together various parts into a whole system is easier than having to always re-configure a multitude of systems or networks. It is conceivable that the GoM geolibrary could become part of larger efforts that scale-up to the DE level. Yes, it is a great leap to think of a geolibrary on a global scale, but as has been said before, the 'moonshot' is an interesting idea to base our efforts on 'within the next decade …' (Boxall 2002 quoting Goodchild).

Questions often arise when we, or outsiders, look at how a project gets implemented. Some might suggest that we are repeatedly discussing that which we wish to create, or worse still that we are discussing for discussions sake. A good project does and should take time (Evans 1997). The success of a project can actually be better predicted based upon the amount of time it takes to lay a foundation, and the breadth or depth of conversations around how and why the project should be carried out.

The Gulf of Maine Digital GeoLibrary will take shape at some point. We need to place some effort at the local level to make sure that our needs *will* be met, and to try and guarantee that the information we need is correct, timely and couched in terms we understand (Coleman and Skogstad 1990; Geodata Alliance 2000; Mapping Science Committee 1999). It should be that such a GoM Geolibrary is created by our own local efforts. As with all such things, the human and organizational (political to name one) are the more complex questions that take the majority of the time (Canadian Global Change Program 1996; Craglia and Masser 2003; Miller and Han 1999; Obermeyer 1995).

Moreover, the most critical need is funding. Even if a GOM geolibrary were to be nothing more or less than a replication of similar projects, there would still be a need to fund such an implementation.

Funding, people, technology and information are needed (in that order, although funding is directly proportional to the support of people). Now is as good a time as any. Maybe we have not talked enough about this or other similar projects—one useful aspect of previous iterations has been the development of dialogues between communities of information users and producers. Perhaps we need to take a little more time and wait to see how related projects take shape. As stated before, some type(s) of digital library for the GoM will happen. It may not be called a digital library, but the functions and services will be so close in comparison that it will not matter. So long as citizens around the Gulf and Bay of Fundy have access to the information they need, and ideally in the conversation-meeting places that are best suited to placing information in context or dynamic discussions, then our goals will be met.

And one final word (or two). There are many activities taking place around the Gulf, with databases and information-sharing structures being put together. These are useful and necessary, but they fall short of a coherent whole, a definable collection of disparate sources that are searchable, preserved and open to more than just the expert community who produced the infrastructure. They are certainly not presented in a manner that allows for serendipitous exploration, a method proven to be as effective as any other narrowly focused way of going about information discovery (especially when one is looking for interdisciplinary works). The current iteration of the Web is an example of something that has grown to be bigger than what it was first thought or planned for; it is nearly impossible to think of what we did before the Web ten years ago. We are communities of experts who each have hold of some kernel of knowledge that may very well be vital to a larger group—especially when combined with other forms of information not thought of as being readily applicable. It is time to find a structure that suits these new forms of communication: a community-based, open, preserved, standardized, well-funded, and library-like digital infrastructure.

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Session Six

FISH, FISHERIES AND AQUACULTURE

Chair: David Scarratt, David Scarratt and Associates, Bridgetown, Nova Scotia

HISTORIC CHARACTERIZATION OF CHANGES TO THE FISH COMMUNITY IN THE AVON RIVER, NOVA SCOTIA

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Abstract

The Avon River, which empties into the Minas Basin, has experienced significant pressures from human activities since European settlement. To date, fishes in the river have been poorly monitored and knowledge of the changes in the fish community through time is incomplete. Consequently, scientific, historic, archaeological and anecdotal data were compiled and analyzed to characterize the history of changes in the fish community. Data sources include scientific reports, archives, and local experiential and expert knowledge. This paper provides preliminary findings with emphasis on key anadromous species, particularly the Atlantic salmon (*Salmo salar*).

Twenty-nine local and expert informants were interviewed and over 200 documented sources of information were located. Preliminary analysis of these sources suggest that fish abundances have declined significantly since European settlement, with the most pronounced changes occurring in the 20th century. Atlantic salmon and other anadromous species were abundant in the river prior to the construction of hydropower dams in the 1920s; subsequently abundances significantly declined. By the mid-1960s, small to fair runs of several species were still spawning in the river; however, after construction of the Windsor-Falmouth Causeway, anadromous fish populations further declined and it appears that salmon may have been extirpated. The causes of the declines are probably the cumulative impacts of numerous human and natural factors occurring in the river, the watershed, and the Bay of Fundy.

Introduction

Since European settlement, the native fish community in the Avon River has experienced significant pressures from human activities. Until recently, these fish populations had been poorly studied, and few known records exist concerning their historic status. Although the few known records suggest many native fish populations, especially anadromous species (those that live at sea but migrate to fresh water to spawn), had declined from historic abundances, the actual timing and extent of changes had previously only been speculated. Additionally, the relative impacts of various human activities, especially hydroelectric dams and the Windsor-Falmouth Causeway, were uncertain and highly controversial.

The purpose of this study was to reconstruct the history of changes in the fish community in the Avon River from pre-European settlement to the present and to identify and explore the potential causes of those changes. The specific objectives are to: (1) assess existing scientific, historic, archaeological and anecdotal data on the fish populations in the river from pre-European settlement to the present; (2) develop a timeline of changes and trends in the status and composition of the fish community; and (3) identify natural and human stresses on the fish community.

As the study is still in progress, this paper provides only preliminary findings, with emphasis on the key (from a commercial or recreational perspective) anadromous species, particularly Atlantic salmon (*Salmo salar*).

Data Collection Methods and Sources

This interdisciplinary project combined both scientific and non-scientific data. Data collection involved two phases completed during the summer of 2004. Phase 1 involved an extensive search for scientific, historic, archaeological and anecdotal documentation on fish and potential impacts. Sources included more than 200 reports, correspondences, newspaper articles, surveys, and other documents from national, provincial and local government records, libraries, archives, and museum collections. Phase 2 involved interviews with 29 key informants (KI) with local experiential and/or expert knowledge, including local recreational and commercial fishers and residents, government agents, and academic experts. The local KIs contributed information dating back as early as the late 1920s, with the majority covering the late 1940s to the present. These data were primarily of a qualitative, anecdotal nature; however, there were a few quantitative sources, including lake surveys, electro-fishing data, and commercial and recreational catch statistics. Little information was found on non-recreational or non-commercial species, and this was limited to whether they had ever been recorded at a particular time and place in the river.

Study Area

The Avon River empties into the southern Minas Basin in the upper Bay of Fundy (BoF), and consists of the Avon estuary and upper river system. The Avon estuary extends from the mouth of the river to a causeway at the town of Windsor. Prior to the construction of the Windsor-Falmouth Causeway in 1969–1970, the tidal influence extended 14–16 km upstream (Daborn et al. 2004). The Avon River above Windsor consists of a freshwater reservoir (Pesaquid Lake), three major river branches (South, West, and Southwest), and many smaller streams and lakes. The broader watershed, which includes several tributary systems that empty into the Avon Estuary (e.g., Kennetcook and St. Croix Rivers), was studied for indications of watershed-level changes.

Human Impacts on Fish in the Watershed

Historic and current anthropogenic stresses on fish in BoF rivers have been numerous, and it is often difficult to attribute changes to any one particular factor (Percy and Wells 1997). Several historic and current factors potentially affecting the fish community in the Avon River were identified in documentation and KI interviews (Table 1). For the most part, key informants suggested that it was not possible to attribute changes in fish abundance to any one specific cause, but cited cumulative impacts of many factors. However, the most commonly cited factors by KIs were the Windsor-Falmouth Causeway, hydropower dams, and modern logging activities. In the 19th and early-20th centuries, mill dams and other obstructions, sawdust pollution, illegal fishing practices, and overfishing were common concerns (e.g., Department of Marine and Fisheries [DMF] 1869; Butler 1894; Hockin 1914). In the 1800s, fishery officers also mentioned natural seasonal variability in water levels as affecting the abundance or scarcity of anadromous fish in a particular season, since low water levels would make it difficult for fish to ascend the river and would also increase their vulnerability to poachers (e.g., DMF 1881).

Dams

Many mill dams were located throughout the watershed from the early 1800s to the mid-1900s, only a few of which permitted fish passage (e.g., Butler 1894; Hockin 1914). In the early 1920s, several hydropower dams were built without fish-ways, thus altering water levels and flows and blocking fish migration (Smith 1965; Shanks 1994). Two hydropower dams were installed on the South branch; the first approximately 20 km upstream of Windsor (Shanks 1994); four storage dams were also built. A natural falls of approximately 15 meters used to be at the site of the second dam, which according to many reports may itself have been a total obstruction to fish passage (e.g., DMF 1869; Butler 1894). In the mid-1930s, a dam was built on the outlet of Black River Lake, which formed the headwaters of the West branch, diverting water flow into the Gaspereau River system (Smith 1965).

Causeway

Possibly the most prominent change to the area occurred in 1969–1970 with the construction of a causeway, with no provision for fish passage, across the river between Windsor and Falmouth. Since its construction, significant local and scientific concern and controversy has been elicited about its long-term impacts on the fish community. This tidal barrier has, among other things, restricted migration of fish and shortened the length of the tidal portion of the river (Sangster 1994). This barrier has undoubtedly had an impact on fish populations (Sangster 1994), but due to other natural and anthropogenic factors and the lack of monitoring before or after its construction, the extent of its effects is unknown.

Fish in the Watershed

Thirty-four marine, diadromous (spend part of lives in fresh water and part at sea), and freshwater species were found to have been identified in the Avon River and estuary at some time (Table 2). This is likely not a complete list of species, since little effort has yet been made to survey (and little attention paid by fishers to) non-game and non-commercial species in the river (J. Gilhen 2004, pers. comm.). Ten of the species have been reported in the river or estuary within the last ten years. However, the lack of recent records or observations does not necessarily signify that they are no longer present.

The only anadromous species' confirmed to still regularly ascend to the upper Avon River are blueback herring and alewife (gaspereau), although sea trout are occasionally observed, mostly when the causeway gate is opened for an extended period. Striped bass, shad and smelt are still found in the estuary (Daborn et al. 2004; KIs 2004, pers. comm.) but have not been reported in the upper river since the completion of the causeway.

Changes in Anadromous Fish: The Case of Atlantic Salmon

The first recorded visit to the Avon River area by French explorers was in 1604 by Samuel de Champlain (Duncanson 1983). At this time, Champlain described an abundance of salmon and other fish in the rivers in the vicinity. Although there are no earlier records of fish in the area, several Mi'kmaq camps were located in the watershed, including a large one on the St. Croix River (Deal and Butt 1990) and another at Indian Orchard on the South branch (KIs 2004 pers. comm.). Mi'kmaq likely chose these sites to exploit the abundant anadromous fish runs such as salmon and gaspereau (*Alosa aestivalis* and *Alosa pseudoharengus*) in the spring and/or fall (Deal and Butt 1990; KIs 2004 pers. comm.).

From European settlement in the area in 1685 to the mid-1800s, all indications were that salmon and other commonly fished anadromous species were abundant. From Acadian settlement in the area in 1685 to the late 18th century, the Avon was known as an important salmon river (Dunfield 1985). In fact, salmon were so plentiful in the river that it was commonly referred to as the "Salmon River", and was thus marked on charts of the time (Public Archives of Nova Scotia 1933). In 1852, Perley observed, "salmon ascend the Avon, and its tributaries, in considerable numbers" (1852: 158; see Perley [1852], for descriptions of gaspereau, shad, smelt, sea trout, striped bass and sturgeon in the river).

By 1868, anadromous populations in the Avon River seemed to have deteriorated such that the Fishery Officer for Nova Scotia reported that few fish of any species visited this river (W. H. Rogers cited in DMF 1869). Roger's theories for the scarcity were: local inhabitants placing nets across the river and taking every fish that attempted to ascend; the natural falls on the South branch, which prevented fish from getting up to the excellent spawning habitat above; and a limited amount of good spawning habitat on the South branch below the falls. The latter two explanations do not, however, account for the former abundance of fish in the river.

In 1877, the DMF began stocking a number of the rivers and streams in the watershed with salmon (DMF 1878). In 1879 and 1880, respectively, the local Fishery Overseer, Burnham, reported that salmon in the Avon had "never been so scarce" (quoted in DMF 1880: 219) and were "almost wholly gone" (quoted in DMF 1881: 154). However, Burnham (cited in DMF 1880) hoped that fishing would improve once the recently stocked fish returned to spawn. Although Burnham (cited in DMF 1881) attributed the 1880 scarcity to natural dry conditions, this factor does not account for the scarcity experienced throughout the preceding decade. Other possible explanations were mill obstructions on the South and West branches, sawdust, and illegal fishing (e.g., Butler 1894; McDougall 1898). In 1885, salmon numbers in the Avon seemed to have improved and fish were of larger size than in previous years (DMF 1886). By 1898, salmon were again reported as being plentiful (e.g., McDougall 1898; DMF 1900).

In the early 20th century, good-sized runs seemed to have existed on both the South (below the falls) and West branches (Smith 1965) and salmon were reported as being caught in higher numbers in the Avon River than ever before (e.g., DMF 1909). Little documentation was located covering the early 1920s to 1965, nevertheless it appears that anadromous species began to decline significantly after extensive hydropower development in the 1920s and 30s. Although local KIs stated that good-sized populations of salmon, shad, gaspereau, striped bass, sea trout, and smelt were present in the river and/or estuary in their early experiences (late 1920s to 1950s), they had never known fish to be as plentiful in the river as in other nearby systems.

In 1965, Department of Fisheries and Forestry (DFF) biologists investigated the possible impacts of the proposed Windsor-Falmouth Causeway on the fishery in the river (Smith 1965). The investigation, of which no methods or sources of information were provided, found that the Avon River was, by that time, of very limited value to anadromous fish due to the diversion and restriction of water flow resulting from the hydro dams. The report concluded that there were only a few small runs of salmon, gaspereau, smelt, and sea trout still spawning in the river (South branch below the power dams and the West branch, which was free from obstructions). The findings were generally supported by the recollections of local KIs, except that many claimed that fair numbers of fish were still observed in those areas.

The DFF investigation formed the basis for the decision to construct the causeway without fish passage (DFF 1968). The report concluded that the only remaining significant population of (commercial or game) fish was resident trout, which would likely benefit from the causeway as it would increase the amount of available freshwater habitat (Smith 1965). Nevertheless, Smith (1965) recommended that a fish-way be placed in the causeway to ensure the remaining anadromous runs could still reach their spawning grounds.

In 1969–1970, the Windsor Causeway was built without any provision for fish passage. It appears that this structure severely restricted or prevented the remaining salmon runs from reaching their spawning grounds. The prevailing opinion of local KIs and other residents (Letters to DFO from Concerned Citizens 1987) was that the Avon salmon population disappeared within a few years of the causeway's construction.

However, two accounts were found of salmon above the causeway in the 1980s. In 1983, a few local fishers claimed that a number of salmon would amass on the seaward side of the causeway waiting for the gates to open at low tide (Deemer and Skelhorn 1983). Evidently, some fish would then ascend the river. The fishers noted that poaching was a problem on the South branch when the water levels were low due to the restriction of water by the power dams. During a three-week period in May 1996, the causeway gates were left open for maintenance purposes, at which time many local fishers and residents reported seeing several salmon and numerous gaspereau on the West branch and other streams just above Pesaquid Lake (Letters to DFO from Concerned Citizens 1987; KIs 2004 pers. comm.). If these reports are accurate, they may suggest that a small run still persisted until this time. Conversely, it is possible that the fish were strays from the Kennetcook or other tributary populations.

Nevertheless, no evidence was found of salmon in the Avon River since the 1986 event, and recent sampling efforts (Daborn et al. 2004; DFO Electro-fishing Database), and KI observations suggests that the Avon salmon population is either at an extremely low abundance or has entirely disappeared. A small run reportedly remains on the nearby Kennetcook River.

Summary of Changes in Anadromous Fish

Similar to the case with Atlantic salmon, there appears to have been a great abundance of anadromous species in the Avon River prior to and around the 1850s. Despite natural fluctuations, there appears to have been an overall declining trend in anadromous fish abundance since the mid-1800s, which intensified at the time of the hydro development in the 1920s. By the mid-1960s, the abundances of most species had significantly declined. After the causeway was built, this declining trend seemed to further intensify. However, it should be noted that the recent declines in anadromous fish have not been restricted to the Avon River and may reflect and/or contribute to broader Bay of Fundy-wide problems. For example, in the late 1960s, the entire inner Bay of Fundy salmon population began to drastically decline (Percy 1997) and is now officially listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Conclusion

The hydropower dams and causeway appear to have played a significant role in the historic and recent changes to the state of the Avon River fish community. It is likely that these impacts have interacted cumulatively with other human activities and natural variables in the river, the watershed, and the Bay of Fundy over a long period. The synthesis of existing knowledge about fish in the system can contribute to the understanding of the interactions at play; however, further research is necessary to confirm and monitor the status and composition of the fish community, since current data are limited. Further investigations can provide information useful for watershed-based management of human activities, and restoration and conservation measures.

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Table 1: Historic and Current Factors Potentially Affecting Fish Populations in the Avon River—results of a survey of 29 key informants (KIs)

Factor	# of KIs	Factor	# of KIs
Causeway	22	Residential Development	6
Hydro development	17	Mining activities	6
Logging activities	16	Mill-dams and other obstructions	5
Fishing pressure/practices	13	Climate change	3
Agricultural activities/pollution	11	Dykes	2
Industrial and residential pollution	11	Sawdust & other mill pollution	2
Introduced species	11	Natural factors/variability	2
Broader Minas Basin/BoF factors	8		

Note: # of KIs refers to the number of KIs who mentioned the factor

Table 2: Fish Species Historically and Recently Identified in the Avon River and Estuary

Scientific name	Common name	Type	Identified in last 10 years (Y/N)
Acipenser oxyrhynchus	Atlantic sturgeon	Anadromous	Y
Alosa aestivalis	Blueback herring (gaspereau)	Anadromous	Y
Alosa pseudoharengus	Alewife (gaspereau)	Anadromous	Y
Alosa sapidissima	American shad	Anadromous	Y
Ameiurus nebulosus	Brown bullhead	Freshwater	Y
Anguilla rostrata	American eel	Catadromous	Y
Apeltes quadracus	4-spine stickleback	Estuarine/freshwater	Y
Catostomus commersoni	White sucker	Freshwater	Y
Couesius plumbeus	Lake chub	Freshwater	N
Esox niger	Chain pickerel	Freshwater, introduced	Y
Fundulus heteroclitus	Banded killifish	Freshwater	Y
Gadus morhua	Atlantic cod	Marine	N
Gasterosteus aculeatus	3-spine stickleback	Estuarine/freshwater/ anadromous	Y
Liposetta putnami	Smooth flounder	Marine	Y
Luxilus cornutus	Common shiner	Freshwater	N
Menidia menidia	Atlantic silversides	Marine	Y
Microgadus tomcod	Tomcod	Estuarine/Anadromous	Y
Micropterus dolomieu	Smallmouth bass	Freshwater, introduced	Y
Morone americana	White perch	Anadromous	Y
Morone saxatilis	Striped bass	Anadromous	Y
Notemigonus crysoleucas	Golden shiner	Freshwater	N
Notropis heterolepis	Blacknose shiner	Freshwater	N
Oncorhynchus mykiss	Rainbow trout[1]	Freshwater, introduced	Y
Osmerus mordax	Rainbow smelt	Anadromous	Y[2]
Perca flavescens	Yellow perch	Freshwater	Y
Petromyzon marinus	Sea lamprey	Anadromous	N
Phoxinus eos	Northern redbelly dace	Freshwater	N
Pseudopleuronectes americana	Winter flounder	Marine	Y
Pungitius pungitius	9-spine stickleback	Estuarine/anadromous	Y
Salmo salar	Atlantic salmon	Anadromous	N[2]
Salmo trutta [3]	Brown trout	Anadromous, introduced	N
Salvelinus fontinalis	Brook trout	Freshwater/anadromous	Y
Semotilus atromaculatus	Creek chub	Freshwater	N
Squalus acanthias	Spiny dogfish	Marine	Y

[1] Confirmed only in Meadow Pond
[2] Avon River population may be extirpated; but may still be in other tributaries; from local KI observations
[3] Presence not confirmed; only evidence are accounts by two local KIs and an unofficial, unpublished NS Department of Lands and Forests (NSDLF) survey of fishery officers (NSDLF 1973)

BENTHIC MACROFAUNAL CHANGES IN THE LETANG INLET: AN ANALYSIS BEFORE AND AFTER AQUACULTURE

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The 14-km long Letang Inlet lies within the Western Isles region of the lower Bay of Fundy. Industries located in the Inlet have undergone major changes over the last three decades, including the start-up of a pulp and paper mill in the 1970s and the initiation of caged salmon aquaculture in the 1980s that now predominates the area. Multivariate analysis of six stations spanning most of the Inlet, indicated that benthic macrofaunal assemblages changed significantly between 1975 and 2000 in all areas of the Letang. Before aquaculture (1975), the benthic community structure of the upper Letang was highly impacted by organic enrichment from pulp mill effluent, the lower Letang being free of impact. After aquaculture (1997+), the lower Letang changed significantly, consistent with general initial enrichment of that area, while the upper Letang recovered from highly enriched conditions as a result of effluent treatment and the installation of a one-way flap gate, which prevented seawater entry above the causeway. Detected changes showed a significant shift in biodiversity, dominant species, trophic structure, and the extirpation of some species. Reference stations, in an area that did not experience such changes in industrial activity, did not show such dramatic changes over the same period of time.

EFFICACY OF RELEASING CAPTIVE REARED BROODSTOCK INTO AN IMPERILED WILD ATLANTIC SALMON POPULATION AS A RECOVERY STRATEGY

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The strategy of releasing captive-reared adult Atlantic salmon (*Salmo salar*) into the Magaguadavic River, New Brunswick, to spawn, was not an effective tool for rebuilding a seriously depressed wild population. The fish were first generation progeny from wild parents, and had spent their entire lives in captivity in either sea water or fresh water. No differences in movement or behaviour patterns were observed between freshwater- and seawater-reared groups. Fish released in the lower river early (35 to 80 days prior to the natural spawning period) moved into a lake low in the system, and most stayed there, near the commercial hatchery where they had been reared from egg to smolt. During spawning season, none moved to upper river reaches where most spawning habitat exists. Most broodstock released in the upper river reaches near the time of spawning, stayed there during the spawning period. However, the following year few to no salmon fry were found, and most appeared not to be offspring of the released adults.

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doi: 10.1111/j.1095-8649.x, Available online at <http://www.blackwell-synergy.com>.

PREVENTING RIGHT WHALE ENTANGLEMENTS IN FISHING GEAR IN THE BAY OF FUNDY

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With only about 350 individuals remaining in the population, the North Atlantic right whale is one of the most endangered large whale species in the world. Their range in eastern North American coastal waters coincides with areas subject to heavy human activities. Some of these activities present serious risks to right whales; in particular, vessel strikes and accidental entanglements in fishing gear are the two main sources of human-caused mortality for the species. As many as two-thirds of the right whales congregate in the Bay of Fundy each summer. WWF is working to bring together fishermen, scientists, fishing gear manufacturers, and government agencies to develop innovative solutions to prevent entanglements of right whales in fishing gear. The project is designed to facilitate the development of conservation solutions voluntarily from within the fishing industry. The project will involve US agencies that have undertaken similar work in northeastern US waters, attempting to determine how practices used in the United States may be adapted for the unique tidal conditions in the Bay of Fundy. The group will plan and conduct tests of fishing gear designed to prevent or reduce the severity of entanglements. The project began in the spring of 2004, and this presentation outlines methods and results to date.

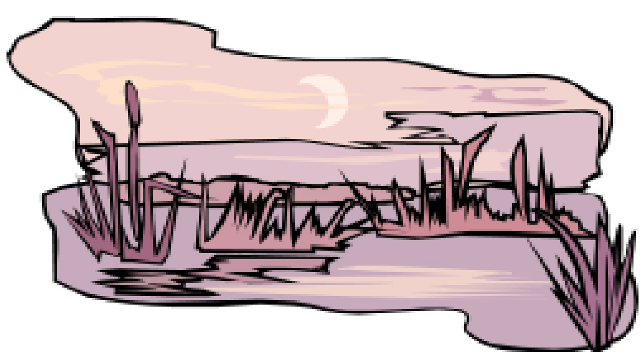
Session Seven

PROTECTING SPECIAL SPACES

Chairs: Maria-Ines Buzeta, Oceans and Habitat Branch, Fisheries and Oceans Canada, St. Andrews, New Brunswick

and

Jennifer Smith, World Wildlife Fund Canada, Haliax, Nova Scotia



MARINE PROTECTED AREAS (MPAS) IN REGIONAL CONSERVATION PLANNING: A FRAMEWORK FOR THE SCOTIAN SHELF AND GULF OF MAINE

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Marine protected areas (MPAs) offer a range of benefits for fisheries, local economies and the marine environment. They serve to prevent habitat damage, maintain biodiversity, and provide a safe haven for fish stocks to recover (Halpern 2003; Gell and Roberts 2003; Roberts et al. 2001; Ward et al. 2001 and others). MPAs, therefore, are an insurance policy for the future, both for marine life and local people. The scientific consensus is growing: setting aside some areas that are managed for conservation is critical to achieving healthy oceans and oceans-based economies.

Despite this, spatial conservation tools are currently underused in marine ecosystems; less than one percent of the world's oceans has any meaningful protection. There is still a great distance to go if we are to implement the protection needed to restore the habitats and living resources of our oceans. For these reasons, WWF-Canada is working towards establishing networks of MPAs.

Networks of Protected Areas

Unless they are very large, individual MPAs are unlikely to capture the full range of habitats characteristic of a large marine ecosystem. They are also unlikely to contain the full range of life history stages for migratory species or species that spend part of their life history floating freely as plankton. Although implementing individual MPAs is important, they can be made more effective and their impact 'scaled up' by creating connected and representative networks of areas managed for conservation. The following paragraphs describe some important elements for the effective use of MPA networks as a tool for regional conservation planning, and some of the work WWF-Canada is doing to advance these goals.

WWF-Canada advocates for networks planned at the scale of a large ecological unit—what we call an "ecoregion". An ecoregion is likely to be on the scale of hundreds to thousands of kilometers, reflecting the scale of processes that maintain the productivity and diversity of the marine ecosystem. Planning at the level of the ecoregion is the best way to protect large-scale process and patterns. In eastern Canada, WWF works at the scale of the Northwest Atlantic Ecoregion and encourages local conservation initiatives to consider their role in this larger ecoregion.

To be most effective, networks should protect representative samples of the full range of habitats within this large area. A representative approach, whereby a spatial array of MPAs and fully protected areas covers all the representative habitats and processes of an ecoregion, provides the basis for a comprehensive program to conserve biodiversity and sustain healthy and productive natural ecosystems. We know very little about the oceans and often cannot predict the long-term effects our actions have on marine ecosystems. Representation is one way to be precautionary in the face of imperfect scientific knowledge. Representative networks of MPAs can succeed in protecting marine ecosystems and processes at relevant large ecological scales, and can also contribute significantly to species and fisheries management. A representative system approach confers insurance against disturbance events by providing replication, and in the absence of comprehensive scientific data, provides a precautionary means of sampling relevant ecological processes and critical life history sites, including providing for connectivity, viable populations and resilience. WWF-Canada has invested in science and mapping to contribute to the development of habitat classifications in our region.

Biodiversity protection and restoration is an explicit goal of a network plan, and planning adheres to the conservation first principle. MPA networks can also be used in fisheries management or tourism, but biodiversity at risk is our priority. This means that, in planning for marine use through ocean zoning or integrated management, conservation needs to come first in the form of a network of areas managed for conservation. WWF-Canada has drawn on expertise from Australia (where the Great Barrier Reef Marine Park Authority recently completed a regional network of highly-protected areas) and elsewhere, and developed our own in-house expertise on the use of computer-based decision support tools and the concepts behind them. These tools help planners to balance biodiversity conservation goals with costs and practical considerations to present stakeholders with a range of solutions.

The level of protection should be meaningful and sufficient to protect the biodiversity values of each MPA. This means that individual MPAs must meet minimum management requirements of ensuring sustainable use and restricting all activities that are detrimental to endangered species, or that compromise ecosystem integrity and function. WWF-Canada has been involved in developing minimum protection standards and indicators of management effectiveness to help guide effective stewardship of marine protected areas.

Finally, it is important to ensure that these sites are formally recognized through designation and governance that ensures their protection now and into the future, and that rules will be enforced and boundaries recognized. This implies a need for strong legislation, sufficient resources for monitoring, management and enforcement, and stakeholder co-operation.

These criteria represent WWF-Canada’s goals for networks of MPAs, and are in line with the guidance from the World Summit on Sustainable Development, the United Nations Convention on Biodiversity, and the World Parks Congress. More than our own standards, they are global commitments.

Systematic Conservation Planning

Achieving a network of protected areas that meets these criteria is nearly impossible when protected areas are implemented one-at-a-time in response to a crisis or a single species issue. Such an ad hoc approach leads to uncertainty for all stakeholders, loss of options as the pace of industrial development outstrips conservation planning, and potentially an inefficient network, the effectiveness of which is diminished by a lack of long-term planning. Neither industry, government, nor the public is well served by this approach.

WWF-Canada advocates an innovative approach that is currently gaining acceptance around the world. Called “systematic conservation planning”, this approach fits naturally into integrated management and ocean zoning initiatives. Systematic conservation planning incorporates the following key principles (after Margules and Pressey 2000):

Systematic planning requires clear choices about the things we want to protect and the goals we set for their protection. These usually take the form of quantitative targets: for example, 20 percent of each habitat type, or 80 percent of all known cold-water coral reefs. Setting clear goals forces us to be transparent and specific, which is important to those who will be affected.

Systematic planning is supported by the best available science, but proceeds even if our knowledge of the ocean is not yet perfect and acknowledges that ecosystems are open, complex and changing.

Systematic planning is efficient in that it meets conservation goals while minimizing cost and displacement, whether associated with ongoing management or impacts to resource users.

There are many possible configurations of a protected areas network that still meet conservation targets. This approach is flexible in that it provides a way to explore the full range of options for design of a network and presents alternatives. This gives us choices and scope for resolving conflicts.

Systematic planning is fair and transparent because it uses clear methods for locating MPAs. These methods aim to achieve specific targets and include phases for consultation.

Systematic conservation planning offers significant benefits over an ad hoc approach. It is a way to make concrete progress on long-term sustainability goals because it implements the MPA tool in a way that maximizes the chance of success. Planning for oceans use can proceed with more certainty because we will have put in place the foundation for long-term conservation. Finally, it produces an outcome that everyone can live with because it incorporates compromise, flexibility, fairness and clarity. Implementing regional-scale, representative networks of areas managed for conservation through a systematic approach is a commitment Canada has made through several international agreements, including the World Summit on Sustainable Development and the United Nations Convention on Biological Diversity.

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DEVELOPING A STRATEGIC FRAMEWORK FOR THE ESTABLISHMENT OF A NATIONAL MARINE CONSERVATION AREA IN THE BAY OF FUNDY

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Abstract

One of Canada's options for conservation, using the marine reserve approach, is Parks Canada's National Marine Conservation Areas (NMCA) program. The purpose of this program is to unite sustainable human activity with the protection of representative marine environments. Parks Canada has divided Canada's oceans and Great Lakes into 29 distinct marine regions. The Bay of Fundy is one of ten such regions delineated in Atlantic Canada. With its high level of unique biological diversity and human activity, the Bay of Fundy may be a good candidate site for pursuing NMCA establishment in the near future. However, it is critical not to base NMCA establishment decisions solely on a biophysical foundation, without considering the social condition and interests of the area. The project reported here explores the potential for NMCA establishment in the Bay of Fundy by examining the current views of various members of the broadly defined Bay of Fundy community. To accomplish this, interviews were carried out with various community members and stakeholder groups.

The research has resulted in a possible framework for NMCA establishment in the Bay of Fundy. The results highlight important initial steps that might be taken in order to optimize the chance of success. These steps include: establishing a non-governmental secretariat to guide the project; a broad education campaign to generate public support; early involvement and commitment from all partners and stakeholder groups; finding non-governmental project leaders from local communityies; and securing funds and other resources.

Introduction

In Canada, two federal departments have mandates to protect the marine environment through the delineation of areas for conservation. Fisheries and Oceans Canada (DFO) is now responsible for creating Marine Protected Areas (MPAs), which are governed under section 35 of the *Oceans Act* (1996). MPAs are created for the conservation and protection of fishery resources, other marine species, habitats, and areas of high biodiversity and biological productivity. Secondly, the Parks Canada agency, within Environment Canada, can establish National Marine Conservation Areas (NMCAs) under the *Canada National Marine Conservation Areas Act* (*CNMCA Act* 2002), "for the purpose of protecting and conserving representative marine areas for the benefit, education and enjoyment of the people of Canada and the world" (*CNMCA Act* 2002: subsection 4(1)). Therefore, NMCAs are designed to serve multiple roles. They are managed for sustainable use and for visitors to "understand, appreciate and enjoy", while providing smaller areas within NMCAs with higher levels of protection (Parks Canada

2004a). It should be noted here that Environment Canada can also create Marine Wildlife Areas (MWAs), as part of a Protected Areas Network, under a 1994 amendment to the *Canada Wildlife Act* (1985); MWAs have a different purpose than MPAs and NMCAs, and protect inshore and offshore coastal habitats, particularly for migratory birds (Environment Canada 2004).

Parks Canada's NMCA system plan divides Canada's oceans and the Great Lakes into 29 natural regions, based on a combination of biological and physical characteristics including: temperature, salinity, currents, depth profiles, and species distributions (Parks Canada 2004a). Ten Atlantic marine regions have been identified, of which the Bay of Fundy is one. To date only two of the 29 marine regions have been afforded protection by Parks Canada: Fathom Five Marine Park (112 km^2) in Ontario and the Saguenay-St. Lawrence Marine Park (1,138 km^2) in Quebec. Both were established before the *CNMCA Act* (2002) came into affect. Recently (March 2004), David Anderson, Minister of the Environment, announced that a feasibility study will be conducted on the creation of a new NMCA in a 5,000 km^2 area around the Magdalen Islands, in the Magdalen Shallows marine region of the Gulf of St. Lawrence. "The purpose of the feasibility study is to determine whether it is possible and desirable to create a national marine conservation area around the Magdalen Islands Archipelago" (Parks Canada 2004b). Currently, none of the other Atlantic marine regions are being examined by Parks Canada in order to identify a candidate NMCA site.

The idea of establishing a marine conservation area in the Bay of Fundy is not new. Although the concept has *not* been studied for almost 20 years following the abandonment of Parks Canada's West Isles proposal, the feasibility studies for which were carried out in the mid-1980s. Neither Parks Canada nor researchers from other organizations are currently exploring the possibility of establishing a NMCA in the Bay. Because the earlier West Isles marine park study is now partly out of date, information gaps currently exist with respect to this issue. In light of the lack of recent information useful in creating a NMCA in the Bay of Fundy, exploratory qualitative research was carried out to identify the information gaps and help fill some of them. One primary research question addressed was: "*How* (if possible) can a NMCA be established in the Bay of Fundy?" In other words, what processes should be employed in the Bay of Fundy to ensure the highest likelihood of successful NMCA establishment there?

The importance of using an appropriate approach and process for NMCA establishment cannot be underestimated; without good process the project will probably not succeed (Fenton et al. 2002). Lien (1999) and Walters and Butler (1995) describe previous unsuccessful processes in the creation of marine conservation areas in the Atlantic region. For example, Walters and Butler (1995) concluded that the process used by Parks Canada for the West Isles feasibility study was one of the primary reasons for the abandonment of this initiative. In contrast, Lien (1999) considered that although there were significant improvements to the process employed in the Bonavista Bay proposal compared to that of the West Isles, the needs and goals of this Newfoundland community, following the local fisheries crisis, were at odds with those of Parks Canada. In Lien's opinion, Parks Canada had essentially given the public advisory committee an impossible task, with insufficient resources, assistance or support (Lien 1999). Parks Canada's most positive experience to date has been in the development and establishment of the Western Lake Superior NMCA. In this case a regional committee, made up of community members and local stakeholders, was established immediately and facilitated the process (Lake Superior Newsletter 2001).

In light of these reports, it appears that for NMCA establishment to be pursued in the Bay of Fundy, a well-founded approach and process needs to be employed. The approach may need to be led by, and take special account of, the interests of the local communities. Taking account of the need for local leadership, in this paper I will discuss and recommend only a few important initial steps to be taken; the remainder of the process should be decided locally and collectively, within the context of the specific area under consideration.

Methods

Primary research involved interviewing members of the broad Bay of Fundy community. Participants were selected from different communities, user groups and stakeholder groups, from both the Nova Scotia and the New Brunswick sides of the Bay of Fundy. Appropriate individuals to interview were identified using published literature, in discussion with research supervisors, and through recommendations from other study participants. Unfortunately due to time and budgetary constraints, it was not possible to include all the suggested participants, but the broad representation captured by the final sample appeared sufficient for the conclusions drawn.

In total, 37 participants were involved, including various individual community members, First Nations community members, scientists, professors, and representatives from the following general groups: fishermen's associations, provincial and municipal governments, conservation groups, economic development, the tourism industry, and the aquaculture industry. Face-to-face interviews, approximately an hour in length, were carried out using open-ended questions to facilitate discussion. When possible and with consent, interviews were tape-recorded to ensure accuracy. The principal researcher transcribed the interviews, and data analysis was carried out using a manual coding method.

Results and Discussion

Many people interviewed were in agreement that if the process is good, and Parks Canada has 'done their homework', then in the end it is probable that a NMCA can be successfully established in the Bay of Fundy. There was consensus, however, that processes used by governments in the past have not worked in the Bay of Fundy region. There needs to be a change, a move towards a more open and discussion-based process. If driven in a bottom-up manner instead of top-down, destructive popular opposition is less likely to emerge. Outlined below are other significant points raised by several participants regarding their advice on an effective process for NMCA establishment in the Bay of Fundy.

1. Identify a region

Parks Canada should first have a general region in mind within the Bay of Fundy before going to the public. The area selected must have clearly definable conservation significance (participants #18 and 20). It is important to identify a region, because people will be suspicious as to government's intentions, or fear that there might be a hidden agenda, if a specific region is not identified at first (participant #13). However, before drawing lines on the map, it is important that the community, including local industries, approve the general principle of creating a NMCA (participants #28, 32, and 37). Specific boundaries should not be delineated when first meeting the public, because specific lines on maps raise fears for people who do not understand what they mean, as was seen in the Upper Bay of Fundy Biosphere Reserve initiative (participant #6). Many people will automatically assume that the lines identify places they will be banned from entering, and people who rely on those areas for their livelihood are likely to become concerned and defensive. Instead, NMCA zones and boundaries should be drawn by the local communities and user groups together.

2. Recognize damage of past mistakes

In the Bay of Fundy, Parks Canada needs to recognize how much damage the fisheries crisis did to people, families, communities and lives (participant #33). Government administrators need to be cognizant, respectful and understanding of this, and of the resulting deep-seated distrust and scepticism of government (participants #15 and 28). The same principle applies when working with First Nations, who have also been hurt by government processes in the past and have some of the same concerns and wariness (participants #24 and 26). Parks Canada needs to be sensitive to the varied situations of people, including their wants and needs (participant #9), and not push a specific government agenda on communities.

Some participants stated that communities feel they have been let down in the past (participant #28), and that it would be helpful for Parks Canada to clearly and openly review, at the outset, what the agency has learned from its own past experiences, both the positive and constructive, as well as from the experiences of others (e.g., DFO, the Upper Bay Biosphere Reserve proposal). The lessons that come from mistakes should be presented in a useful and productive manner, and Parks Canada needs to clearly describe how they are trying to avoid similar difficulties in the Bay of Fundy (participants #1, 6, 31, and 34).

3. Begin with building trust

The first, and likely most important, step is building trust in communities and beginning to empower them (participants #18, 19, and 33). This can only be accomplished through open communication (participant #25) and by forming genuine partnerships with as many groups as possible in the area (participant #6). The process needs to be very open and non-secretive (participants #15 and 18). It must clearly not be a government venture with a hidden agenda (i.e. trying to reach some goal other than those presented), and be genuinely founded in good conservation principles (participant #22). For example, some community members felt Parks Canada's West Isles proposal was really an attempt to create a "tourist haven" for divers and others (participant #18). Transparency and accountability in the process is very important. Some people involved in unrelated initiatives have felt governments have been motivated by a desire for political success, rather than for conservation as they claimed (participants #15, 18, 21, and 22).

4. Create a non-governmental establishment committee

Although Parks Canada must explain their legal mandate to establish NMCAs (participants #16, 18, and 25), they need to approach the community in a spirit of commitment to conservation (participant #21), but do so in ways compatible with community needs or aspirations. Creating a NMCA cannot be solely a government initiative; it needs to be a community-led process involving both industry and non-industry participants in which Parks Canada is a team member and an equal (participants #16, 27, and 28). The public should be involved from the beginning and throughout (participant #6). It is critical, however, that a Parks Canada representative also be involved throughout, to act as a resource, to ensure there is clear understanding of NMCAs, and to resolve any misconceptions about them, both on the establishment committee and in the public.

The issue of how to bring all interested parties together to make this a joint initiative is a difficult but important one. Many participants share the opinion that using a non-governmental NMCA establishment committee, made up of community members, industry and other stakeholders, is probably the best approach. The reason for using a multi-stakeholder committee of this kind is two-fold: to give as many people and groups the opportunity to participate, and to gather as much knowledge and experience together as possible, thereby avoiding duplication of work already done by various groups (participant #25). However, every effort should be made to ensure that all members of the committee are equal, and no one has a stronger voice, is more dominant, or has more power within the group than another (participant #28).

5. Enlist local leadership

With respect to leadership, a Parks Canada representative should *not* be the primary organizer, facilitator, or mediator. Instead, the committee should be co-chaired by both a local community leader, with credibility among different user groups and stakeholders, and a leader from the aboriginal community (participants #24 and 33). The co-chairs should be from the region and know the communities in the area very well (participants #10, 30, 33, and 34). The co-chairs should have strong facilitation skills (participant #27) so that the committee can work towards consensus. It will be necessary for Parks Canada to give them authority, decision-making power, and support throughout the process (participants #13 and 24).

It was suggested that, ideally, the establishment committee might be a group already functioning in the area (such as the St. Mary's Bay Working Group, a Nova Scotia example), or a committee convened by a respected community group or local organization (such as the Bay of Fundy Marine Resource Centre). The process may be best initiated not by Parks Canada, but by the community itself (participants #19 and 34). This was the case for the Musquash Estuary Marine Protected Area proposal on the New Brunswick side of the Bay, and was judged to be one of the primary reasons for the project's success. The community (including the Conservation Council of New Brunswick and the Fundy North Fishermen's Association) put the proposal together, and then approached Fisheries and Oceans Canada with the idea. With broad community support from different user groups and stakeholders, the proposal had validity and strength (participants #1, 6 and 13).

6. Begin an education campaign

The first job for the establishment committee is to educate the public and generate support for the idea of a NMCA in the Bay of Fundy. A conceptual question that must be addressed for everyone in the area is “How is this going to affect me?” Although difficult, given the wide diversity of interests, the issue of impacts on people needs to be clearly addressed at the outset, in order to put people’s fears at rest. Particularly important concerns in this regard are those of the fishing communities. These communities were described by a participant as somewhat “paranoid” about losing access to resources and, therefore, their livelihoods in the future (participant #18). A NMCA needs to be, and needs to be presented as, a “win-win situation” for everyone (participants #13 and 28). Thus all educational materials should be presented in this light, including showing that the long-term sustainability of the environment is necessary for long-term sustainability of industries. Plain language should be used to explain that a NMCA does not automatically mean that users lose something (e.g., access to resources). This is important because many people will expect losses, but will not immediately recognize the potential benefits (participant #6). Educational materials should also make clear that when sacrifices must be made, these will be distributed among many, and will not fall on only one user group or industry; specific individuals or sectors will not be targeted and asked to relinquish more than others (participants #21, 22, and 28).

7. Make the long-term commitment needed

Several participants noted that no matter what process is followed, the project will be challenging and will take a long time (five or more years) and will therefore need a significant commitment from Parks Canada at the start (participants #1, 6, 21, and 22). In order to keep people engaged, there must be ongoing progress and information sharing (participant #33). Incentives will be needed to keep the NMCA establishment committee working, as many will be involved outside of their regular employment. One participant proposed that the committee be paid by Parks Canada for their time.

In a similar vein, participants explained that the project will be complex, detailed and expensive. For example, significant financial support will be required to run an effective education campaign (participant #37). Parks Canada’s commitment must, therefore, include ongoing provision of resources (participant #17). Another participant considered that the public will want to be aware of this commitment in order to have confidence in the process (participant #36). Participants also noted that Parks Canada must not try to “cut corners” or “back out of” their financial commitments (participant #25), as has been experienced in some projects, not involving Parks Canada, which resulted in problems and resentment (participant #14).

Assessment, Conclusions and Recommendations

Among the benefits of the approach taken in this study is that a wide range of relevant opinions has been obtained, which are open to analysis and synthesis. Among the intrinsic limitations of the study, with respect to drawing firm conclusions, is that it is difficult to eliminate subjective input. The motivation of participants was not examined, nor can these motivations be examined easily. Nevertheless, recommendations made by several participants who belong to differing interest groups are of special value in overcoming this limitation. The conclusions and recommendations outlined below are of this sort.

It is not possible to determine all the steps required for a successful NMCA establishment process in the Bay of Fundy without first identifying a general area of interest, because it is critical to understand the local context before solidifying a process and pursuing it. It is clear, however, that specific requirements and initial actions are needed for success anywhere in the Bay. These include committing to a bottom-up approach, clearly identifying a general area of interest and conservation needs, recognizing the interests of the local communities to ensure that their goals fit with those of Parks Canada, openly recognizing mistakes from the past and identifying a new approach, beginning by building trust through open communication, developing partnerships with community members and user groups so that the process can be community led, forming a multi-stakeholder establishment committee, finding community leaders to co-chair the committee, beginning a public education campaign to dispel myths, and seriously committing to success by allocating sufficient resources to the project. Many of these recommendations support those previously identified by Fenton et al. (2002), who examined community involvement in MPA establishment in Atlantic Canada, and identified many of same key components for success.

In the end, one major issue remains: how to decide, and who should decide, the constitution of the NMCA establishment committee, both in terms of personnel and procedures. This should be addressed by considering the local context of the area of interest, and through discussions with the potential co-chairs or other coordinating bodies. Further investigation of the communities in the area will be required.

Although not discussed here, a second research question was investigated in the study, namely *where* in the Bay of Fundy it may be possible to pursue NMCA establishment, based on both local community perspectives and stakeholder responses? Is there a location in the Bay where communities and industries were identified as being interested in discussing and possibly pursuing this idea? Such a region was found and will be discussed in a later work.

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CONSERVATION AND LOCAL COMMUNITIES: EXPLORING THE UPPER BAY OF FUNDY BIOSPHERE RESERVE INITIATIVE IN NOVA SCOTIA

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Environmental conservation has typically emphasized the protection of the physical environment with the exclusion of humans. Local people in and around protected areas often perceive conservation policies to be a threat to their land-use rights and source of livelihood. This is the situation in northern Nova Scotia with the Upper Bay of Fundy Biosphere Reserve Initiative (UBoFBRI). The original proponent of the project, which began in 2000, was an umbrella organization of tourism groups from Nova Scotia and New Brunswick. It was to be the first such reserve in Canada with a focus on the marine environment, and the first inter-provincial biosphere reserve. In the summer of 2002 the UBoFBRI planning committee, in response to perceived community opposition and volunteer burnout, dropped the Nova Scotia region. The main goal of this research is to explore the reasons why the Initiative was not successful in Nova Scotia.* The overall process of establishing a biosphere reserve and the role of communities in this process is examined. Insights gained from the research are used to make recommendations for future conservation projects and to offer insight into the best practices to be used when working with communities to propose new conservation areas.

Recognition as a biosphere reserve requires a voluntary long-term commitment at a local level for conservation and sustainable development. Biosphere reserves attempt to reconcile conservation with the preservation of economic and cultural values. Three zones, each with differing levels of protection and development—the core area, buffer zone, and zone of co-operation—as well as goals for the sustainable development of the surrounding regions do characterize a biosphere reserve. Biosphere reserves offer a more flexible approach to conservation than traditional protected areas. There are twelve biosphere reserves across Canada, and an increased amount of time is being spent on the designation process and on community consultation efforts.

Interviews were conducted in 2004, primarily in the communities along the Joggins-Apple River and Advocate Harbour-Economy shorelines, with community members and members of the planning committee. This rural area is where one of the most contentious community meetings was held. The research found that misconceptions abounded, and information obtained from anti-biosphere reserve websites influenced those opposed to the UBoFBRI. Several interview subjects expressed concern that the project was too secretive and questions remained unanswered, leaving them confused and frustrated. Several key factors were at play in Nova Scotia, including antagonism over Cape Chignecto Provincial Park, and confusion between UBoFBRI and Minas Basin Working Group community meetings, which were held at a similar time.

* Note: The biosphere initiative is continuing on the New Brunswick side, upper bay

To be commended are the strengths of the initiative, including helping to build a positive relationship between the tourism industry and wildlife/conservation managers, and having a greater community consultation effort than any previous biosphere reserve in Canada. The UBoFBRI shows us that public consultation needs to start earlier in the designation process and needs to increase in size. Projects should focus on a smaller area, growing larger as support and success is achieved. The process of achieving biosphere reserve designation can be difficult, as seen by the hostile response the UBoFBRI proponents encountered in some Nova Scotian communities. In some cases, the biggest lesson to be learned is knowing when to continue and when to walk away.

EMAN AND PROTECTED AREAS: CO-OPERATING IN PROVIDING INFORMATION FOR ECOZONE AND LOCAL ECOSYSTEM MANAGEMENT

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The Ecological Monitoring and Assessment Network's (EMAN) focus is the fostering of a scientifically sound, policy-relevant ecosystem monitoring and research network, based on a network of case-study sites operated by a variety of partners, and developing several co-operative dispersed monitoring initiatives. These partnerships and initiatives will deliver unique and needed goods and services. These include efficient and cost-effective, timely reporting of status and trends to meet the requirements of adaptive management and responsive priority setting.

Co-operatively, EMAN is developing a suite of standardized protocols for ecosystem monitoring, as well as data management, interpretation and communication tools which can be utilized by interested sites, networks and communities to establish whether and how local ecosystems are changing, while at the same time contributing to timely, status and trends reporting at all levels. These can serve as a basis for developing partnerships with protected areas managers and stakeholders. This paper will describe the standardized approaches to ecosystem monitoring that have been most recently developed by the Network.

THE PROPOSED MUSQUASH MPA: A CASE STUDY ON BOUNDARY DELIMITATION CONCEPTS

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Abstract

In this paper the authors will show that, although bathymetry data is best known for its use in the development of navigational tools, when combined with other geographic data and information, bathymetric data adds an important dimension to marine boundary delimitation principles. These principles are instrumental in furthering our understanding of how natural and anthropogenic phenomena affect property rights in marine space, and by extension, the important role that bathymetry data can play in coastal and offshore management of property rights. This paper will show how bathymetry data was used in a sample coastal zone management program, the Musquash Marine Protected Area, to outline options for the establishment of boundaries.

Introduction

Bathymetry is the measurement of the depths of water bodies from the water surface. It is the marine equivalent to topography. The premise that bathymetric data can be used for coastal resource management is not a new one. There is legal precedent that bathymetry data has historically been used to determine thalwegs (the line following the deepest part of the bed or channel of a river or lake) in ownership disputes (see, for example, Mukherjee and Gray 1987). However, the use of bathymetry for property rights management is not only historical, but also has a current context as demonstrated under the United Nations Convention on the Law of the Sea (UNCLOS), where bathymetry and other scientific information are used in delineating the juridical continental shelf which is a boundary of rights in marine space. Several authors (e.g., Monahan and Mayer 1999; van de Poll et al. 1999) are in agreement that the scientific and technical guidelines of the Commission on the Limits of the Continental Shelf (CLCS) can be interpreted as endorsing bathymetric data (raw water depth and calculated water depths) as important data content in a nation's claim to the continental shelf. This represents a new approach in boundary delimitation as scientific information is actually being used to provide evidence of a juridical boundary.

Resource Management and Bathymetry Data

Resource managers have traditionally tended to rely on scientific information regarding the quality and quantity of resources for the purpose of identifying, evaluating and managing resources in

** Second Place Student Paper award winner marine space. Apart from identifying the location of a resource, bathymetry data is also used to identify how much of the resource is available at the location, and the quality (or condition) of the resource.

Resource management is concerned with inventory, allocation, development and conservation. It balances several objectives, including the social objective of respecting existing property rights (both public and private) associated with a resource. To be able to accomplish this objective, information about two classes of boundaries is required: one boundary defining the resource extent and the other defining the extent of rights within, or in the vicinity, of the resource. The former boundary is referred to as the resource boundary, while the latter boundary is referred to as the legal boundary. The primary objective of a legal boundary is to ensure that it gives notice of the spatial extent of rights of individuals (or groups of individuals) with respect to the resource.

In information management terms, one can frame the foregoing observations in the context of three assumptions: a) it is possible to provide information regarding the identity and location of the resource, b) the information can be used to allocate or identify private or public rights (and restraints) to the resource, and c) information on resource location and associated interests is accessible in an easily understandable form to decision makers. The authors will demonstrate and discuss these assumptions using a case study involving an environmentally regulated area in the Bay of Fundy—the proposed Musquash Marine Protected Area (MPA).

Protecting Marine Areas

The Canadian government currently has three formal protected area programs for the marine environment (DFO 1998). These are administered by Canadian Heritage (Parks Canada, now in Environment Canada 2004), Environment Canada and most recently Fisheries and Oceans Canada (DFO). Canadian Heritage's National Marine Conservation Areas (NMCA) Program is in the process of establishing a number of NMCAs. Environment Canada has three marine-conservation-oriented designations available that focus on habitats for migratory birds: National Wildlife Areas, Migratory Bird Sanctuaries, and Marine Wildlife Areas (DFO 1997a, 1997b). DFO administers the Marine Protected Areas Program under the *Oceans Act* (1996).

MPAs in Canada are defined in Section 35 of Canada's *Oceans Act* as "an area of the sea designated for special protection that forms part of the internal waters of Canada or the exclusive economic zone of Canada". An area[1] can be designated as an MPA to conserve and protect one or more of the following:

1. Commercial and non-commercial fisheries resources, including marine mammals and their habitats;

[1] This is very close to the definition of MPAs developed at the 4th World Congress and adopted by the International Union for the Conservation of Nature (IUCN): "Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment".

2. Endangered and threatened marine species, and their habitats;
3. Unique habitats;
4. Marine areas of high biodiversity or biological productivity;
5. Any other marine resource or habitat as is necessary to fulfill the mandate of the Minister of Fisheries and Oceans.

Introducing the Proposed Musquash MPA

On February 8, 2000, DFO announced publicly that Musquash Estuary had been accepted as an Area of Interest (AOI), the first milestone in the official Marine Protected Areas (MPA) process.[2] Identification of a site as an "Area of Interest" is the first step in the Department's evaluation process to identify and protect important ecological areas in the marine environment. Musquash is located in New Brunswick and borders the Bay of Fundy. It is Atlantic Canada's second inshore "Area of Interest" identified in the MPA Program under the *Oceans Act*.

Musquash Estuary is located approximately 20 kilometers west of the city of Saint John, New Brunswick. The estuary, which is approximately 1 km wide at the mouth, empties into the Bay of Fundy, the site of some of the highest tides in the world. In 1998, the Conservation Council of New Brunswick (CCNB), with support from the Fundy North Fishermen's Association, proposed the Musquash Estuary and the surrounding salt marshes, as a potential MPA. This area is unique as it represents the last healthy estuarine system in the Bay of Fundy.[3] The proposed MPA's outer limits included all subtidal and intertidal areas inside a line drawn from Musquash Head through the southern tip of Gooseberry Island, and extending to the coastline at the western tip of Gooseberry Cove. The inland limit was the head of the tide at the Musquash Hydro Station.[4]

University Research at the Proposed Musquash MPA

In the winter of 2001, the Land Studies and Ocean Mapping Groups at the University of New Brunswick (UNB) were involved in a Geomatics for Informed Decisions (GEOIDE) project dealing with good governance of Canada's oceans. This project focused on providing information on what resources (living and non-living) there are to govern; who holds the rights and responsibilities for their

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[2] There are six steps in the framework for establishing and managing individual MPAs: AOI identification, initial screening, evaluation and recommendation, development of a management plan, designation, and management.

[3] Between 1996 and 1998, CCNB surveyed the state of habitat in 12 major estuaries in the Bay of Fundy region, from St. Croix to Lobster Bay. This was done under the auspices of the Gulf of Maine Estuaries Restoration Project, a partnership of CCNB, the Conservation Law Foundation (Boston) and the Island Institute (Maine), and part of the larger Restore America's Estuaries initiative supported by The Pew Charitable Trusts. The survey revealed that all Fundy estuaries have been seriously altered and degraded, save the Musquash Estuary, which is relatively unpolluted and undeveloped (Rangeley and Singh 2000).

[4] These are general boundary descriptions of the proposed Musquash MPA. The boundaries are described as including all salt marshes, mud flats and estuary below the high water mark (Singh et al. 2000).

safe and orderly conservation, distribution and exploitation; and the spatial limits (boundaries) of those rights and responsibilities (Nichols et al. 2000). One of the case studies of the project involved the proposed Musquash MPA in the Bay of Fundy in Atlantic Canada.

The UNB research group was asked to review the proposed boundaries of the MPA and provide options regarding the placement of boundaries for resource management. In order to fulfill this mandate, the UNB Ocean Mapping Group (OMG) carried out a hydrographic, oceanographic and geophysical survey of the proposed MPA. This survey involved the collection of multi-beam bathymetry and backscatter data by undergraduate students as part of a fifth year hydrographic field operations undergraduate course. To carry out a preliminary analysis of the estuary tidal-flushing patterns, an Acoustic Doppler Profile (ADCP) survey was done (see Ocean Mapping Group 2003; Byrne et al. 2002).

Results

The following subsections indicate how the three assumptions (outlined above) were verified and then used to outline resource management decisions. This was accomplished following an analysis of the results from hydrographic and oceanographic surveys of the Musquash.

Spatial Extent and Scallop Zone

While there were several reasons for the hydrographic and oceanographic survey of the Musquash, the focus for the data collection campaign was backscatter and bathymetry that might indicate natural features on the estuary floor. These were to be used to justify, or rebuff, the preliminary delimitation of both the outer boundary of the Musquash MPA and the limit of the special scallop zone. From an inspection of the bathymetry, backscatter, and tidal-flushing patterns, it became evident that, while there might be sediment distributions that closely tracked a preliminary straight-line land-terminating boundary (see Figure 1), this was considered coincidental evidence, as over time the sediment distributions would vary with changing flushing patterns in the estuary. If this boundary were then used as the outer boundary of the Musquash, it would in effect be an ambulatory boundary of undefined uncertainty. With regard to the scallop zone boundary, neither the backscatter nor bathymetry data offered any indication of scallop habitat, and consequently any evidence supporting the location of the previously proposed straight-line boundary. For an in-depth description of this investigation, the reader is directed to Byrne et al. (2002).

Herring Weirs

Visits to the Musquash Estuary indicated that private fishing rights (in the form of herring weirs) had at one time been in effect in the estuary. Prior to the data collection campaign, the authors were able to view what they perceived to be all the abandoned fishing weirs at high and low tides. On one bathymetry image, however, the remains of abandoned fishing weir posts were clearly visible (see Figure 2). This weir could neither be seen at high nor low tide and was the focus of considerable excitement to the research group. The weirs in the estuary could easily be indicative of present, abandoned or expropriated private fishing rights and might prove quite valuable. Marshall (2001) describes how the development of aquaculture in the Bay of Fundy created a demand for historical fishing weirs, and hence market value for the sites.

Landing Craft

The survey of the Musquash also revealed three wrecked ships in the areas north of Five Fathom Hole in the Musquash River. Before they were abandoned decades ago, the three ships were used as barges to haul pulpwood, but the 60-meter vessels were originally built as landing craft for the United States Navy during the Second World War (Thompson 2001; CBC 2004). Byrne (2002) observes that one landing craft lurks just over a meter below the surface at high tide and poses a potential navigation hazard. Sun-illuminated bathymetry (taken during high tide) clearly captured this wreck. These wreck sites could in the future be earmarked for protection as historic or heritage sites.[5]

Fisheries Habitat

Bathymetry and backscatter evidence of the location of a habitat for scallops, and therefore the presence of a scallop zone in the Musquash, was inconclusive. Byrne et al. (2001) indicate that while sidescan sonar data showed marginal changes in backscatter as one moved north of the proposed scallop zone boundary, these same changes were neither reflected in the multi-beam backscatter nor present by inspecting the bathymetry. And although the researchers knew the location of lobster fishing pots, they could not be detected with the resolution of the equipment used. Decisions regarding the fishery habitat were, therefore, deferred.

Pipelines

Since the survey launch used for multi-beam data collection was docked at Saint John, extra multi-beam coverage was obtained as it transited to and from the Musquash. Apart from expanding the bathymetry and backscatter coverage in the Bay of Fundy area, the transit was also used to detect any other features that might be of interest in the Bay of Fundy. Two pipelines, licenced to transit crude oil from the Canaport terminal offshore in the Bay of Fundy to Mispec Point (on the mainland), were clearly visible on the multi-beam imagery collected.

Sand Wave Features

Interesting sand wave and whaleback features can be observed on inspecting the bathymetry of the area off Musquash Head (see Figure 1, southeast section). While there is undoubtedly a geological explanation for these features, the local community and conservation groups in the area claimed “ownership” of them and were exploring means of using them to advance their case for protection of the Musquash.

[5] Ron Swanson, a member of the Landing Craft Preservation Society, is very interested in the history of the ships (CBC 2004).

Navigation Areas

From the bathymetry of the Musquash, it was quite clear that the area around Musquash Head is deeper that the area around Western Head. An analysis of the tidal flushing patterns indicated that the incoming tide into the estuary has a predominant signature on Musquash Head while the outgoing tide, depositing sediments from the estuary, is biased towards Western Head. This is particularly interesting to fishermen and other persons who operate craft in the estuary as it presents a visually pleasing justification for navigation lanes into the estuary.

Conclusion

Although the multi-beam bathymetry and backscatter data indicated that there was a sediment boundary distribution closely following the original proposed MPA boundary, researchers at OMG considered this to be coincidental. Analysis of the ADCP survey data indicated that tentative conclusions could be drawn about the general tidal flushing patterns at the mouth of the Musquash Estuary. To explain the sediment boundary distribution, OMG concluded that a strong ebb tide-biased towards Western Head, was responsible for depositing sediments from the estuary (see Byrne et al. 2002). A shearing effect, caused by stronger flood and ebb tides effects in the Bay of Fundy, might be responsible for the ambulatory sediment boundary at the mouth of the estuary, closely coinciding with the proposed external boundary.

This information led OMG to observe that pollutants and contaminants located outside the proposed straight-line boundary might find their way into the estuary, given the tidal flushing patterns in the Bay and at the mouth of the estuary. OMG recommended that a buffer zone might be appropriate to mitigate these circumstances, and ultimately, to accomplish the overall goal of protection and conservation of the salt marshes found in the proposed Musquash MPA.

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Figure 1. Colour coded bathymetry showing proposed scallop zone (inner red straight line) and outer boundary (outer red line) of the proposed Musquash MPA. North is at the top of the image. (Background orthophoto imagery courtesy of Service New Brunswick, and bathymetry image courtesy of the Ocean Mapping Group at UNB)

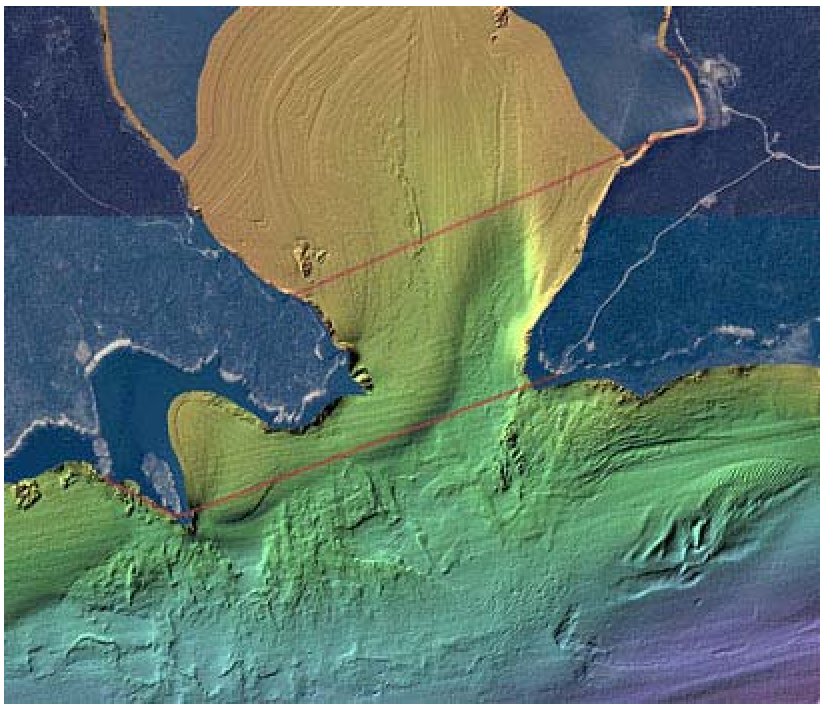
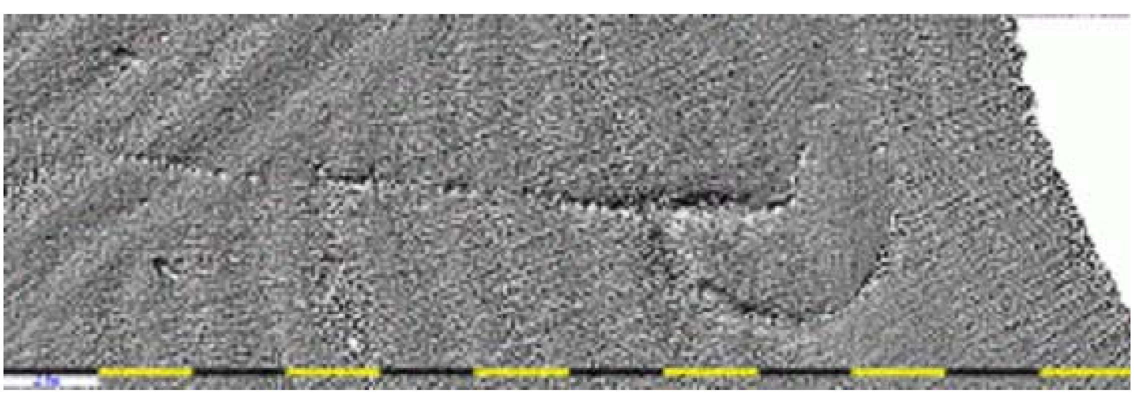


Figure 2. The remains of a fishing weir on the southwest corner of the old Musquash Harbour (image provided by the Ocean Mapping Group at the University of New Brunswick)



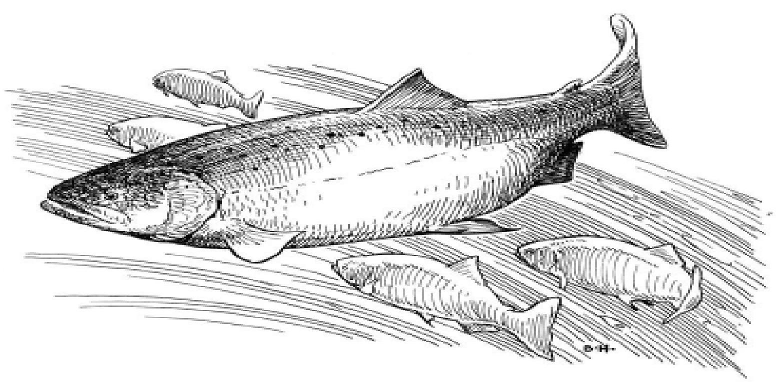
Session Eight

MONITORING ENVIRONMENTAL IMPACTS IN COASTAL AREAS

Chairs: Kelly Munkittrick, University of New Brunswick Saint John (UNBSJ), Saint John, New Brunswick

and

Brian Craig, EMAN Coordinating Office, Environment Canada, Burlington, Ontario



DEVELOPMENT OF AN EFFECTS-BASED MONITORING PROTOCOL FOR COASTAL AREAS IN THE BAY OF FUNDY

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A wide variety of stressors affect aquatic ecosystems. While changes can be identified at a range of ecological levels, we have been developing an approach to aquatic, cumulative-effects assessment that is driven by the responses of fish populations (Munkittrick et al. 2000). This approach is defined as “effects-based”, as opposed to the more common stressor-based or values-based approaches to environmental assessment. The effects-based approach (Munkittrick and Dixon 1989; Gibbons and Munkittrick 1994) was used as the basis for the development of the fish survey component of the federal Environmental Effects Monitoring (EEM) requirements for pulp and paper mills (1993; see Munkittrick et al. 2002), metal mines (2001; see Ribey et al. 2002), and sewage treatment plants (Kilgour et al. 2003).

The effects-based approach uses fish population characteristics such as growth rates, reproductive investment, energy storage and age distributions to identify areas where fish performance is different from that seen at reference sites. The identified areas of concern become the sites where detailed, iterative, hypothesis-driven research is conducted to identify the stressors responsible for those changes. The sentinel species are selected based on their life history characteristics and suitability for providing the information required to answer specific receiving environment questions. The priority issues to consider are abundance, exposure, and the ability to measure the endpoints in question (Environment Canada 1997). Additional factors affecting suitability for monitoring relate to residency, longevity, spawning time and location, spawning guild, food preference, and other species-specific characteristics (Munkittrick et al. 2000). If the questions of interest relate to potential human impacts from accumulated chemicals, then the life history characteristics of sentinel species should include late maturity, long life, slow growth, small reproductive investments and piscivorous feeding habits; if ecological health is of interest, then sentinel species characteristics would include benthic feeding, early maturity, short life spans, fast growth, etc (Munkittrick et al. 2000). The interpretation of environmental monitoring studies depends on the ability of the organisms to reflect local conditions and the ability of the regulators to interpret species-specific information (Ribey et al. 2002). We originally described the optimal, sentinel-species characteristics based on studies involving large-bodied fish species (Munkittrick 1992), but small-bodied species of fish are becoming more widely used in assessment programs because of their increased abundance, and assumed lower mobility and higher site fidelity (Courtenay et al. 2002; Munkittrick et al. 2002).

As industrial operations, processes and waste treatments have improved, changes in fish populations due to pollution have become more subtle, and changes in growth and reproduction are often within the range of responses to natural environmental variability. This has increased the challenges associated with defining changes in wild fish populations, and assessing the significance and causes of the changes. These assessments suffer from an absence of background, baseline information on spawning times, fecundity, growth rates, and mortality of many species of fish. There is considerable controversy about the causes of changes near anthropogenic developments, as well as the magnitude of change in whole organism characteristics that should be accepted or tolerated. Selecting the best sentinel species is essential for addressing the ecological relevance of changes, and understanding normal life history strategies and plasticity is crucial for evaluating the significance and the causes of changes. This process requires the development of specific targets for interpreting the ecological or regulatory relevance of changes in individual-level performance endpoints such as growth or reproductive investments.

The effects-based assessment framework was developed initially in a northern river basin with a low human population density and relatively few industrial developments (Munkittrick et al. 2000). Since 1993, we have been progressively moving towards more complicated environments that receive multiple stressors. We initiated an assessment of the Saint John River basin (Curry and Munkittrick 2004) in 1999. The effects-based approach is being successfully applied in the freshwater portions of the Saint John River (Gray et al. 2002; Galloway et al. 2003, 2004; Doherty et al. 2004; Gray and Munkittrick 2004).

It has previously worked well in many freshwater receiving environments (Munkittrick et al. 2002), but the approach has been less successful in saltwater environments (Courtenay et al. 2002). The lower success is related to challenges to developing sensitive study designs. Studies in marine and estuarine environments face a number of challenges, including a lack of fish, high dilution of effluents, trapped plumes, migratory sentinel species, confounding discharges, shipping, dredging and tidal fluctuations (Environment Canada 1997), and other factors related to effluent dilution and dispersion (Mathiessen 2003), and residency of fish (Hurst et al. 2004). As a result, demonstrating the same degree of exposure in marine species is typically more difficult than in freshwater species. Some of these difficulties are magnified because marine systems are typically more open and challenging to sample, and because of the non-homogenous distribution of habitat, and of fish within the habitat (Courtenay et al. 2002).

The largest challenge may be the development of background information for fish species to assist in study design and data interpretation. Existing monitoring and assessment programs often operate in the absence of suitable data to design or interpret the studies, depending on limited species-specific information published in the 1970s (Scott and Crossman 1973; Scott and Scott 1988). The situation is worse for nearshore and coastal, small-bodied species that are of little commercial importance.

While there is a considerable amount of ongoing research related to the environmental health of fish in estuaries (Weisberg et al. 1997; Leamon et al. 2000; Nordlie 2003), and in coastal areas in both saltwater (Belliard et al. 1999) and freshwater (Randall and Minns 2002), the assessments are largely conducted through the use of fish community-based monitoring approaches. Historically, environmental monitoring programs were effective at describing changes based on the absence of species or changes at the fish community level. These approaches are useful for regional assessments (see papers in Simon 2003), but cause and effect relationships are still largely evaluated by correlation (see papers in series by Collier 2003). They are not effective for evaluating point-source discharges, or for evaluating the specific causes of changes once they are documented (Fitzgerald et al. 1999; Adams 2001).

We were interested in developing an assessment protocol for the Saint John Harbour area. Our assessment of the Saint John River is nearing completion for the upper portions of the basin from the Canadian border to the Mactaquac dam upstream of Fredericton. We anticipate initiating our detailed assessment of the river in 3–5 years, and need to have an assessment protocol in place. Our initial approach involved cataloguing the known nearshore species and evaluating whether there were any potential sentinel species available. We were also interested in evaluating some of the smaller coastal streams that discharged into the harbour, since they also receive various wastes.

Saint John Harbour is located at the mouth of the Saint John River Estuary on the Bay of Fundy, New Brunswick, Canada (latitude 45º 16'N, longitude 66º 3' W). For many years, a wide variety of industrial, commercial and residential waste streams have been discharged into the harbour. Some of the present industries in the area include three industrial parks, a pulp mill, tissue plant, paper mill, an oil refinery, New Brunswick Power generating station, brewery, and the Saint John Port Authority which exports and receives cargo from around the world. In addition, Saint John residents also have an impact on the harbour. The population of the Saint John is approximately 70,000 and currently just over 50% of the municipal sewage is treated.

In evaluating the potential nearshore species, we settled on evaluating whether the rock gunnel (*Pholis gunnellus*) would be a suitable sentinel species for documenting contamination levels around Saint John Harbour (Vallis 2004). The species had been poorly studied in Canada, and we were able to document baseline growth, size distributions, age distributions, habitat and behaviour (Vallis 2004). Although site differences were seen around the harbour, rock gunnel move offshore to spawn late in the fall and are absent from intertidal areas from November to March. While juvenile abundance and growth rates were useful parameters, gonads were very undeveloped by the time the fish moved offshore, and it was not possible to evaluate the reproductive development of this species. Little is known about their interannual site fidelity, but we were able to document some site differences in juvenile recruitment to intertidal areas, and changes in liver size that developed at contaminated sites during nearshore residency.

Additional potential sentinel species need to be identified. We are currently completing a number of studies evaluating seasonal changes in fish species assemblages in small coastal streams (Vallieres 2005). Our studies so far have conducted initial sampling on more than ten small estuaries in the Maritimes, including small coastal streams, river estuaries, and nearshore coastal areas. While there are seasonal changes in diversity and abundance, the "normal" fish community during peak periods of diversity is six to ten species. The communities vary temporally (seasonally, fortnightly tidal cycle, day/night, flood vs ebb tide) and geographically (bay to bay, upstream-downstream, with differences in depth, salinity, substrate and vegetation). Low effort beach seining or minnow trapping can be used to identify the dominant fish species, but a quantitative estimate of all species will take considerable effort and multiple gear types.

Studies by Vallieres (2005) have demonstrated that it is possible to find site differences at some locations using only species diversity and gross abundances. Sentinel-species approaches in nearshore areas and small coastal streams are challenged by the absence of resident species, and the high variability. New research efforts are required to determine when and how to sample and how much effort is enough. New studies are examining seasonal availability of potential sentinel species in nearshore (Arens and Methven, in progress) and offshore areas (Casselman and Methven, in progress).

We have not yet developed an assessment protocol, but several additional potential sentinel species are being evaluated. At some sites, simple estimates of species richness and abundance have been sufficient to document dramatic site differences. In other cases, it may be that a multiple-species sentinel approach will be required, with evaluations of growth, reproduction, and survival potentially utilizing different species and life stages to get an assessment framework that will provide a framework for assessing impacts and defining causes.

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EXPLORING THE USE OF MARINE GASTROPODS AS ENVIRONMENTAL MONITORS IN THE BAY OF FUNDY

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The framework for assessing anthropogenic effects in freshwater systems has been outlined by the Environmental Effects Monitoring (EEM) Program. EEM protocol recommends comparing demographic (e.g., size structure) and physiological (e.g., body, liver and gonad mass) endpoints of sentinel fish species in "receiving" and "reference" environments. However, sentinel fish species are particularly difficult to establish in estuarine and marine habitats due to the lack of site-fidelity of most marine species, which can limit their use as indicators of environmental conditions at a particular locality. Therefore, we have begun investigating the use of marine gastropods to acquire appropriate endpoints in accordance with EEM objectives. Periwinkles (*Littorina spp.*) are particularly good candidates as marine sentinels due to their broad distribution, limited mobility, and high abundance in intertidal areas. In this study, we assessed the effect of industrial effluent by (i) comparing population demographics, size at maturity, and fecundity of snails in "receiving" and "reference" environments, (ii) investigating the gradient of effect by measuring endpoints at successive distances from an industrial discharge, and (iii) employing a reciprocal transplant experiment to compare endpoints of same-origin snails caged in a "receiving" and a "reference" environment. Our objective was to make initial recommendations regarding the value of gastropods as potential sentinel species in estuarine and marine "receiving" environments.

STRUCTURE OF THE NEARSHORE FISH ASSEMBLAGE IN THE LOWER BAY OF FUNDY: SHORT-TERM VARIABILITY AND IMPLICATIONS FOR SAMPLING DESIGN

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Monthly sampling, from November 2002 to January 2004, at two shallow water sites in the Saint John Harbour Estuary showed the fish assemblage to be dominated by eight species that accounted for 95.6 percent of the fish collected. The nearshore zone was used as a nursery area by juvenile fish, as a migration corridor for anadromous and catadromous fish on their way to spawning sites, and by a small number of highly mobile species that do not appear to be year-round residents. Abundance and species richness were highest at night, peaked from July to September when water temperatures were highest, and reached minimal values from December to March when ice was present and temperatures were <0°C. The fish assemblage was dominated by silver-sided, pelagic, schooling species (*Menidia menidia*, *Osmerus mordax, Alosa pseudoharengus, A. aestivalis*) that spawn demersal eggs. Two size modes representing ages 0 and 1 were evident in some species. The vast majority of fish collected by the 10 m seine were small bodied and averaged <85 mm SL. Despite this small average size, many species were judged to be adults (*M. menidia, M. tomcod, G. wheatlandi, G. aculeatus, O. mordax*), based on size of first spawning reported elsewhere. Eleven of the 20 species collected were rare, with <5 individuals per species being taken. We suggest that small-scale, temporal variation at tidal and diel scales, in addition to the lack of three dimensional habit structure (e.g., aquatic vegetation, reefs) at the two smooth bottom sampling sites, are important factors influencing the dynamic makeup of this estuarine assemblage.

THE REFERENCE CONDITION APPROACH: ON TRIAL IN THE BAY OF FUNDY

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Traditional biomonitoring field methods using control and impact sites are limited by spatial variation confounding data interpretation, and high costs of replication and analysis. The Reference Condition Approach (RCA) has been shown to be a powerful alternative to assess the state of freshwater environments around the world, and is used in Australia, the United Kingdom, and Canada.

The RCA eliminates the need for replicate samples within sites, with reference sites (unimpacted) serving as replicates using inferential statistics. Using multivariate techniques, reference sites are grouped into subsets that characterize the biological conditions of a region, in this case the Minas Basin intertidal mudflats (400 km^2) in Nova Scotia. Test sites (disturbed by intertidal clam or baitworm harvesting) are compared to the appropriate subset of reference sites with probability weightings, and thus the degree of impairment can be established.

An intertidal survey of the Minas Basin was conducted in 2002, and a multivariate predictive model was constructed using 40 reference sites, against which 11 test sites were compared. This is the first known, and successful, attempt of this freshwater approach in an intertidal marine environment. The RCA methodology, and its implications for monitoring intertidal clam or baitworm harvesting effects, will be discussed.

Further Reference

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INVESTIGATION-OF-CAUSE APPROACH TO DETERMINING SOURCES OF CONTAMINANTS AT THE IRVING PULP AND PAPER LTD. MILL IN SAINT JOHN, NEW BRUNSWICK

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Since 1997, we have been using a number of approaches (artificial stream exposures, lab bioassays) to identify waste-stream sources of contaminants at the Irving Pulp and Paper Ltd. (IPP) mill, in Saint John, New Brunswick. IPP discharges into the Reversing Falls area of the Saint John River Estuary. We have used reproductive endocrine endpoints in the mummichog (*Fundulus heteroclitus*), an endemic fish species, to determine the sources and chemical characteristics of bioactive contaminants in the mill's waste-streams. Our studies at this mill have provided a case study for development of an investigation-of-cause framework within the federal government's Environmental Effects Monitoring Program. The estuarine fish protocols developed for these studies have enhanced the environmental relevance of the work.

COMMUNITY AQUATIC MONITORING PROJECT TO QUANTIFY ECOLOGICAL IMPACTS OF FISH PROCESSING PLANTS DISCHARGING EFFLUENTS INTO COASTAL WATERS OF THE SOUTHERN GULF OF ST. LAWRENCE

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Introduction

Seafood processing is a major industry in New Brunswick. Processing plants generate a considerable volume of effluent that can have a significant impact on the coastal environment into which they are released. Since 1975, no new regulations or guidelines have been promulgated (Environment Canada 1975). The primary guidelines in effect for the control of liquid effluents from fish, shellfish and fish meal processing operations are: (1) the use of a mesh screen that has wire openings of 0.71 millimeters at the end of the pipe for solids removal and (2) the use of outfalls located in such a manner as to be submerged at low tide (Environment Canada 1975). Meanwhile, similar sources of coastal marine pollution, such as pulp and paper mills and metal mines, are under strict Environmental Effects Monitoring (EEM) programs (Lowell et al. 2003). As a result of the lack of regulations, it has become apparent in recent years that some southern Gulf of St. Lawrence (sGSL) coastal areas, receiving effluents from fish processing plants have become severely degraded by eutrophication (e.g., Lameque in 2002). As a follow-up to a workshop held in Shippagan, NB, in February 2003 to address the growing problems caused by fish plant effluents in the Gulf Region (Morry et al. 2003), a best management practices guide for fish processing plants, focusing first on conventional and easily instituted improvements in water conservation and product recovery within the plant, was developed (Tchoukanova et al. 2003). These practices are currently being considered by the industry. In order to quantify the success of in-plant process changes with respect to environmental protection, an EEM program is required. We, therefore, saw the need to move forward in the design of such an EEM program. This was accomplished by comparing two monitoring tools, the “fish community” approach and the “sentinel species” approach. The study objective is to determine which monitoring tool would be most sensitive for detecting any effects on fish.

Monitoring Program Descriptions

In 1997, Canada passed the *Oceans Act* to better manage and protect estuarine, coastal and marine environments. To meet the guidelines put forth in the *Oceans Act*, Fisheries and Oceans Canada (DFO) collaborated with governments, industries and communities by promoting resource stewardship programs in hopes of spurring greater understanding of ocean resources, and to improve conservation efforts within these valuable ecosystems.

In 2003, the Stewardship and Environmental Science Sections of DFO collaborated with environmental community groups on the development of a monitoring program. The program was designed to provide a framework, within which the ecological health of bays and estuaries in the sGSL could be determined. The objectives of this program, known as the Community Aquatic Monitoring Project (CAMP), are: (1) to identify the ecological health of an estuary or coastal shoreline by studying the diversity and relative abundance of fish and crustacean species which dwell within specified bays and estuaries, and (2) to encourage local community groups to participate in the development of such a program. Consequently, the same groups are able to launch the monitoring program in their own community and provide hands-on help to determine the health of an estuary or coastal shoreline.

To initiate this program, a pilot project was set up during the summer of 2003 to test this monitoring approach at four sites within the three provinces of the sGSL. The four sites were: Lameque Bay (NB), Scoudouc Estuary (NB), Basin Head Lagoon (PEI), and Antigonish Harbour (NS). The CAMP program, developed for use by different community groups, was also used to develop an EEM program for fish processing plants. During the pilot project, two out of the four sites were in close proximity of fish plants (i.e. Lameque and Scoudouc).

In 2004, as a result of the growing interest of different community groups in the project, the CAMP program was extended in all three provinces to a total of 17 sampling sites (Figure 1). Three sites with nearby fish plants were sampled intensively: Scoudouc Estuary, Cocagne Cap and Village Bay (Richibouctou) for the concurrent EEM program. Each of the three fish plants processes lobster or crab and discharges near shore into shallow water. Lameque was sampled for CAMP but not for the EEM program, because it processes a wider variety of species and discharges into deeper water.

The "sentinel species" approach was added to the EEM fish processing plant program. Note that this monitoring tool is not being used in the CAMP program. The sentinel approach has often been used in coastal pollution studies (Swanson et al. 1996), and is also part of the EEM program for the pulp and paper mills in Canada (Lowell et al. 2003). The "sentinel species" approach quantifies the effects of point-source pollution by measuring the growth, reproduction and survival of a specific species as compared to the same factors in identical species found at a non-polluted reference site (Underwood and Peterson 1988). In 2003, we were able to identify two potential sentinel species: the mummichog (*Fundulus heteroclitus*) and the Atlantic silverside (*Menidia menidia*). Both species were chosen because of their abundance and their presence at all four sites in 2003. They are typical estuarine species found in the sGSL (Scott and Scott 1988), with a relatively small home range and a short lifespan. In addition, they can be easily caught with a beach seine or minnow traps. Finally, they can be easily dissected in the field or in the lab.

In 2004, we were able to collect these two sentinel species and start the preliminary analysis. We are now capable of moving toward a better understanding of the advantages and disadvantages of the two monitoring tools.

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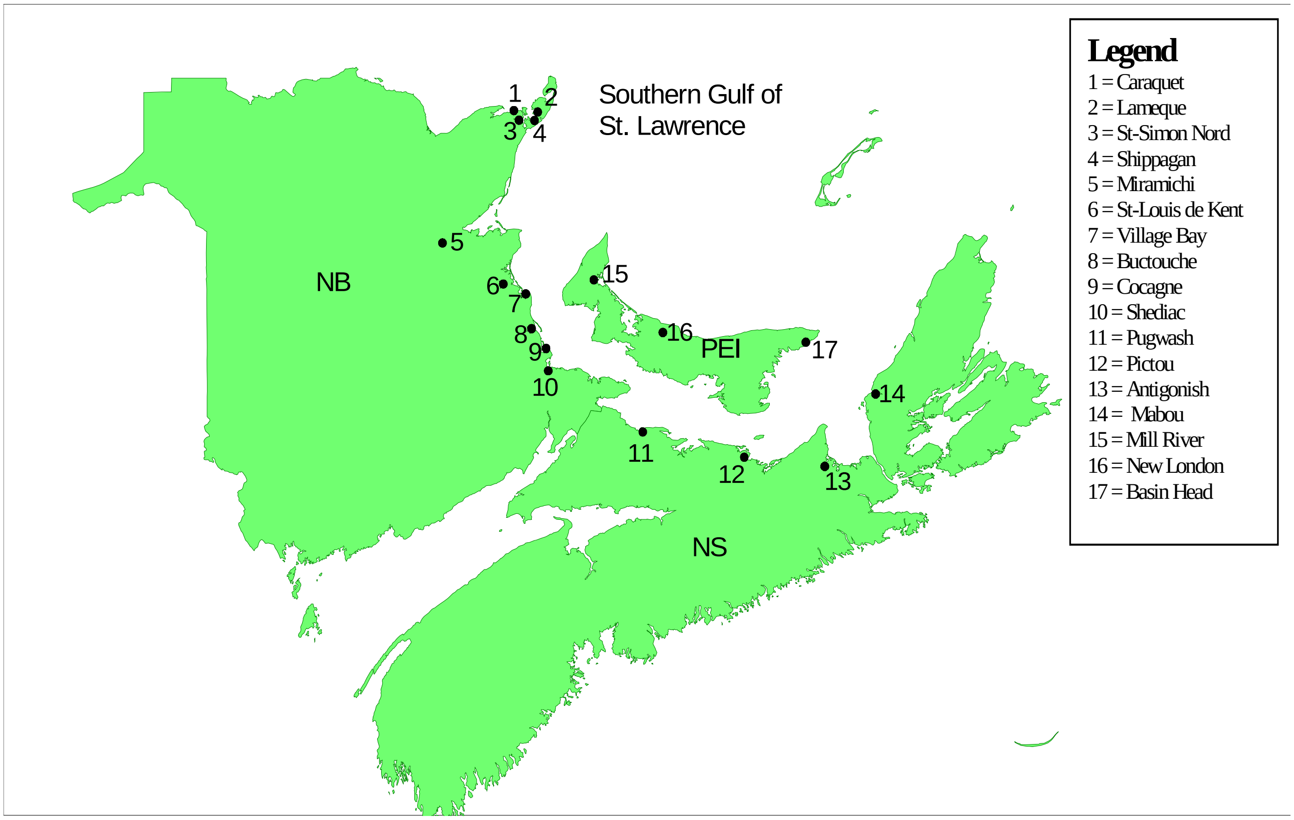
Figure 1: Map showing all sites for CAMP and EEM programs in 2003 and 2004



THE ROLE OF COMMUNITY-BASED MONITORING IN THE FUNDY ECOSYSTEM: THE CASE STUDY OF THE ANNAPOLIS RIVER GUARDIANS

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The Clean Annapolis River Project (CARP) is a charitable, not-for-profit corporation. It works with the community and interested organizations to foster the conservation, restoration and sustainable use of the freshwater and marine ecosystems of Nova Scotia's Annapolis River and its watershed. Since 1992, CARP has operated the Annapolis River Guardians, a community-based program to monitor water quality in the Annapolis River.

Through the use of the Annapolis River Guardians as a case study, this presentation will examine the broader role of community-based monitoring (CBM) in the greater Fundy ecosystem. The placement of community-based environmental monitoring at the interface of government, academia and the general public will be discussed. The importance of developing community-based approaches through multi-agency partnerships will also be examined.

The presentation will consider the factors that have contributed to the success and longevity of the Annapolis River Guardians program. The strengths and weaknesses of the program will be described, as well as its impacts on pubic environmental education, public policy and decision making in the region. Lessons learned over the past 12 years and future challenges will be discussed. The presentation will conclude with an examination of the extent to which the program can be used as a template for other community-based environmental monitoring programs in the region.

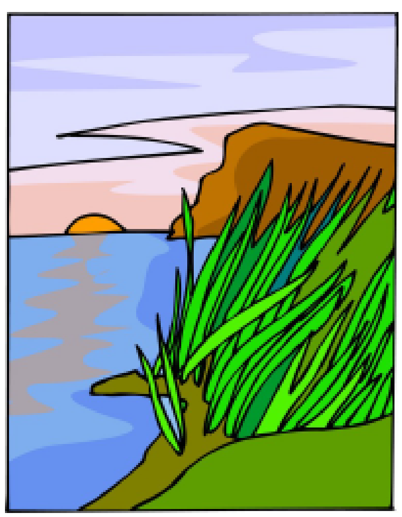
Session Nine

COASTAL HABITAT – EELGRASS AND SALT MARSH

Chairs: Al Hanson, Canadian Wildlife Service, Sackville, New Brunswick

and

Gail Chmura, Department of Geography, McGill University, Montreal, Quebec



STATUS AND CONSERVATION OF EELGRASS (*Zostera marina*) IN EASTERN CANADA

Alan R. Hanson

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Although eelgrass (*Zostera marina*) has been widely recognized as an important component of coastal ecosystems in Eastern Canada, the workshop held 17–18 December 2003, in Sackville, New Brunswick, was the first meeting of its kind to bring together people interested in the status and conservation of eelgrass in this region. The workshop (Hanson 2004a) had three main themes: mapping and monitoring changes in eelgrass distribution and abundance; the importance of eelgrass to coastal ecosystems; and causes of eelgrass declines.

Regional surveys to monitor changes in eelgrass distribution and abundance do not yet exist for Eastern Canada. Presentations by Hanson (2004b), Forbes et al. (2004), Duggan (2004), and Pinsent (2004a) on mapping wetlands, coastal morphology, significant coastal habitat, and eelgrass donor sites, respectively, indicated that tools and procedures exist to undertake a comprehensive regional mapping and trend analysis program. However, it would require additional resources and coordination to undertake such a program on a regional scale.

Collectively, the information presented by the various researchers from specific study areas (summarized below) provided consistent evidence of a widespread decline in eelgrass distribution and abundance in the Maritime Provinces.

Sharp and Semple (2004) analyzed a series of 1:10,000 colour air photos from 1978, 1989 and 2000 for two areas in Lobster Bay, Yarmouth County, Nova Scotia. They estimated a loss of 30 percent and 44 percent in the area covered by eelgrass in these two areas during the period 1978–2000.

Chapman and Smith (2004) calculated the total intertidal area occupied by eelgrass in four inlets along the Atlantic Coast of Nova Scotia (Cole Harbour, Chezzetcook, Petpeswick, and Musquodoboit Harbour) in 1992 and 2002. They estimated that the average decline of intertidal eelgrass beds over 10 years was 79.5 percent ± 20.8 percent (SD), with Petpeswick having the greatest loss (96 percent) and Cole Harbour the least (49 percent).

Locke and Hanson (2004) sampled above-ground eelgrass biomass in 13 southern Gulf of St. Lawrence estuaries in 2001 and 2002. In 2001, eelgrass biomass was reduced in the eastern part of the study area, coinciding with the area invaded by green crabs (*Carcinus maenus*). By 2002, biomass was reduced throughout the study area irrespective of the distribution of green crabs or other invasive species. The mean reduction between years was about 40 percent. The most dramatic reduction (88 percent) was in Rustico, Prince Edward Island.

Garbary et al. (2004) documented a 95 percent decline in Antigonish Harbour, Nova Scotia in 2001 compared to 2000. They subsequently asked Harbour Masters throughout Nova Scotia to comment on the status of eelgrass beds and changes in the biology of their harbour. Within the geographic area that included all reported sites of eelgrass decline, 31 out of a total of 40 sites reported a decline in eelgrass. All sites where eelgrass declines were reported also reported abundant or increasing numbers of green crabs.

Presentations documented the importance of eelgrass to waterfowl (Hanson 2004c), mobile epifaunal communities of estuaries in the southern Gulf of St. Lawrence (Joseph et al. 2004), and juvenile cod in Newfoundland (Gregory 2004).

Reasons suggested for declines in eelgrass distribution may be geographically specific, or may reflect synergistic interactions among several factors. These include eutrophication (Lotze et al. 2004), disturbance by green crab (Garbary et al. 2004), and environmental changes (Locke and Hanson 2004). Protocols for restoring eelgrass beds by replanting root stock have been tested in Newfoundland (Pinsent 2004b) and hold promise for future management action.

Recommendations from the working groups on mapping and monitoring (Milton and Methven 2004), ecosystem importance of eelgrass (Gregory and Locke 2004) and causal mechanisms (Garbary and Munro 2004), had two common themes. They confirmed the ecosystem level importance of eelgrass in estuaries of Eastern Canada ,and that this role is being compromised by severe and continuing declines in the Maritime Provinces. They also emphasized that increased integrated efforts will be required to build the collective knowledge necessary to conserve eelgrass in Eastern Canada.

A BoFEP Eelgrass Working Group was established during 2004 to facilitate the exchange of information and development of collaborative research and management activities. Go to the BoFEP Website to join the working group. Copies of the workshop report are available as a pdf file on the site at <http://www.bofep.org/eelgrass_wg.htm>.

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HYPERSPECTRAL IMAGING FOR MAPPING SUBTIDAL INVASIVE ALGAL SPECIES

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Abstract

The green alga *Codium fragile* ssp. *tomentosoides* is one of the most invasive seaweeds in the world. Since it was first reported along the Atlantic coast of Nova Scotia, a decade ago, *C. fragile* has become a serious threat to the ecological integrity of shallow, coastal ecosystems and to the economy of the Canadian Maritimes. Our inability to address this problem, and to develop adaptation strategies is directly linked to the absence of accurate tools to map the extent, and to determine the pattern and rate of spread, of the alga over synoptic scales. This paper provides an overview of hyperspectral remote sensing and geographic information system (GIS) technologies for mapping the distribution of algal species along the coast of Nova Scotia, specifically *C. fragile*.

Introduction

Non-indigenous species (NIS) are increasingly conspicuous in marine and estuarine habitats worldwide, which clearly are a significant force of change on native communities globally (Ruiz et al. 1997). The Asian green alga, *Codium fragile* ssp. *tomentosoides*, is one of the most invasive macro algae worldwide, with transoceanic and inter-oceanic spread since the beginning of the last century (Trowbridge 1998). The first report of *C. fragile* in the northwestern North Atlantic was in 1957 at Orient Harbor on Long Island, NewYork (Carlton and Scanlon 1985). Since then, the alien species or NIS has spread southerly and northerly and is now encountered from North Carolina (USA) to Prince Edward Island (Canada) (Bird et al. 1993; Garbary et al. 1997).

A striking example of the pervasive effects of *C. fragile* on subtidal communities is found along the Atlantic coast of Nova Scotia. Repeated observations in this region (R. Scheibling, personal observation) suggest that the alga is gradually replacing the native vegetation, including the productive kelp beds known for their high ecological and economic importance (Mann 1973; Chapman and Johnson 1990). Based on a recent (2000) distributional survey of subtidal vegetation at random point-locations using SCUBA diving, it was estimated that the epicentre of the invasion of *C. fragile* in Nova Scotia was Mahone Bay (R. Scheibling, unpublished data). Despite the valuable nature of this data, we still ignore the exact, current, distribution of *C. fragile* along the rest of the coast, which severely limits our ability to study the epidemic nature of the alga and assess the associated community changes in the coastal ecology.

Over the last two decades, progress in, and greater accessibility to, remote sensing technologies have significantly increased our ability to study spatial and temporal patterns over much larger scales than is feasible with common, conventional SCUBA diving techniques (Lillesand et al. 2004). One of the most promising technologies to map shallow, coastal habitats over large areas is the compact airborne spectrographic imager (CASI). CASI is readily deployed from a small plane and can provide high spatial resolution (1 m per pixel) depending on flight altitude. It is capable of simultaneous recording of radiance in up to 19 user-selected channels over the wavelengths (400–950 nm) necessary to detect marine vegetation. These attributes make CASI particularly suitable in distinguishing vegetation types in a heterogeneous assemblage of subtidal vegetation.

The objectives of this paper are to: 1) present the guidelines of a developing approach at Hyperspectral Data International to map shallow vegetation (including *C. fragile*) along the coast of Nova Scotia, 2) provide an overview of the current extent of *C. fragile* in Mahone Bay, and 3) discuss potential applications of our developing approach for coastal resource management.

Methodology Overview

Study Sites

Our study was conducted during the summers of 2001 and 2004, in the subtidal zone of Little Tancook Island, Big Tancook Island, East Ironbound Island, and Flat Island, in Mahone Bay, Nova Scotia (Figure 1). The islands were selected based on previous reports of occurrence of *C. fragile* (R. Scheibling, unpublished data), and on their close proximity to the coast, which facilitated field operations.

Preliminary Survey of Algal Distribution

One key step to generate accurate classification maps of benthic vegetation using remote sensing is to collect as much information as possible on the species structuring the community under study. The relative abundance of dominant algal species around each island was visually estimated between June and July 2004 (Figure 2). A diver did this at haphazardly chosen point-locations located at the surface of the water. The depth and the geographic position of each sampling point were also determined using a graduated line and a differential global positioning system (DGPS). The distance between two successive samples varied from 50 m to 100 m.

CASI Data Acquisition

On 25 July 2001 and 12 August 2004, the CASI was installed on board a Cessna 172 and flown at an altitude of ~900 m over the four study sites. The whole area (~35 km^2) was subdivided into 22 parallel flight lines, each 550 m wide, and was entirely covered in less than two hours. These dates were selected because of suitable atmospheric and water conditions (i.e. clear skies, minimal wave action, high water clarity) at that time.

Ground Truth of CASI Data

To assign pixel values in CASI imagery with actual algal species in the field (required for habitat classification, see below), we video recorded the sea bottom along 20-m transect lines at locations with the algal species of interest. For each algal species, a series of transect was taken at various depths. The geographic position of both ends of each transect was recorded with a DGPS for further localization in the CASI imagery.

Water Column Correction

Because light intensity decreases (exponentially) with increasing depth, the same habitat feature (e.g., *C. fragile*) appears darker in deeper water than it looks in shallow water (Figure 3). This effect must be removed from the imagery before the habitat classification is performed. To quantify this decrease in light at our study site, reflective PVC panels were deployed over a depth gradient on the north side of Little Tancook Island. The panels were deployed at a location enclosed in the CASI survey for further calculation of a light attenuation curve from which the amount of light (DN) to add in the imagery can be derived.

Habitat Classification and Map Generation

In this final step, CASI imagery (Figure 4) is used in conjunction with the ground truth data, the light attenuation curve, and a source of bathymetric data to perform a supervised habitat classification with the image analysis software PCI Geomatica. The distributional maps of algal species are exported into a GIS environment, the extent of *C. fragile* is calculated for each year (2001 and 2004), and the difference in the distribution from both years is calculated to provide an estimate of the pattern and rate of spread of *C. fragile*.

Summary

The guidelines for developing an approach to synoptically map the extent of shallow, benthic, algal assemblages in optically dense waters, as found along the coast of Nova Scotia, have been presented. Although the focus was on the usefulness of this approach to study the pattern and rate of spread of invasive species, such as *Codium fragile* ssp. *tomentosoides*, a number of other major coastal applications can be envisioned, including 1) large-scale and site-specific management of the exploitation of targeted macrophyte resources (e.g., kelp, rockweed, Irish moss) and their associated fisheries (e.g., American lobster, green sea urchin), 2) establishment and control of new and existing fishery and aquaculture areas, 3) delineation and monitoring of marine and coastal protected areas, and 4) implementation of adaptation strategies to marine community changes associated with the global climate change.

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Figure 1. Location of study sites in Mahone Bay, NS: Big Tancook Island, Little Tancook Island, Flat Island, and East Ironbound Island

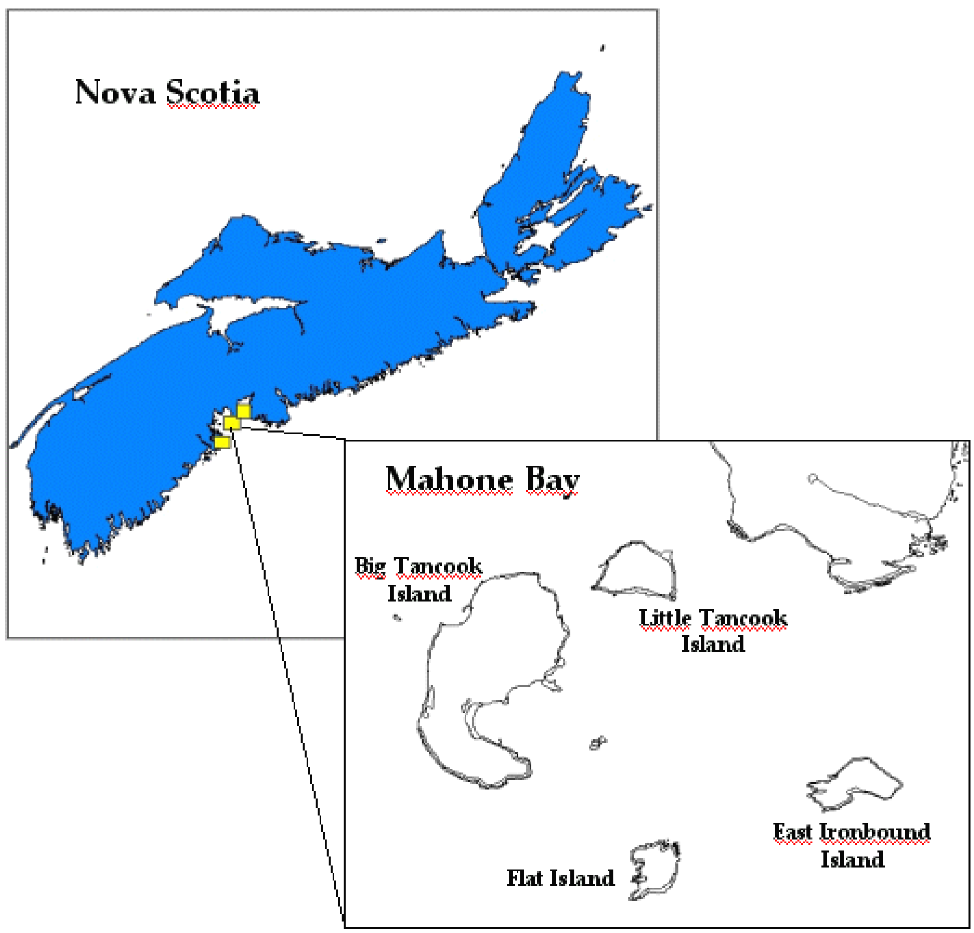

Figure 2. Distribution of *Codium fragile* ssp. *tomentosoides* and other dominant algal species around Flat Island, as revealed by the preliminary SCUBA survey in 2004. The contour of the island is outlined with the thin, blue line. The larger the size of a particular shape, the greater the abundance (percent cover) of the corresponding algal species. (Circles = *C. fragile*, Squares = the kelp *Laminaria digitata*, Triangles = the kelp *Laminaria longicruris*).

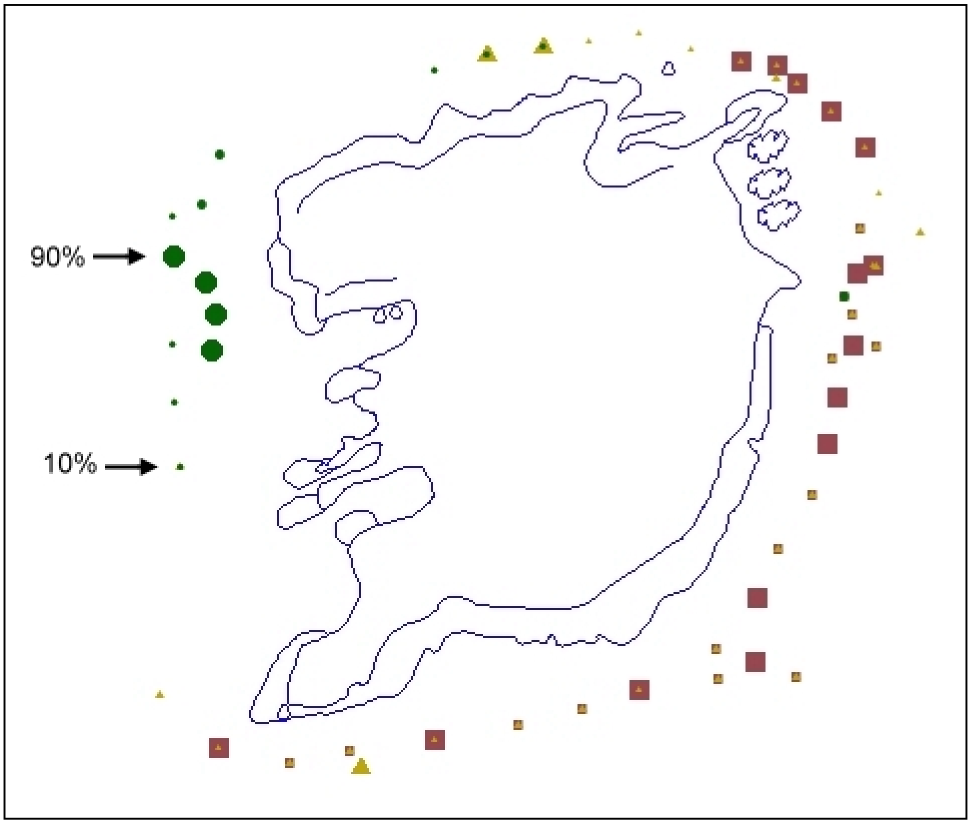

Figure 3. CASI imagery of a selected portion of the Mahone Bay, NS, showing the extent of algal assemblages and changes in appearance associated with variation in water depth (0–8 m deep from left to right)

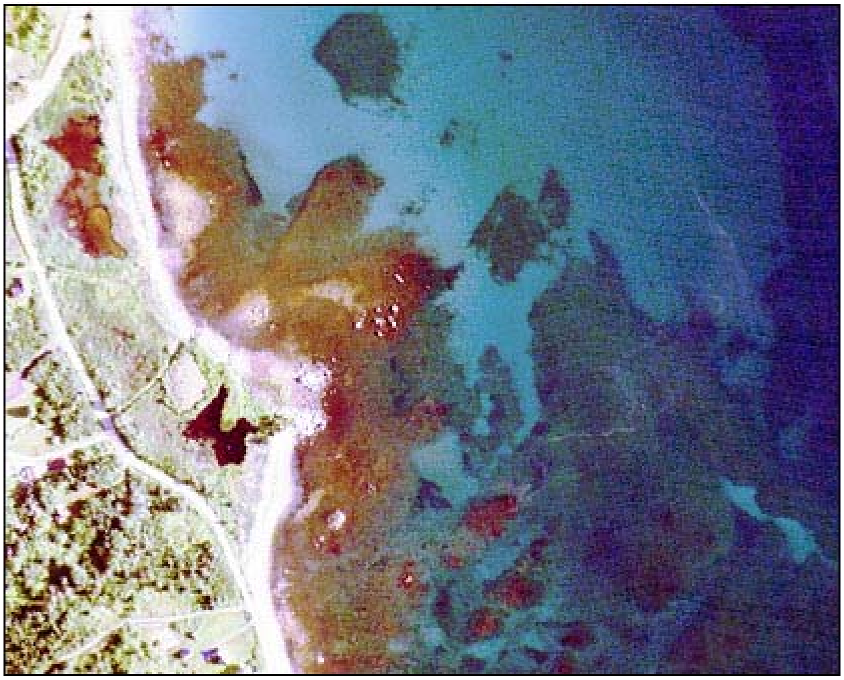

Figure 4. Distribution of algal assemblages around Flat Island, as revealed by the 2001 CASI data

SEDIMENTATION AND MECHANISMS OF SALT MARSH COLONIZATION ON THE WINDSOR MUDFLATS, MINAS BASIN

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Abstract

Construction of causeways across tidal estuaries causes significant change to the coastal system, and salt marshes are the first environments to feel these effects. This paper presents results from a field study and geographic information system (GIS) analysis on quantifying the spatial evolution of *Spartina alterniflora,* and current rates of sediment accretion, on a macrotidal salt marsh/mudflat system since the construction of the Windsor Causeway in 1970. The spatial patterns of change in *Spartina alterniflora* were examined and quantified using both global positioning system (GPS) field surveys and historical aerial photography. Detailed measurements of sediment and vegetation characteristics and sediment accretion were made during the 2002 summer season. The rate of growth of the area of marsh vegetation has been increasing at an exponential rate since causeway construction due to high rates of sediment deposition and consolidation as well as ice rafting of rhizome material. The rate of growth increased markedly, from 11 percent to 37 percent per annum, after 1992 once the vegetation was firmly established. Short-term monitoring of the buried plates in 2002 indicates that the majority of the marsh surface has increased in elevation by 0.3 (± 0.4) $cm \cdot mo^{-1}$, with most accretion occurring in the vegetated areas colonized after 1995. Mean rates of sediment deposition, based on trap data, were 54 (± 39) $g\ m^{-2}\ TC^{-1}$ and suspended particulate matter (SPM) ranged from 40 to 550 $mg\ l^{-1}$ (mean = 173 $mg\ l^{-1}$). Erosion was recorded on the seaward edge of the mudflats and along the banks of the steeper tidal channels. Examination of patterns of vegetation growth, coupled with modern sedimentation trends highlighted the importance of ice rafting of rhizome material in the initial establishment of *Spartina alterniflora* colonies in the Bay of Fundy.

Introduction

Construction of causeways across tidal rivers and estuaries causes significant change to the geomorphology and ecology of the coastal system, and salt marshes are the first environments to feel the effect of coastal modification (Daborn 1987; Miller et al. 2001). The Windsor Causeway, in the Minas Basin of the Bay of Fundy, is no exception. Barriers decrease turbulent energy in the tidal system causing sediments and other particles to drop from suspension and accumulate as deposits of mud, sand and silt (Wells 1999). Since the causeway's completion in June 1970, a salt marsh/mudflat system has built up on its seaward side (Figure 1), whose characteristics have visibly changed during the last three decades as it became colonized by *Spartina alterniflora*.

Preliminary research by Amos (1977) and Amos and Joice (1977) suggested that sediment was accumulating at distances up to 20 km seaward of the causeway, as a result of the decrease in tidal prism. Direct measurements were made of the rate of sediment accretion on the Windsor mudflats during 1975 and 1976; rates ranging from 1.0 to >14 $cm \cdot mo^{-1}$ were calculated.

The purpose of this research was to examine and model the spatial and temporal patterns of salt marsh colonization after causeway construction in a macrotidal environment. By examining the spatial and temporal patterns of colonization by vegetation, coupled with modern sediment dynamics, the mechanisms of evolution and future of the Windsor salt marsh system might be understood. This paper will provide a general overview of data collected, and preliminary results of ongoing studies (Daborn et al. 2003; van Proosdij and Townsend 2004), on this newly-created marsh and mudflat ecosystem.

Study Area and Methodology

The research was conducted on a section of the Avon River Estuary in the Minas Basin near the town of Windsor, Nova Scotia (Figure 2). This region is subject to semi-diurnal tides with a tidal range up to 15 m and high suspended sediment concentrations. In addition, the intertidal zone is covered by ice and snow for at least three months of the year. During this period, much of the marsh vegetation is either sheared off, exposing base sediment, or buried and reburied under dynamic layers of snow and ice. The study area consists of 750,000 m^2 of intertidal habitat adjacent to the Windsor Causeway. A detailed site description is presented in Daborn et al. 2003.

The extent of both 'established' and 'juvenile' colonies of *Spartina alterniflora* was surveyed in the field at low tide in the fall of 2001 using a Trimble Pro XR system with a set base station and carrier phase mode. The horizontal and vertical accuracy of the surveys ranged from 0.1 to 1.2 m. The lower accuracy resulted from the spatial variability in mud surface strength that made surveying difficult. An 'established' colony was identified as a vegetated area measuring over 2 m^2, containing mature *S. alterniflora*, possessing flowers or seedpods (van Proosdij and Townsend 2004). Juvenile colonies were identified by *S. alterniflora* lacking flowers or seedpods, between areas of established vegetation and non-vegetated mud surfaces, with a distribution density of more than 10 shoots per m^2 (Townsend 2002).

The historic spatial distribution covered by salt marsh vegetation was determined from aerial photographs of the study area from 1973, 1981, 1992 and 1995. No vegetation was present prior to 1973. Aerial photographs were scanned at an appropriate resolution to produce a 1 m ground pixel size, and visible vegetation was outlined using on-screen digitizing in ArcView 3.2^{tm} with Spatial and Image Analyst extensions. The annual rate of growth and change in total marsh area from causeway construction in 1970 to 2001 were quantified and analyzed.

Detailed sampling of sediment (for grain size, organic matter content, and bulk density) and vegetation characteristics (species richness, height and density) was undertaken at 47 stations arranged along ten transects during the 2002 summer season in a collaborative study (Figure 3) with Acadia University (Daborn et al. 2003). Ten-cm core samples were analyzed for grain size using a Coulter Laser 2000 system, and organic matter content was determined from loss on ignition. Sediment accretion was measured from buried aluminium plates at 33 sampling stations at two-week intervals over the course of the summer and monthly during the fall and winter seasons. In addition, spatial variability in suspended sediment concentrations was measured using 12 rising-stage bottle samplers over four successive tides in July 2002. Co-located measurements of sediment deposition were collected using surface mounted sediment traps. These traps measure the amount of sediment deposited over one tidal cycle.

Results

Figure 4 summarizes the sequence of marsh growth from 1973 to 2001. Initial marsh growth was found adjacent to the dyke near the Tourist Bureau in 1973, and subsequently (1981) at the western end of the causeway. The first detectable marsh on the mudflat was recorded as an isolated patch in 1981 in the northeast portion of the mudflat; it was presumably rafted in by ice.

By 1992, there were more than 30 such isolated patches, probably representing several ice-rafted events as evidenced by the presence of cobbles and a 0.5 m boulder near some of these colonies. These isolated groups coalesced as *Spartina alterniflora* spread by rhizome expansion. However, between 1992 and 1995, approximately 30 m of mudflat erosion was recorded at the junction between the St. Croix and the Avon River. By 1995, an additional 26,550 m^2 of *S. alterniflora* had become established. Between 1995 and 2001, the marsh grew from ~41,000 m^2 to >390,000 m^2. At the same time however, approximately 105 m of mudflat erosion was recorded along the northeast edge, and a number of established vegetation satellite communities were lost in this region. The overall rate of growth of *S. alterniflora* over the 32-year period is 15 percent. However, closer examination of the data suggest that the rate of growth increased markedly around 1992. An exponential curve was therefore fitted to the pre- and post-1992 data, creating two rates of growth (Figure 5).

From 1969 to 1992, the area of *Spartina alterniflora* increased at a rate of 11 percent. After 1992, the rate of growth tripled to 37 percent, or at the very least doubled to 29 percent if only the established vegetation were used in the calculation. Since the juvenile vegetation could not be distinguished from established vegetation when interpreting the aerial photographs, the rate of 37 percent will be accepted as the final rate of growth. Barring a significant environmental event, and no modification to the existing causeway structure, theoretically the exponential growth of *Spartina alterniflora* (37 percent) will result in it covering almost all of the Windsor tidal flats by late 2005. However, closer examination of the 2003 aerial photograph in relation to the 2001 survey reveals that this rate might be slightly lower, since the primary changes in vegetation since 2001 have been infilling of gaps within the 'juvenile' vegetation surveyed. Furthermore, field observations also suggest that the furthest extent of new vegetation growth may be being limited by ice scour and grazing by migratory geese.

The marsh/mudflat surface consists primarily of clayey silts, with water contents ranging from 30 to 57 percent and containing between 0–17 percent organic matter (Daborn et al. 2003). Short-term monitoring from sediment plates indicates that the majority of the marsh surface has increased in elevation by 0.3 (± 0.4) $cm \cdot mo^{-1}$ with most accretion occurring in the vegetated areas colonized after 1995.

Mean rates of sediment deposition, based on trap data, were 54 (± 39) g m^{-2} TC^{-1} and SPM ranged from 40 to 550 mg l^{-1} (mean = 173 mg l^{-1}) (Figure 6). Erosion was recorded on the seaward edge of the mudflats and along the banks of the steeper tidal channels. Decreases in elevation were recorded in areas adjacent to tidal channels where there was visible evidence of slumping and erosion.

Discussion

From the spatial analysis of aerial photographs and GPS field data, and growth models of *S. alterniflora*, it is possible to begin to understand the relationship between the Highway 101 railway causeway construction, the development of a salt marsh ecosystem and the mechanisms of *S. alterniflora* colonization. The distribution of *S. alterniflora* colonies and satellites (Figure 7) on the Avon River mudflats supports previous observations on the colonization and development of salt marshes in temperate latitudes. The survival of *S. alterniflora* is dependent on sedimentation to bring the mudflat surface to an elevation less than 1.8 m below the mean high water mark in a tidal system (Schwimmer and Pizzuto 2000). With a reduction in tidal inundation, there is a reduction in the tidal flow and an increase in siltation. The equivalent of 20 years of natural siltation occurred in the estuary in seven years after the causeway was constructed (Amos 1977). The highest monthly sediment accretion values measured within the study by Amos (1977) correspond directly to the location of the initial clear group of *S. alterniflora* satellites deposited due to ice rafting processes (Figure 7a) in 1992. Once these colonies became established, the vegetation would enhance the accretion process, and enable the vegetation to spread via rhizome growth. Approximately 40 percent of rhizome growth occurs in the top 5 cm of the mudflat surface (Smart 1982), and can be disturbed and distributed by ice movement in estuaries (Gallagher et al. 1983). As water in the mud freezes, it expands and lifts mud and rhizome material, forming raised blocks of ice and mud on the mudflat surface (Figure 7). These frozen masses or ice cakes, are less dense than fluid water and can be rafted with the rising tidal water and deposited on higher sections of the mudflat or salt marsh (Gordon and Desplanque 1983; Desplanque and Bray 1985; Ollerhead et al. 1999). If the required conditions exist, fragmented *S. alterniflora* rhizomes in the ice mass can establish as a satellite community (Gallagher et al. 1983). *S. alterniflora* then has the ability to rapidly colonize uninhabited adjacent mudflat surface through rhizome growth (Redfield 1971).

Conclusion

In general, the construction of tidal barriers can cause the destruction of intertidal habitats upstream of the barrier. However, this study documents a positive impact of the causeway, the establishment of a thriving downstream salt marsh ecosystem. A salt marsh may have eventually developed in the area if the causeway had not been built, given the configuration of the shoreline. However, the barrier altered the sediment dynamics of the region such that the likelihood and rate of establishment of a salt marsh by *S. alterniflora* increased dramatically. By combining GPS and GIS technology, with contemporary measures of sedimentary processes, the evolution of the Windsor salt marsh complex since causeway construction could be modelled. The development and growth rate of *S. alterniflora* on the Avon River mudflats, increasingly contributes to the productivity of the Bay of Fundy through the export of stem detritus, and also provides a large resting and feeding area for migratory bird species

(Daborn et al. 2003). In addition, this study clearly demonstrates the importance and role of ice in stimulating the colonization of barren mudflats by salt marsh vegetation in temperate locations.

Acknowledgements

The field work would not have been possible without help from the following Saint Mary's University geography undergraduate students: Tony Barressi, Nolan Boutilier, Lila Dolansky, Kirk Garrison, James Kellough, Jeff Lipton, Melissa Landry, and Jessie McFarlane. Additional thanks to Judy Bell, Graham Daborn and Mike Brylinsky (Acadia Centre for Estuarine Research), Philip Giles (Saint Mary's University) and Jeff Ollerhead (Mount Allison University) for field support and loan of GPS equipment. Special thanks to Ken Carroll of the Nova Scotia Department of Agriculture and Fisheries for continued encouragement during the cold November days and for logistic support. The study was supported by a research grant from the Natural Sciences and Engineering Research Council (NSERC) to D. van Proosdij and Contract #02–00026 Nova Scotia Department of Transportation and Public Works to G. Daborn.

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Figure 1. Avon River and Town of Windsor (bottom of map) a) in 1955 at high tide before causeway construction and b) in 2003, after causeway construction and significant amounts of sediment had accumulated seaward of the barrier. Note the establishment of marsh vegetation.

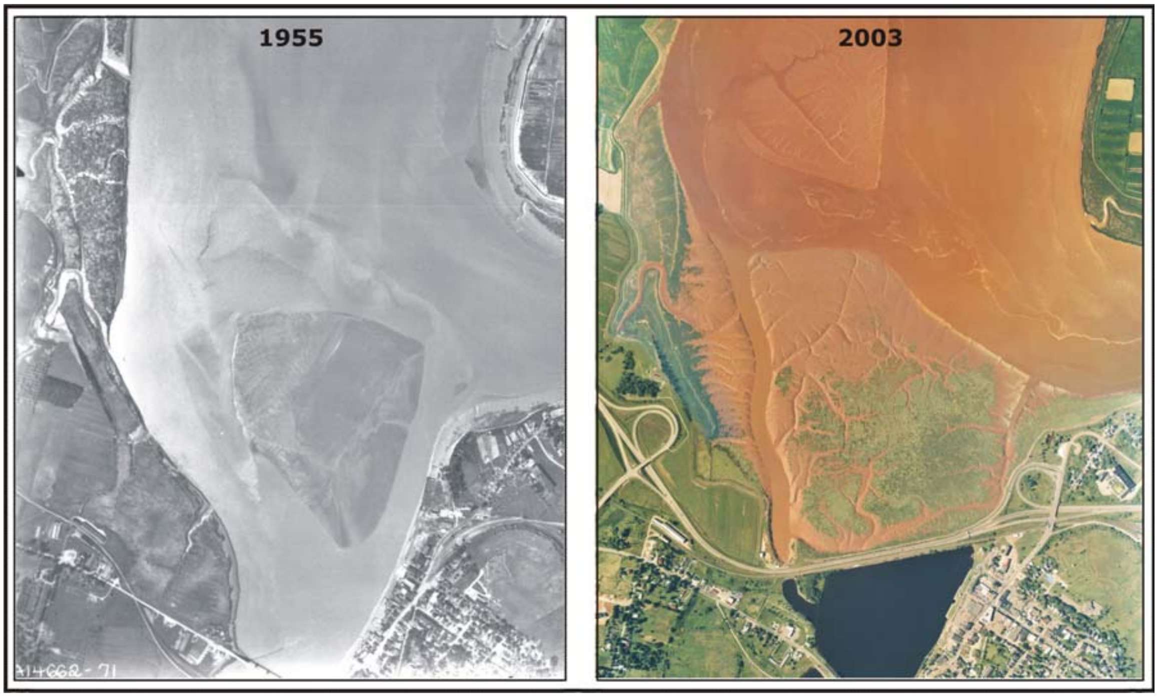


Figure 2. Satellite image depicting the location of the study area in the Avon River Estuary of the Minas Basin near Windsor, NS

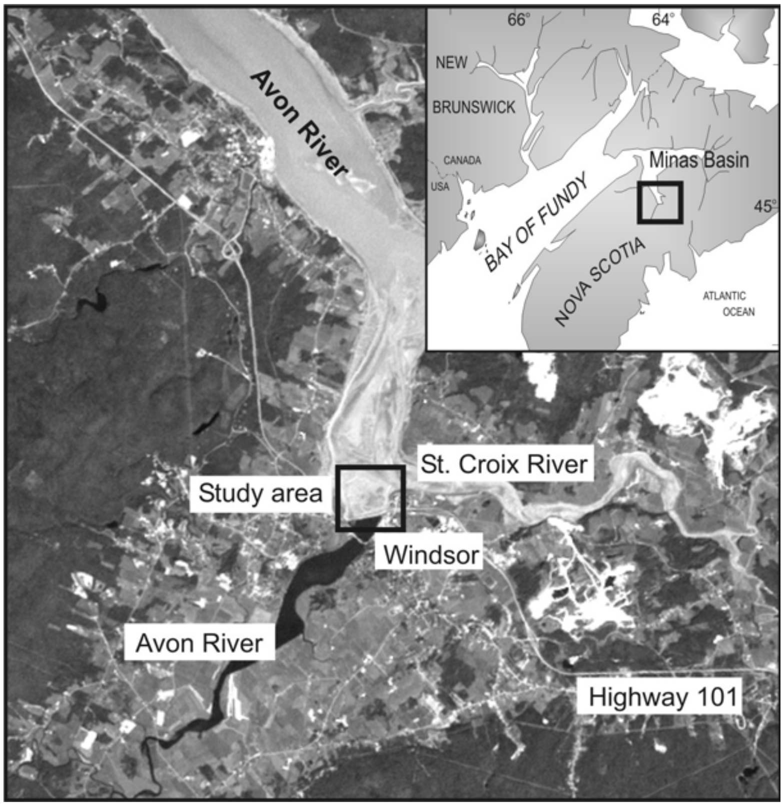


Figure 3. Location of sampling stations and transects on the Windsor mudflats, July 2002 (Daborn et al. 2003)

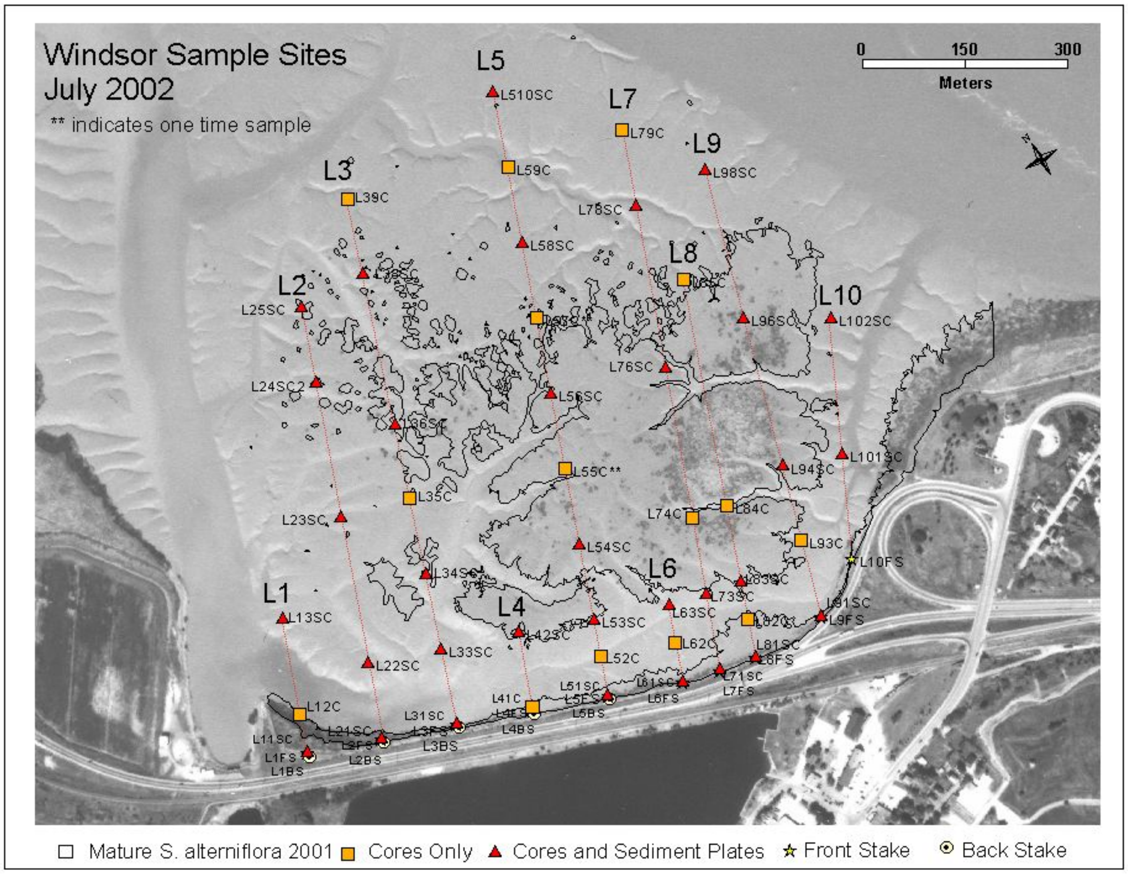


Figure 4. GIS analysis of spatial patterns of colonization by *S. alterniflora* in 1973, 1981, 1992, 1995, and juvenile and mature or established *S. alterniflora* surveyed in 2001

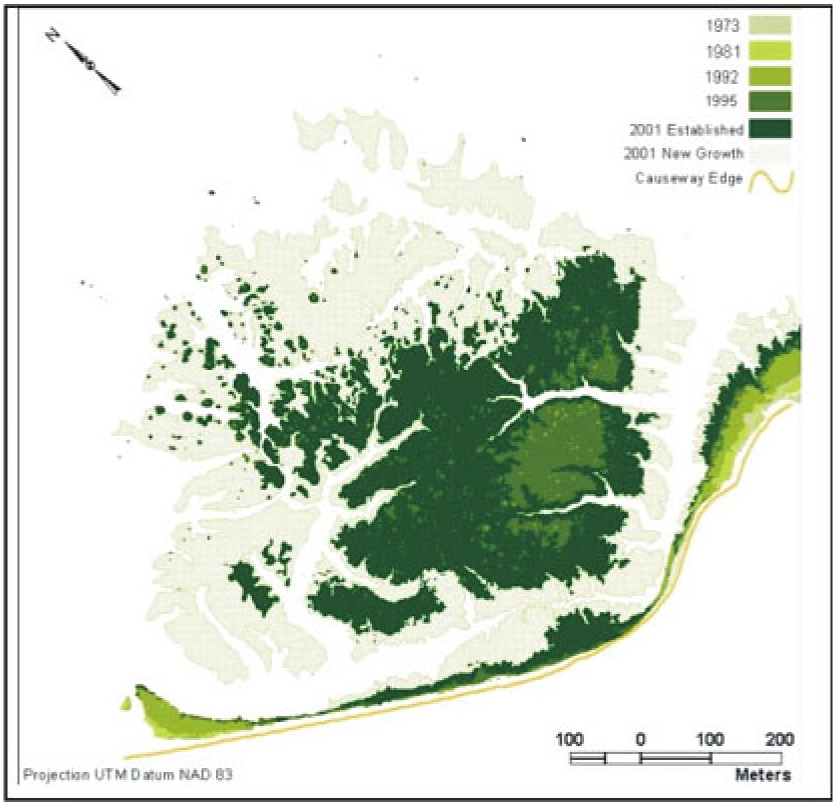


Figure 5. Change in marsh area since causeway construction, divided into three classes: vegetation 1969–1992, 1992 to 2001 (restricted to established vegetation only for 2001 survey), and 1992–2001 (based on both established and new vegetation) (van Proosdij and Townsend 2004)

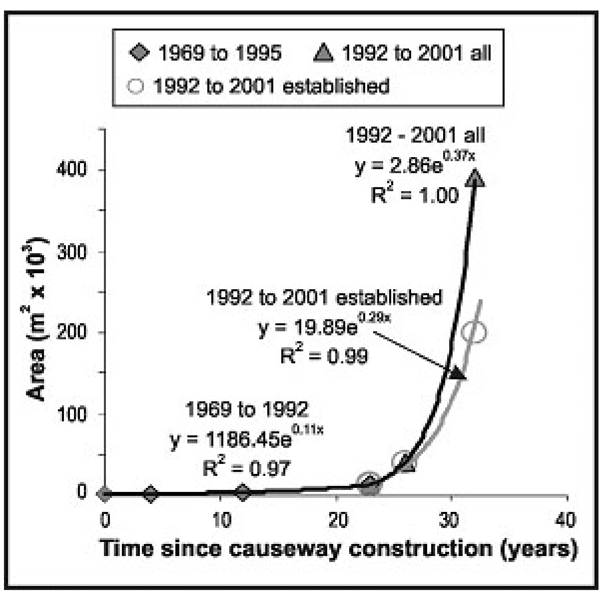


Figure 6. Interpolated mean sedimentation and suspended sediment concentration-surfaces at the Windsor Causeway mudflat, based on surface mounted sediment traps and rising-stage bottle sampler data. Surfaces were interpolated using a tension-spline algorithm and 2 m pixel resolution.

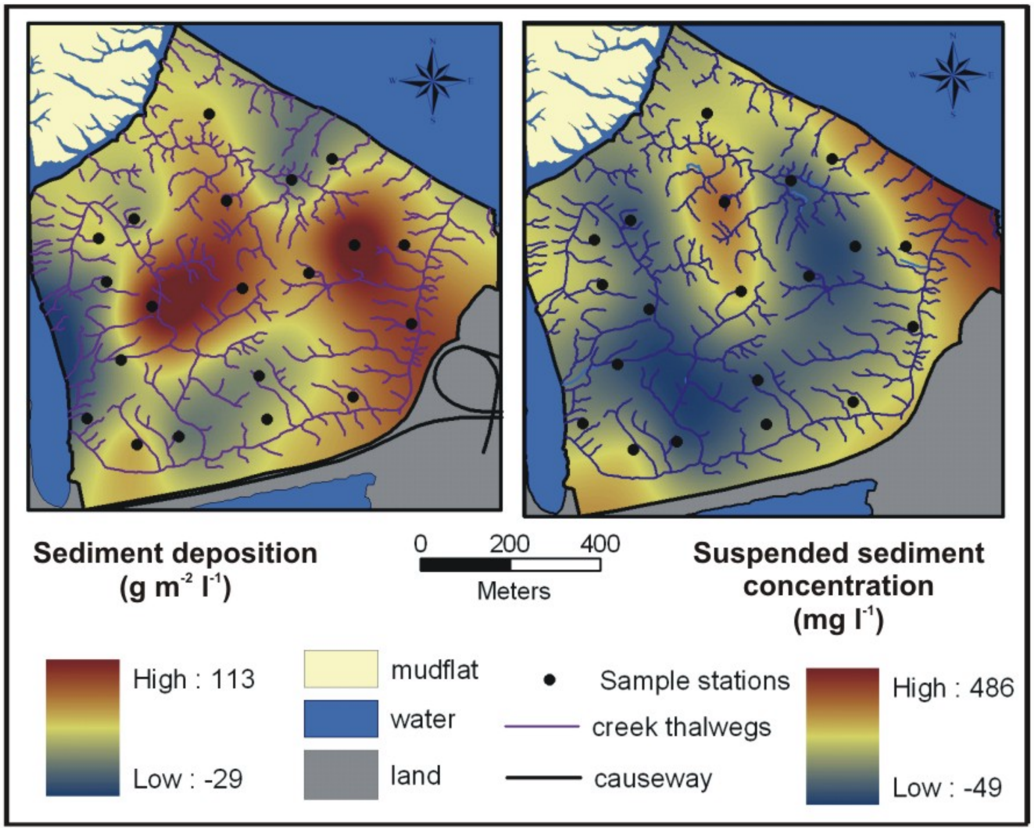
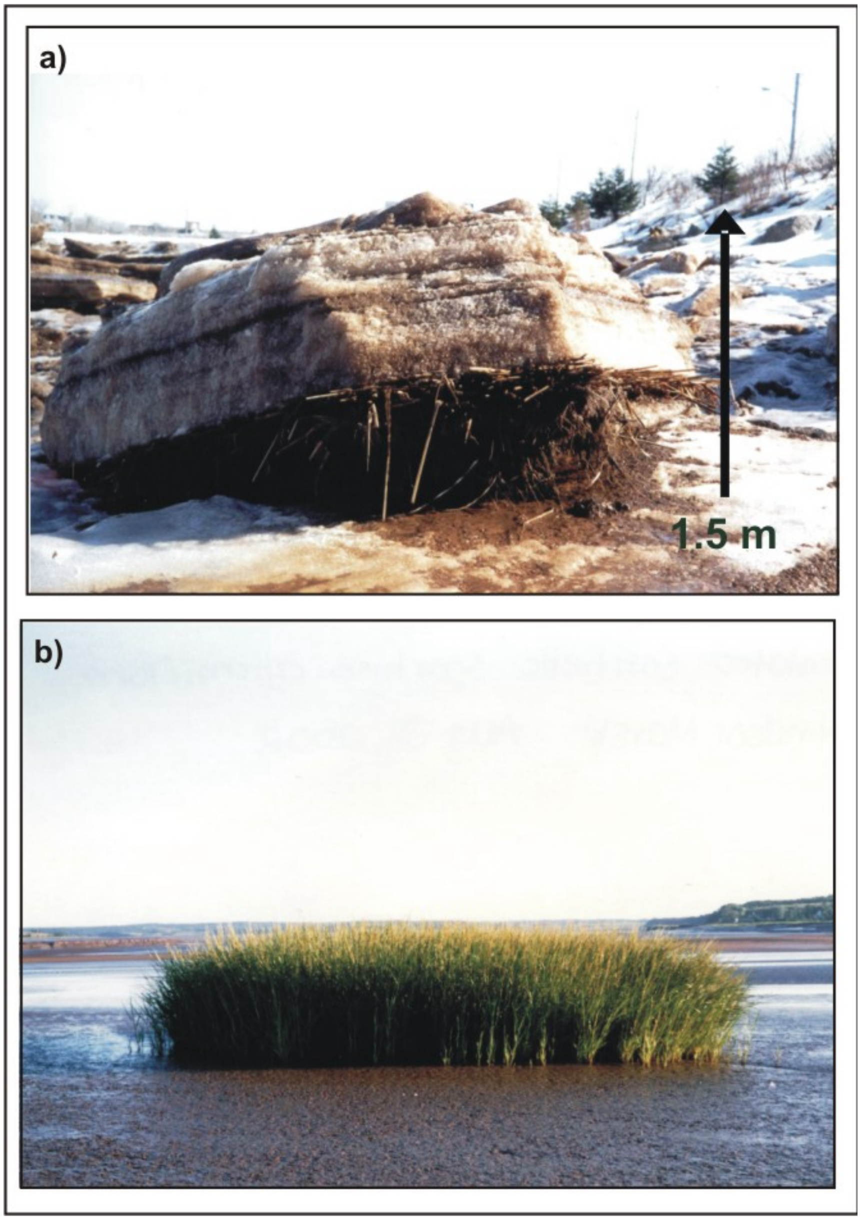


Figure 7. a) Ice cake, containing sediment and rhizome material, adjacent to the Windsor Causeway in February 2002, and b) newly-established 'satellite' of vegetation in July 2002



CYCLES OF SALT MARSH EXTENSION AND CONTRACTION, CUMBERLAND BASIN, BAY OF FUNDY

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The purpose of this study was to document changes in the location of the seaward margins and tidal creek networks for salt marshes around the Cumberland Basin, Bay of Fundy, and to evaluate some geomorphic controls on the form and stability of these features at these marshes. Field measurements and observations, and measurements from historic aerial photographs, were used to map changes in margin and creek positions over a 60-year period. To provide a framework for analysis, a conceptual model was created to describe the observed patterns of cyclic salt marsh development. The results suggest that there are important differences between the mechanisms by which Cumberland Basin marshes evolve and the mechanisms by which marshes in other locations evolve, and that understanding the cyclic nature of their evolution is key to understanding the marshes themselves, and to predicting their future evolution.

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HISTORICAL CHANGE IN SALT MARSH HABITAT SURROUNDING COBEQUID BAY, NOVA SCOTIA: EXAMINING CHANGE WITH THE AID OF AERIAL PHOTOGRAPHS

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Abstract

This project attempts to quantify historical change of the area of salt marsh habitat in Cobequid Bay, Nova Scotia. The study uses three sets of vertical aerial photographs spanning the years 1938 to 1994 as an historical record upon which to base measurements.

Salt marsh habitat has been removed from the region by both land reclamation and erosional processes. The area of habitat shrank slightly between 1938 and 1975. During this period, the gross increases and decreases were large, but the net change was small.

Between 1975 and 1994, the region has seen noticeable net growth of salt marsh habitat, although the gross increase of habitat between 1975 and 1994 is less than the gross increase between 1938 and 1975.

Introduction

The mudflats of Cobequid Bay, at the eastern reaches of the Minas Basin, provide habitat for salt marshes. Ground truthing has identified species including *Spartina alterniflora*, *Spartina patens*, *Limonium nashii*, *Solidago sp.*, and *Triglochin maritima*.

Cobequid Bay, under the influence of 14–16 metre tides, is subjected to strong forces of erosion and deposition. The region has also seen land reclamation, by the use of dykes to convert marshland into agricultural land, since its settlement by the Acadians. These natural forces, along with new dykes, affect the location of salt marsh habitat, but the magnitude of the impact is unknown.

Modern survey techniques can be used to determine the current extent of marsh habitat, but they cannot indicate the conditions that existed in the past. Local knowledge on the subject provides historical insight into change, but cannot reveal quantitatively how much change has occurred.

Vertical aerial photographs have been taken in Nova Scotia on a regular basis since the 1930s. The detail in these photos is sufficient to identify marshland. Taken approximately every ten years, they provide a historical record of temporal and spatial patterns in the region.

The Study Time and Area

Cobequid Bay is located at the far eastern reach of the Minas Basin, which is itself the most eastern portion of the Bay of Fundy. The area presented itself as an ideal location for this study for three primary reasons.

Firstly, in preliminary conversations, local experts indicated that there was a great deal of change in the salt marsh habitat throughout recent history. Secondly, the region was a manageable size for the project. With up to twenty photos for each epoch, the region is large enough for a significant study, but small enough to be practical. Thirdly, the region also had a good set of historical photos available. It does not cross county boundaries and it can be covered in two or three flight-lines, which are usually all flown on the same day.

The time periods of this study were constrained by the availability of photographs. Although there are photos from each decade, not all epochs are useable. The primary use of these photos is for land-based applications and flights were flown when conditions were good on land, but not necessarily good in intertidal zones. For this reason, it is only by chance that some photos were taken at low tide. Most photographs available were taken at high or mid-tide. The photos from 1938, 1975, and 1994 were used in this study because they were taken at low tide.

The area of the study includes all the mudflats of the Bay, starting at the eastern shore of the Debert River as far as the first meander curve in 1994, following along the coast, up the Chiganois River as far as Aboiteau Six on the western side, and a line extended from the next meander on the opposite shore of the river. It continues along the shore and up the Salmon River as far as the current site of the bridge for Provincial Highway 102, then back westward, and upstream along the eastern side of Shubenacadie River as far as Lockherds Point at Black Rock. The region is illustrated in Figure 1.

Methods

The airphotos were scanned, then registered and rectified against planimetric maps using ESRI's ArcGIS^{tm}. A second-order, polynomial transformation was used to account for aircraft position, altitude, attitude, roll, and pitch. The photos were mosaicked with a custom Arc Macro Language (AML) for Arc/Info Desktop^{tm}. This process resulted in photo-mosaics with a cell size resolution of one meter.

The resulting mosaics were manually digitized to quantify marsh habitat. Both low and high salt marshes were classified as a single unit. The digitized vector data were then used to calculate total marsh areas for each epoch. The geoprocessing tools of ArcGIS^{tm} were used to overlay the marshes from each epoch to determine areas of new, common, or former marsh between 1938 and 1975, as well as between 1975 and 1994.

Because the photos from 1938 do not cover the entire region covered by the 1975 and 1994 photos, two lists of statistics are presented: study area A is common to all three sets of photos, whereas Area B is common to only 1975 and 1994.

Results

Figures 2 and 3 show the extent of salt marsh habitat in 1938 and 1975. Over 4,006,000 m^2 were identified as salt marsh in the 1938 photos. These marshes were adjacent to farmland. During the period between 1938 and 1975, there were dyke-building projects to reclaim land. Dykes near Mass Creek and Baird Brook on the north shore were responsible for the removal of marsh habitat. However, by 1975, marsh grew into Cobequid Bay in front of the dykes. Erosion also took place to the east of the dykes at Mass Creek.

In the 1975 epoch, there were over 2,673,830 m^2 of former marsh (1,667,870 m^2 of that was converted to agricultural land). Nearly the same amount (2,574,730 m^2) of marsh was new marsh. While there are large gross changes, the net change in marsh habitat between 1938 and 1975 was only -99,090 m^2 (-2.5 percent of the 1938 marsh).

Figure 4 shows the change between 1975 and 1994 is much greater than the change between 1938 and 1975. Net change in Area A was +830,340 m^2. During this time, the habitat expanded 21.5 percent. There was even greater growth when Area B is considered. In Study Areas A and B, the salt marsh habitat expanded 32.5 percent. The majority of habitat growth during this period was along the shores northwest of Clifton. Minor growth also occurred along the north and south shores of the Salmon River Estuary, east of Old Barns. Most habitat removal occurred due to erosion near Mass Creek.

These analyses have shown that the area of marsh is highly variable. Of the 4.7 km^2 classified as marsh in 1994, less than one-quarter (1.1 km^2) of that area was also classified as marsh in 1975 and 1938. It also appears that the region acts as an inter-dependent unit, with changes in one area affecting other areas. The complete set of values is listed in Table 1.

Discussion

Areas of high variability deserve closer scrutiny. The marsh at Old Barns is particularly variable and subject to sedimentation. Inspection of supplemental photographs from 1954 and 1967 (not shown) reveals events such as sedimentation and subsequent dredging of stream channels.

While the amount of change in marsh habitat area, channel position, and mudflat deposition may appear to be constant and steady from one epoch to the next, this may not be the case. Northwest of Clifton, it appears the marsh is rapidly expanding, but visual examination of photos taken in 1991 and 1994 shows very little difference between the two epochs. Earlier photos show the marsh had already grown to its 1975 extent by the time the 1954 series was flown. Contrasting this finding are photos from 1938 and 1939, in which the main channel moved completely across the river to cut into the mudflat northwest of Clifton, creating a cliff (Figure 5). This may suggest that large changes in habitat occur suddenly, separated by periods of equilibrium.

It must also be noted that while it appears there is a great deal of movement in the air photos, this movement is on the horizontal plane only. That is to say, this may not be significant if the mudflats of the Bay were very flat. If this were the case, only a small change in elevation could result in a large change in horizontal movement. The analysis of this project cannot detect changes in elevation, but supplemental land and global positioning system (GPS) surveys, as well as light detection and ranging (LIDAR) surveys could. Such surveys also offer finer measurement techniques than the air photos. With the techniques used, the margin of error for this project is approximately ± 50 m.

In future studies, the incorporation of the mid-tide 1954 photo series and the 2003 Hurricane Juan assessment series (not available to the author at the time of the study) would also offer insight into regional processes. Examination of the "Juan" series near Old Barns shows greater changes between 1994 and 2003 than any other period.

Other ways to improve understanding include examining smaller regions, where better photo availability or shorter intervals exist.

This project is part of a larger study that will help better explain the causes of habitat change in this region. These projects include studies of historical land use patterns and ground surveys conducted by Saint Mary's University and the Nova Scotia Department of Agriculture and Fisheries, Resource Stewardship Division.

Conclusion

This project found that there have been noticeable changes in the extent of salt marsh habitat in Cobequid Bay. While the photographs that exist provide insight into historical change, data at greater scales and at shorter collection intervals between study epochs would aid in the understanding of this region. Future projects will build on this information.

References and Data Sources

Vertical Aerial photographs copyright Her Majesty, the Queen. Flown by various federal and provincial agencies. 1938, 1939, 1975, 1994. Supplied by Service Nova Scotia and Municipal Relations and the National Airphoto Library.

Basemap data extracted from the Nova Scotia Topo DataBase (NSTDB). Provided by Service Nova Scotia and Municipal Relations.

Ground-truthing survey conducted June 2004.

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The author would like to thanks Darrell Hingley and Hank Kolstee of Resource Stewardship, Nova Scotia Department of Agriculture and Fisheries for their invaluable local and long-standing knowledge of the area. Thanks also to all others who offered assistance and provided insights for this project.

Table 1. Characteristics of study areas A and B in Cobequid Bay, Minas Basin

Marsh Area (m^2)	Study Area A	Study Area B
1938 Marsh		
Total Area	3,970,300	
Change Between 1938 and '75		
Decrease	2,673,800	
Increase	2,574,700	
Net Change	-99,100 (-02.5%)	
1975 Marsh		
Total Area	3,871,200	5,083,400
Change Between 1975 and '94		
Decrease	720,100	731,400
Increase	1,550,400	2,383,800
Net Change	+830,300 (+21.4%)	+1,652,400 (+32.5%)
1994 Marsh		
Total Area	4,701,500	6,735,800

Figure 1. Study area in Cobequid Bay, Minas Basin

Figure 2. 1938 photo-mosaic of Cobequid Bay, showing extent of salt marsh habitat

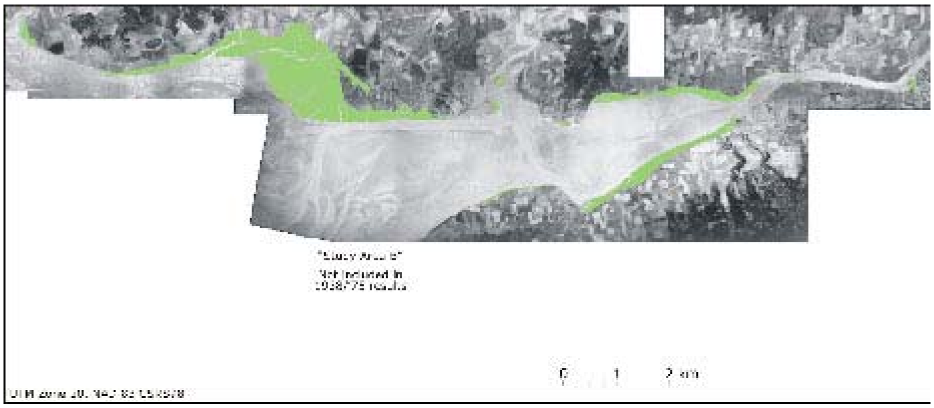


Figure 3. 1975 photo-mosaic of Cobequid Bay, showing extent of salt marsh habitat

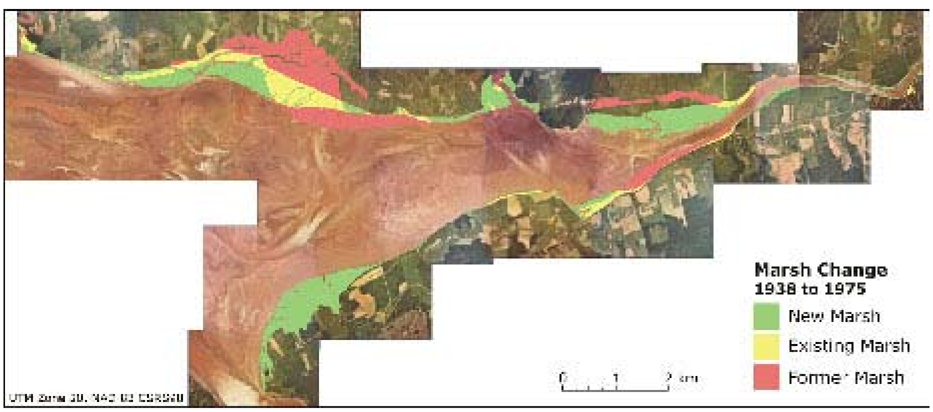


Figure 4. 1994 photo-mosaic of Cobequid Bay, showing extent of salt marsh habitat and marsh change, 1975–1994

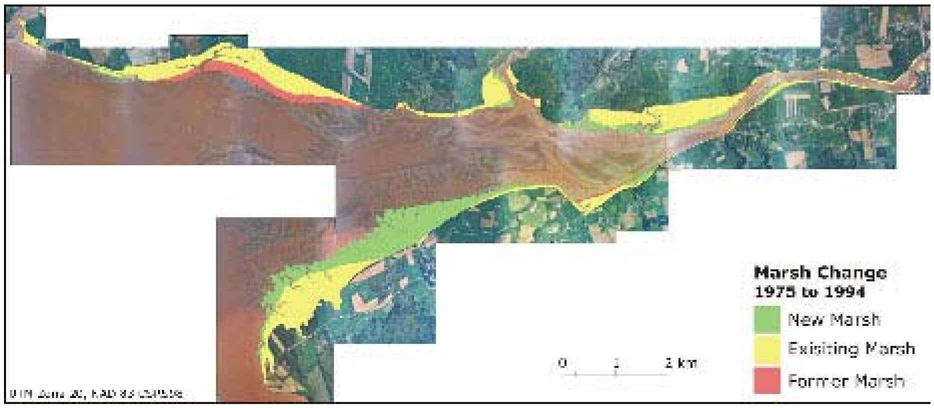
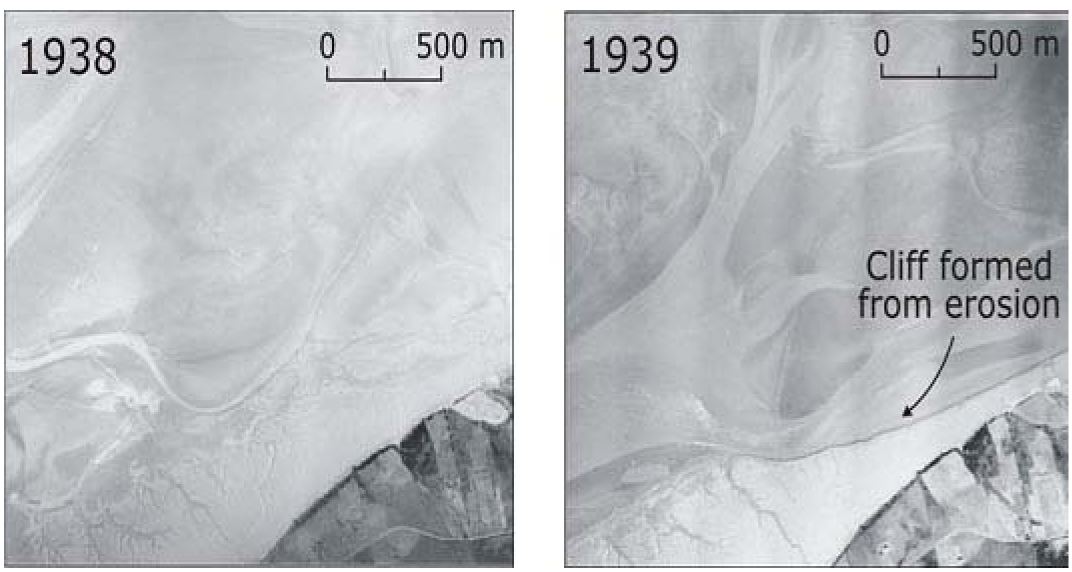


Figure 5. Northwest of Clifton, coastline showing changes in marsh habitat area



BIRD USE OF SALT MARSH HABITAT IN THE MARITIME PROVINCES

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Salt marshes and associated wildlife populations have been identified as priorities for restoration and conservation in northeastern North America. Three distinct biophysical regions of salt marshes occur in the Maritime Provinces: Bay of Fundy, Atlantic coast and Gulf of St. Lawrence. Surveys of salt marsh birds were conducted on 160 marshes located throughout the Maritime Provinces by Canadian Wildlife Service (CWS) staff and volunteer naturalists during 2000–2002 (Hanson 2004). The surveys utilized ten-minute point counts spaced 200 m apart, a protocol similar to that used in New England. Information on habitat characteristics, such as vegetation type at the point count location, number and total area of salt ponds, marsh area, and presence of dykes or ditches, were collected by CWS staff. Landscape-level descriptors of habitat such as proximity to adjacent houses, salt marshes, and dykelands were derived from air photos and wetland inventory maps.

It was observed that Bay of Fundy study marshes were larger and less isolated compared to study marshes in the Gulf of St. Lawrence or those along the Atlantic Coast. Analysis of Maritime Wetland Inventory data revealed a similar trend. An analysis of study marshes for all biophysical regions showed that species richness was greater on larger salt marshes. Moreover, the density of Nelson's Sharp-tailed Sparrows and Savannah Sparrows was positively correlated with marsh area. This relationship was asymptotic, with no increase in density of Nelson's Sharp-tailed Sparrows for marshes greater than 10 ha. Willet density was not influenced by marsh area but was positively influenced by pond area, which was in turn correlated with marsh area.

Proximity to other marshes, or the number of dwellings within 125 m of the study marsh did not affect any aspect of bird use. Nelson's Sharp-tailed Sparrow density was positively influenced by the presence of adjacent dykeland. *Phragmites* is not widespread in the Maritimes and was, therefore, not a useful predictor of avian habitat use. A review of findings from studies across northeastern North America indicates that (1) the size of the marsh is important for many species of salt marsh birds, (2) habitat quality is assessed at multiple spatial scales by salt marsh birds, and (3) marsh protection policies and conservation and restoration activities need to specifically address the collective habitat requirements and conservation concerns for individual bird species and locales.

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MULTIPLE TECHNIQUES FOR IDENTIFYING THE RECLAMATION SURFACE OF A RECOVERING DYKELAND: SAINTS REST MARSH, SAINT JOHN, NEW BRUNSWICK

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Abstract

Dyked sometime between 1786 and 1864, Saints Rest Marsh was first managed for pasture and hay production. Other disturbances included construction of barns and roads, adjacent forestry and gravel extraction, and use of the marsh for military training prior to World War II. Subsequent abandonment in the 1950s resulted in breaching of the dyke. Currently, a sewage treatment plant discharges at the head of the marsh creek. Now the largest salt marsh in Saint John, New Brunswick, Saints Rest is part of the Irving Nature Park. Saints Rest Marsh is a natural laboratory in which to study the process of recovery in salt marshes after tidal restrictions (and other disturbances) are removed. To study recovery requires recognition of the buried reclamation surface in a recovering marsh. Here we report on a pilot study that uses paleoecological techniques to identify the historical surface. Fossil rhizomes and colour in sediments outside the dyke reveal a simple progression from low marsh to high marsh. Detailed analyses were performed on sediments from inside the dyke to interpret the more complex stratigraphy there. A higher abundance of weed pollen and coprophilous fungi (as an indicator of pasturing) occurs at a depth clearly recognized by its sediment colour. Reduction in organic matter content and appearance of *Spartina alterniflora* rhizomes above this layer indicate return of tidal flooding to the system.

Introduction

Efforts are being made to restore salt marshes that have had their tidal hydrodynamics altered or removed completely by dyking and draining. These programs would benefit from a more complete understanding of how marsh systems recover from such alterations. A paleoecological approach to studying these altered salt marsh systems allows us to reconstruct changes in the marsh environment before, during, and after dyking. The McGill paleoenvironments lab is presently developing paleoecological indicators to identify the reclamation layer in recovering Bay of Fundy salt marshes. This study was undertaken by a paleoecology class at McGill to apply the techniques used in the thesis work of Graf (2004), at John Lusby Marsh in the Upper Bay of Fundy, to Saints Rest Marsh in the Lower Bay.

Saints Rest Marsh is a natural laboratory in which to study the process of recovery in salt marshes after tidal restriction. Dyked sometime between 1786 and 1864, the marsh was first managed mainly for pasture and hay production. Barns were constructed in the marsh, roads traversed it, and forestry and gravel extraction occurred in the adjacent upland and beach. Sometime prior to WWII, the marsh was greatly modified as a military shooting range. Subsequent abandonment in the 1950s resulted in the dyke falling into disrepair and eventually being breached. Currently, a sewage treatment plant discharges at the head of the marsh creek.

Methods

Sediment samples were collected in the high marsh on either side of the creek, to examine changes inside the remains of the dyke. Samples collected outside the dyke serve as reference material for undisturbed conditions (Figure 1). Cores were extracted to a depth of 1 m using a McCauley corer, and 40 cm deep monoliths (bricks) of sod were also collected. Colour stratigraphy of the cores was recorded in the field immediately after extraction.

Roots and rhizomes present in the sediments were identified using a key (Niering et al. 1977) and comparing them to samples of known species. The monoliths from the sites inside the dyke were then sub-sampled for pollen and soil organic matter analysis. Organic matter content was determined through loss on ignition (LOI) using the method described in Ball (1964).

The samples for pollen analysis were processed using conventional methods to remove mineral and organic matter (Moore et al. 1991). Two-centimeter sections were cut out of the monoliths and processed for examination of pollen and other microfossils. Though this technique can provide a great deal of information about the location and surrounding area, it is the most time-consuming technique used; therefore, only a limited number of samples could be examined. A black-brown horizon, thought to be the reclamation surface, was targeted for pollen analysis, with additional samples taken above and below this layer for comparison. In total, four depths from site B and three depths from site C were examined for microfossils. A minimum count of 200 pollen grains per sample was attempted. Pollen was counted at 400x magnification and identified using published keys (Moore et al. 1991; McAndrews et al. 1973). Pollen considered to represent marsh taxa included Cheno-Am type, Cyperaceae, *Glaux*, *Ligusticum* sp., *Limonium* sp., *Plantago* sp., Poaceae, *Polygonum* types, *Potomogeton* type, and *Typha* sp. (Beecher and Chmura 2004). Other pollen identified included shrub pollen (*Myrica, Alnus, Betula, Acer, Salix,* Rosaceae, and Ericaceae), weed pollen (*Ambrosia, Artemisa,* Compositae, *Mentha,* Ranuculaceae, *Rumex, Oenothera,* and monolete and trilete spores), and tree pollen (*Pinus,* Picea, *Fagus, Quercus, Tsuga,* and *Tilia*). Dung fungus was identified using Van Geel's 1978 monograph on bog microfossils.

Results and Discussion

Colour and rhizome stratigraphy

Cores from our reference sites (A and D) show a simple progression from low to high marsh. The sediment colour in the core from reference site A changes from grey to reddish brown at about 22 cm below the surface. *Spartina alterniflora* rhizomes are dominant below this depth and *Spartina patens* rhizomes above (Figure 2). In reference site D, *S. patens* rhizomes are again dominant to about

23 cm. Below this depth, *S. alterniflora* and *S. patens* rhizomes are mixed, and a grey-brown colour was observed from 10.6 to 34.4 cm (Figure 2). The mixture of *S. alterniflora* and *S. patens* rhizomes in the lower section of core D may represent fluctuations between low and high marsh environments.

Stratigraphy of cores from inside the dyke (B and C) is more complex (Figure 2). A distinct dark (black-brown) sediment horizon is visible in cores from both sites inside the dyke, from 11.4 to 21 cm depth in core B and 19.7 to 29.3 cm in core C, indicative of oxidation under terrestrial conditions of the reclamation surface. Both contained *S. alterniflora* rhizomes at, or just above, this dark horizon, indicating a progression from the reclamation surface to low marsh conditions. In core B, *S. alterniflora* rhizomes extend to a depth of 30 cm, suggesting that this area of the marsh may have experienced an earlier dyke breach and temporarily reverted to low marsh conditions. This may explain why the reclamation surface appears to be at a shallower depth at site B than at site C, as some accretion could have occurred during a breach. Caution should be applied to this interpretation, however, as *S. alterniflora* rhizomes can penetrate 40 cm below the growing surface (Connor et al. 2001).

Organic Matter Content

Salt marshes generally exhibit lower LOI values compared to terrestrial soils due to large minerogenic input from tides. Within a marsh, LOI values are expected to increase with elevation. LOI data for monolith B were inconclusive. There is a decrease at 5–7 cm, but this does not correspond to the observed grey layer in the field at 9.5–11 cm (Figure 3). In monolith C, LOI increases between 31 and 18 cm (Figure 3), suggesting development of high marsh (*Spartina patens*) that is flooded at less frequent intervals than the low marsh and, therefore, has a lower mineral input (Connor et al. 2001). LOI decreases above this level, corresponding to the flooding of the reclamation surface and reversion to low marsh (*S. alterniflora*) with an increase in minerogenic input. The LOI data from core B does not show a similar correlation with observed sediment colour changes.

Pollen Analysis

The black-brown sediment horizon observed inside the dyke was targeted for pollen analysis to verify it as the reclamation surface. Pollen composition is expected to change with marsh elevation. In the low marsh, increased tidal flooding imports regional tree pollen that dilutes the autochthonous pollen (Chmura 1994). The observed decrease in tree pollen, relative to marsh pollen, at 11 cm and 21 cm for cores B and C, respectively, indicates decreased tidal influence at these depths (Figure 4). Below the dark horizon, the percentage of tree pollen is more than twice the percentage of marsh taxa pollen. This indicates the lower samples represent marshland with periodic flooding, as the local Poaceae (grass) pollen is being diluted by large amounts of widely-dispersed tree pollen. Apart from Poaceae, there was not much variation in amounts of pollen from marsh taxa at different depths. An exception to this is the large increase in Potemogeton type pollen, probably indicating *Triclochin maritima*, at the upper sample in monolith C. Large amounts of *T. maritima* roots were found at this depth (Figure 2).

The large increase in shrub and weed pollen (from 20 to 110 percent of the number of wetland pollen) in monolith B at the shallow depths is indicative of clearing of land and development in the local area over time. This pattern was not observed in the C monolith, which may indicate a different pollen taphonomy at this site. The increase in shrub and weed pollen is indicative of general land clearing in the area but may also indicate the presence of these species on the reclamation surface. In particular, dandelion (Compositae-liguliferae) pollen was found only in the upper two samples of monolith B and the middle sample of monolith C, corresponding to the dark sediment horizon. Dandelion pollen is not widely dispersed, and is uncommon in salt marsh sediment (Chmura et al. 2001). The associated decrease in conifer pollen at these levels suggests a local source.

Studies by Graf (2004) of modern dykeland soils (at Nappan experimental farm) have shown that the abundance of corophilous (dung) fungal spores is significantly higher in soils of grazed fields. Corophilous fungal spores were found at 11.5 cm depth in Monolith B and 20 cm depth in Monolith C (Figure 4). The changes in the pollen record, along with the presence of dung fungus spores from grazing cattle, support the hypothesis that these depths correspond to the reclamation surface.

Conclusions

The techniques used in this study, colour, rhizome and pollen statigraphy, and the presence/absence of corophilous fungal spores, all corroborate the identification of the reclamation surface. There are variations from site to site. The LOI data did not show expected changes at site B, and the increase in weed pollen on the reclamation surface was not found at site C. Using multiple techniques, however, should allow for adequate confirmation of the reclamation surface from any sample.

This preliminary study has located the reclamation surface in the marsh sediment. Based on maps and historical photos, we know that the tidal gate failed between 1945 and 1960. If we take the mid-point, 1953, 11 cm and 21 cm of sediment accreted at sites B and C over the last 50 years, representing average accretion rates of 0.22 to 0.42 cm yr^{-1}. The reclamation surface would have been below sea level when the dyke was breached (Anisfeld et al. 1999). Initial accretion following the breach was probably very rapid and then slowed as elevation increased. It is also likely that the dyke was not breached in one event, rather in a series of repeated breaches that allowed pulses of sediment to be deposited. The Marsh was able to recover without reverting to a mudflat. Sediment deposition rates of a nearby salt marsh have been measured to be 1.4 cm yr^{-1} in the low marsh and 0.3 cm yr^{-1} in the high marsh (Chmura et al. 2001b). Compaction may be high in parts of Saints Rest Marsh due to building of roads and structures on the marsh (Figure 1). The rapid development of the surrounding area, and the Marsh itself, in the 1950s and 1960s may have increased the sediment supply to the Marsh. Further investigation, including more extensive coring and pollen analysis, as well as measuring present day surface elevations of the Marsh, would help to elucidate the process of recovery over this surface as well as the effects that the various anthropogenic disturbances on the Marsh have had on this recovery.

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Figure 1. (a) 1945 aerial photo showing intact dyke. Scale: 1:24000; bar= 0.5km (b) 1994 aerial photo showing breached dyke and location of sampling sites. Scale: 1:12500; bar= 0.5km

(a) **(b)**

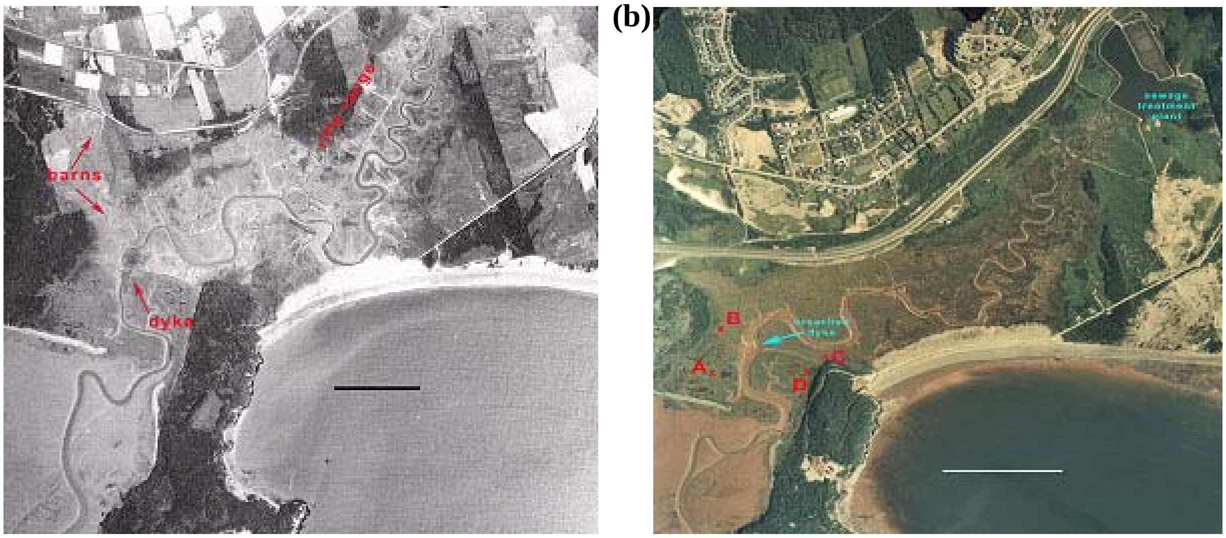
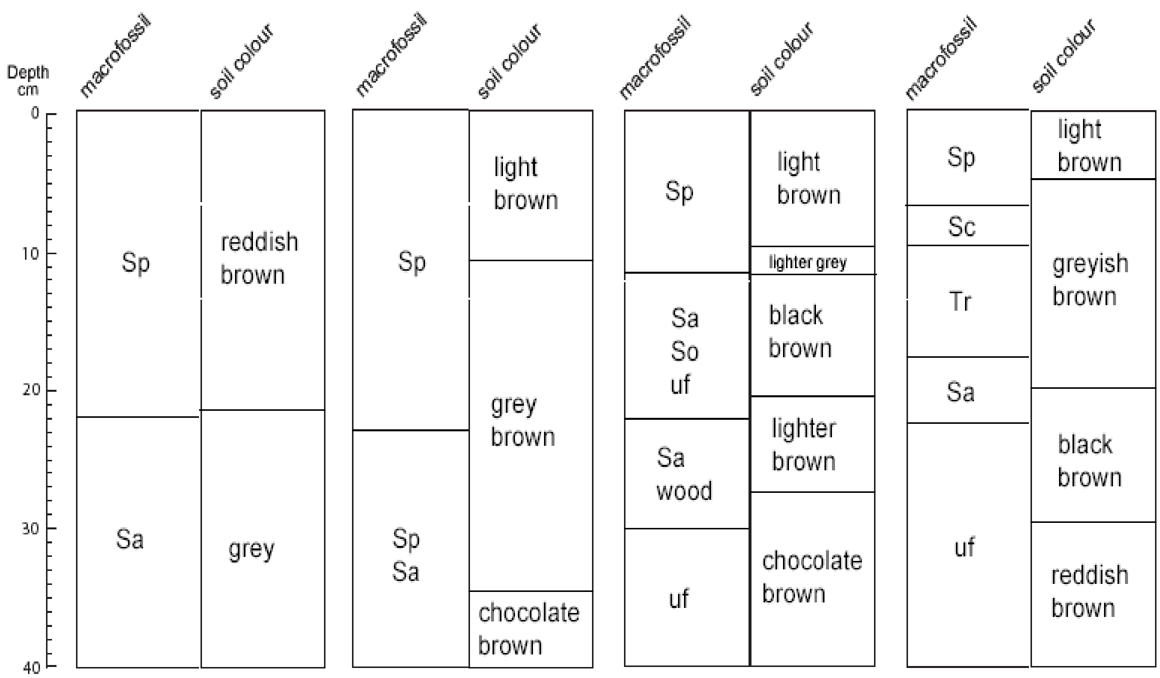


Figure 2. Macrofossil and colour observations. Sp = *Spartina patens,* Sa= *S. alterniflora,* So=*Solidago* sp., Sc= *Scirpus* sp., Tr= *Triclochin maritima*, uf=unidentified fine material.



Site A **Site D** **Site B** **Site C**

Reference cores (outside the dyke) **Cores inside the dyke**

Figure 3. Percentage lost on ignition (LOI) in salt marsh sediment cores

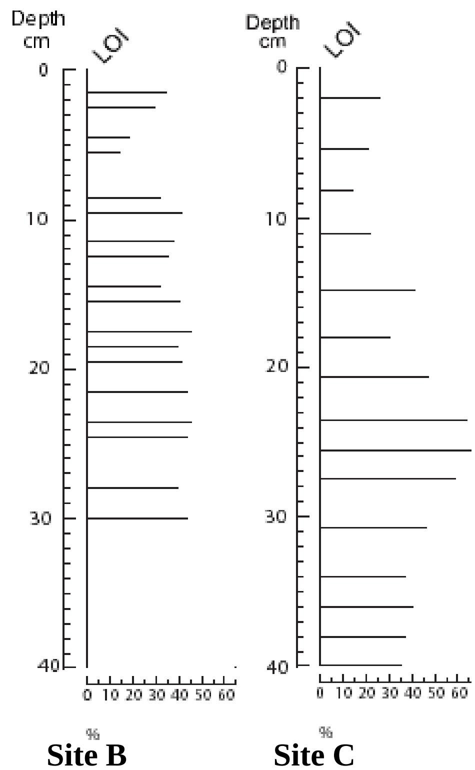
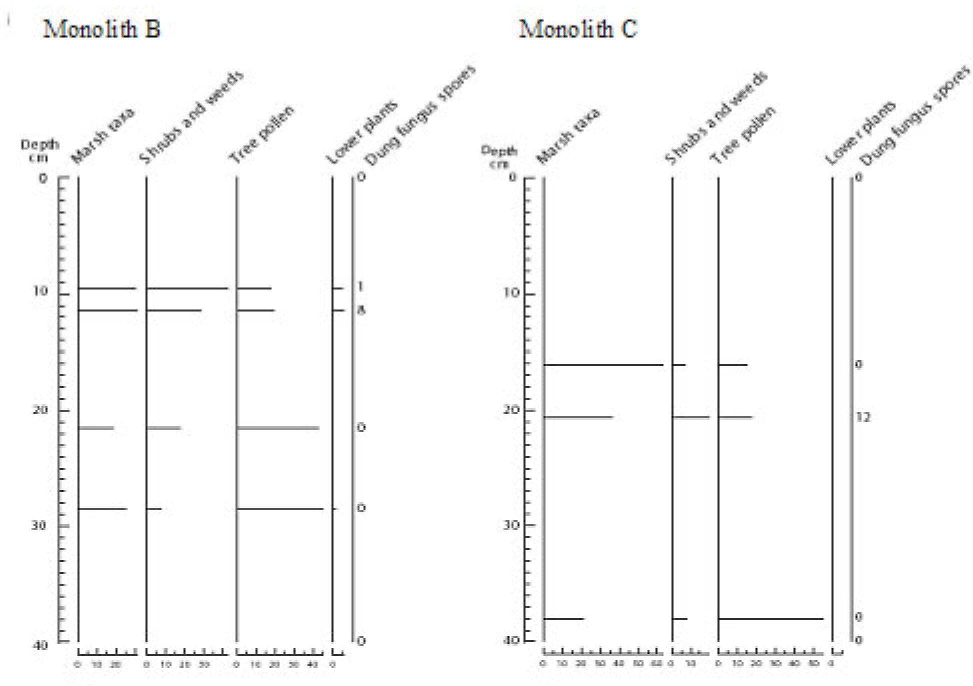


Figure 4. Results of pollen analysis of salt marsh sediment cores



THE CHEVERIE CREEK SALT MARSH AND TIDAL RIVER RESTORATION PROJECT

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The Cheverie Creek Salt Marsh Project is designed to restore a more natural tidal regime to a tidally restricted salt marsh and tidal river system. Restoration activities, including replacing a small culvert with a larger one, will create the hydrological and biological conditions for Cheverie Creek to return itself to a functional salt marsh and tidal river system, and for further maturation to continue through natural processes. Restoration efforts at Cheverie Creek are part of a larger project that is building a coalition of awareness and support for restoration activities in the Bay of Fundy.

To date, with financial and in-kind support from a mix of local, provincial, regional and international organizations, agencies, and individuals, the project team has completed extensive pre-restoration monitoring in accordance with the Global Programme of Action Coalition for the Gulf of Maine (GPAC) protocols, at both the restoration site and at a nearby reference site. The project team has also initiated education and stewardship activities at both the local and provincial level.

Over the last three years, the project team has completed tidal barrier audits for the four counties on the Nova Scotia side of the Upper Bay of Fundy (Cumberland, Colchester, Hants and Kings Counties). This is leading towards the identification of future salt marsh, tidal river and migratory fish passage restoration sites.

This presentation will provide an overview of project activities, results and insights from five years of effort to promote the protection and restoration of salt marshes and tidal rivers in Nova Scotia, including the monitoring and outreach activities and next steps. The presentation will conclude with some findings about the status of coastal wetlands in the Bay of Fundy and the urgent need for greater protection and restoration measures for the province.

Session Ten

ECOSYSTEM MODELING IN A MACROTIDAL ESTUARY—COBSCOOK BAY

Chairs: Peter Larsen, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbor, Maine

and

David Brooks, Department of Oceanography, Texas A&M University, College Station, Texas

MODELING CIRCULATION AND EXCHANGE PATHWAYS IN COBSCOOK AND PASSAMAQUODDY BAYS: IMPLICATIONS FOR ECOSYSTEM MANAGEMENT

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Abstract

Cobscook and Passamaquoddy bays lie on the border between the United States and Canada at the entrance to the Bay of Fundy, where the mean tidal range is about 6 meters. Vigorous tidal currents maintain cold temperatures and efficient mixing, supporting an unusually productive and diverse ecosystem. This paper summarizes results from a circulation model that was part of a Cobscook Bay ecosystem study, reported elsewhere (*Northeastern Naturalist* 2004). Tidal-mean flushing times vary, from less than a day near the entrance, to over a week in the inner arms of the Bay. A pair of counter-rotating eddies form in the central bay during each flooding tide, which influences the distribution of particles and dissolved materials.

Over the last several decades, net-pen salmon aquaculture has developed in both bays. Recent outbreaks of fish diseases have led to heightened concerns about tidal coupling between net-pen sites and potential pathways for disease transmission. Model experiments including both bays and their connecting passages, indicate that neutral particles carried in the flow can cross the border in both directions, pointing to the importance of well-coordinated international plans for ecosystem management.

Introduction

Cobscook and Passamaquoddy bays (Figure 1) have long been associated with rich resources, including great quantities of alewives, herring, pollock, cod, haddock and other fish species (Kilby 1884). Vigorous tidal exchange with the offshore waters is largely responsible for the unusually productive and diverse ecosystem of the bay environment (Larsen et al. 2004). Once-abundant herring supported a prominent sardine industry that collapsed in the late 1950s, and has only slowly been recovering. Likewise, stocks of cod and haddock have significantly declined in recent decades. Currently, Cobscook Bay supports a wide variety of commercially important benthic organisms, including scallops, clams, mussels, urchins, and macro-algae (Trott 2004).

In the early 1990s, net-pen salmon aquaculture was introduced in Cobscook and Passamaquoddy bays, and aquaculture has become an important contributor to the economy on both sides of the border (Sowles and Churchill 2004). Increasing numbers of floating net pens led to concerns about pollution, particularly the potential for eutrophication associated with fish wastes and the transmission of pathogens. Recent outbreaks of infectious salmon anemia (ISA) have lead to fallowing of fish farms on both sides of the border, severely impacting the local economy. There is also growing concern about potential genetic impacts of farmed-fish on the wild salmon population (NRC 2003). Such concerns highlight the need for international co-ordination and management based on sound knowledge.

To address such questions, it is necessary to understand the capacity of the tidal circulation to flush pollutants from the bays. It is also important to assess the effectiveness of tidal water movements and mixing that may couple the bays. As a step in this direction, numerical models have been used to study the tidal circulation, dispersion and flushing times in Cobscook Bay.

The Tides

The large tidal range in Cobscook and Passamaquoddy bays results from a near-resonance of the semidiurnal tide of the North Atlantic Ocean with the Gulf of Maine-Bay of Fundy system (Garrett 1972). The principal lunar semidiurnal tidal constituent (M-2), by far the most important in the region, has a period of 12.42 hours, or 12 hours and about 25 minutes. Generally, two highs and two lows occur per solar day, but the times of high and low water are delayed each day by about 50 minutes because of the moon's prograde orbital motion. For discussion purposes, it is convenient to reckon the M-2 tidal period as exactly 12 lunar hours, noting that one lunar hour equals 1.035 solar hours.

Circulation Models

A variant of the Princeton Ocean Model (Blumberg and Mellor 1987; Casulli and Cheng 1992) was used to study the tidal circulation in Cobscook Bay (Brooks et al. 1999 give details). Briefly, the model approximately represents the coastal outline and bottom topography (Figure 2), using a stretched vertical coordinate with 11 levels and a horizontal grid resolution of 255 meters. The model is forced with M-2 tidal oscillations at an open boundary near Eastport, and inflow from principal rivers. The important influence of the wind is excluded here, and drying of intertidal regions is not fully represented. Starting with initial data from survey cruises (Phinney et al. 2004), the model calculates the time evolution of water velocity, temperature and salinity at each grid cell and each level. The present discussion is limited to a few salient features and implications.

The flood and ebb currents generally follow the deep channel from the open boundary into the central bay, with maximum current speeds reaching about 2 m s^{-1} (about 4 knots). The rising flood is partially blocked by the narrow opening leading into the inner bay, producing a pair of counter rotating "back-set" eddies in the central bay. Figure 3 shows the model surface currents near the time of maximum flood. Direct and indirect observations, as well as local knowledge, are consistent with the eddy pattern (Brooks 2004). The northern eddy supplies water to the rising tide in Pennamaquan and East bays, and the southern eddy directs part of the inflow into South Bay. The development of the eddy dipole largely determines how the flood spreads throughout the central bay, and the eddies play an important role in the horizontal and vertical dispersion of particles and tracers.

The model shows that about one-third of the high-water volume of the Bay moves in and out with each tide—roughly equal to the mean outflow of the Mississippi River during the same interval. Thus, if the vertical mixing were complete on each flood, the bay-averaged flushing time would be about three tidal cycles or 1.5 days. This is a reasonable overall value for the main tidal channel in the outer Bay, but there are wide variations over the entire Bay.

A map of flushing time for the Bay can be developed by seeding model runs with neutrally-buoyant surface particles released in every grid cell at different phases of the tide and then averaging over a full tidal cycle (Figure 4). In the main channel of the outer Bay, most particles escaped regardless of the phase of the tide at the time of release. Residence times less than two days are almost entirely confined to the outer Bay with the lowest values on the eastern side where the deep channel lies close to Moose Island. In the extremities of the inner arms of the Bay, especially South and Whiting bays, none of the particles escaped, regardless of the phase of the tide when released.

Residence times of three days or less occur in a larger region of the northern eddy than in the southern one, and the particles released into the northern eddy escaped the Bay during a greater range of tidal phases than in the southern eddy. The flooding tide is preferentially directed toward South Bay.

Next, we consider a tracer or dye-release experiment with a surface source of 100 units in the channel between Birch and Gove points. The source was active only for the first 24 hours. Thereafter the model tracks the spatial and temporal evolution and decay of the tracer distribution at all levels. Figure 5 shows a single frame of the tracer concentration *at the bottom,* one week after the source became inactive, when concentrations were reduced to less than one percent everywhere except in the innermost tip of South Bay. The full animation sequence (http://cobscook.tamu.edu/review) shows that detectable tracer levels persist in South Bay because the material emitted at the source location is preferentially steered toward the south as each flood forms off Birch Point, and then is captured by the southern half of the eddy dipole. Although the absolute concentrations are low, the particulate matter represented by the tracer may include phytoplankton, benthic diatoms, and macro-algal detritus, important food sources for filter-feeding organisms such as scallops.

Coupling of the Bays

To address questions about possible tidal coupling between proximate pen sites, a circulation model was applied to the full Passamaquoddy-Cobscook region (Figure 1), including the principal islands and passages that connect the bays with each other and with the offshore waters. The model (Hess 2000) is similar to the Cobscook-only version, except for a simplified vertical turbulence scheme. In the absence of adequate field data, initial temperature and salinity values were specified at open boundaries and at river mouths and interpolated at interior points. Annual-mean freshwater inflows were included for five principal rivers, and M-2 tidal sea level variations were imposed at open boundaries; wind influences were not included. Figure 6 shows results from a surface drifter (tracked particle) experiment in the passages linking the bays. Drifter tracks were determined by integrating the model velocity field, starting from the initial positions of the particles (open circles). The drifters were released simultaneously at the surface near the time of maximum flood in Head Harbor Passage and tracked for eight tidal cycles.

The tracks, augmented by many others not shown, suggest that much of the surface water reaching Cobscook Bay flows close to the inner side of Campobello Island. For example, one of the Head Harbor drifters (no. 1) moved along the western shore of Campobello, passed near Treat Island, and thereafter became trapped in Johnson Bay. The drifter released closer to Indian Island (no. 2) escaped the inflow toward Cobscook Bay and moved toward Western Passage, where it was drawn into the narrow channel between Indian and Deer Islands; thereafter it continued northeastward along the eastern shore of Deer Island. The tendency for the flood in Head Harbor Passage to divide, with the branch adjacent to Deer Island turning northward into Western Passage, is also evident in a statistical study of model particle tracks in the region by Thompson et al. (2002). The drifter released near the west side of Western Passage (no. 3, track marked by stars), crossed Friar Roads off Eastport and then moved southward along the west side of Campobello Island, following nearly the same path as drifter 1 (marked by crosses). Drifter 4, initially only about 300 m from drifter 3, continued northward along the west side of Deer Island.

Management Issues

The apparent coupling of the bays points to the importance of an international integrated management plan based on knowledge of the circulation patterns. Although there are uncertainties associated with, for example, inadequate resolution of the intense tidal eddying in Head Harbor and Western Passages, the preliminary model experiments suggest that aquaculture sites in outer Cobscook Bay may be influenced by sites on the western side of Campobello Island. The same Campobello sites appear to be "downstream" of sites on the US side of Western Passage, so effective management strategies should include all of those areas simultaneously.

Acknowledgements

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Much of the material in this short paper is summarized from a review article in the special Cobscook issue of *Northeastern Naturalist* (Special Issue 2) (2004).

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Figure 1. The Cobscook-Passamaquoddy Bay archipelago at the entrance to the Bay of Fundy, showing the mainland, passages and islands defining the bays. The international border is shown by the dash-dotted line. The inset box identifies the domain of the circulation model for Cobscook Bay.

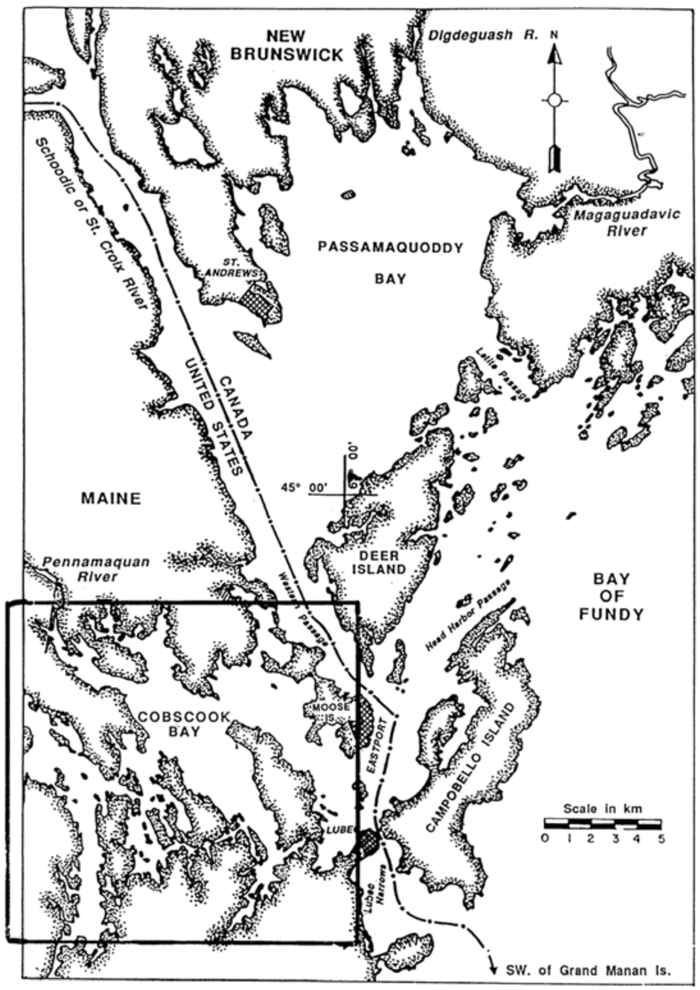


Figure 2. Map showing the detailed geographic features and place-names defining Cobscook Bay, Maine. Note the location of the Dennys and Pennamaquan rivers. For discussion, the Bay is divided into inner, central and outer sub-regions.

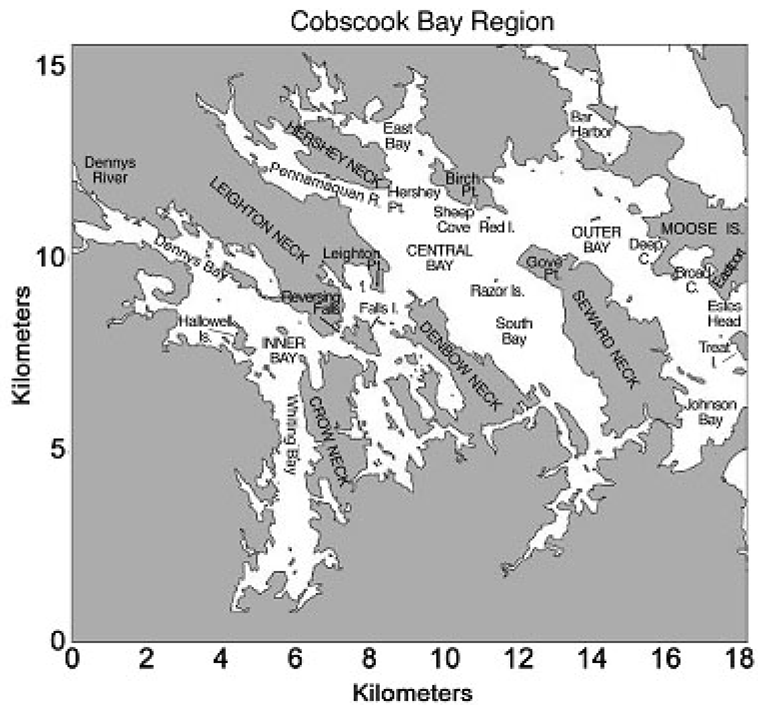


Figure 3. Model surface currents in Cobscook Bay at 11 lunar hours after high water at Eastport

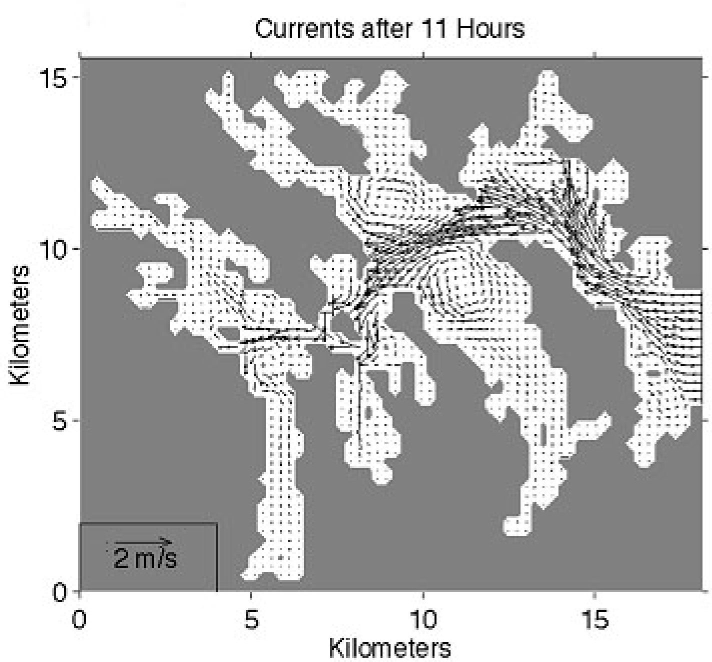


Figure 4. Colour-coded map of tidal-average residence time (in days) for particles released in each grid cell at the surface. Particles not flushed from the Bay after eight days were assigned a residence time of eight days.

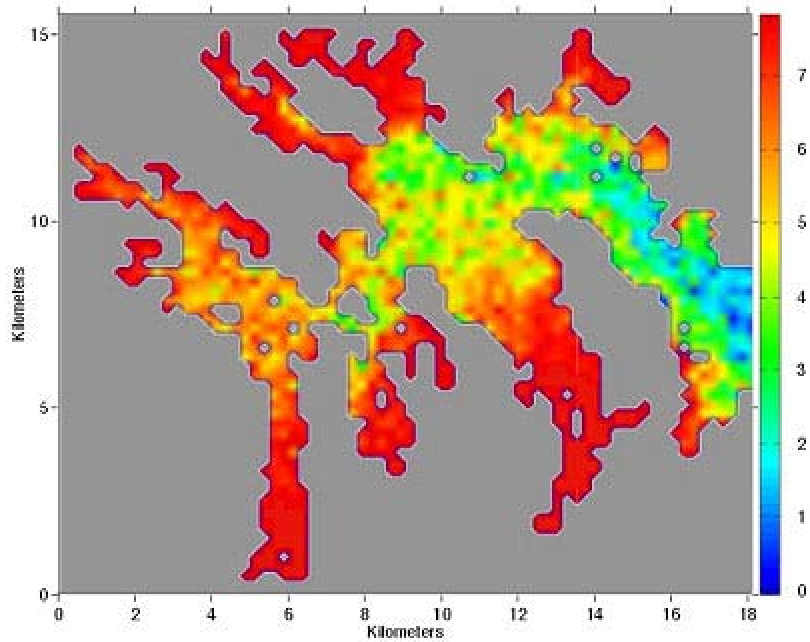


Figure 5. Concentration of tracer at the bottom seven days after a surface source was deactivated. Values are listed in percentage of source concentration in the central bay. Note expansion of concentration scale.

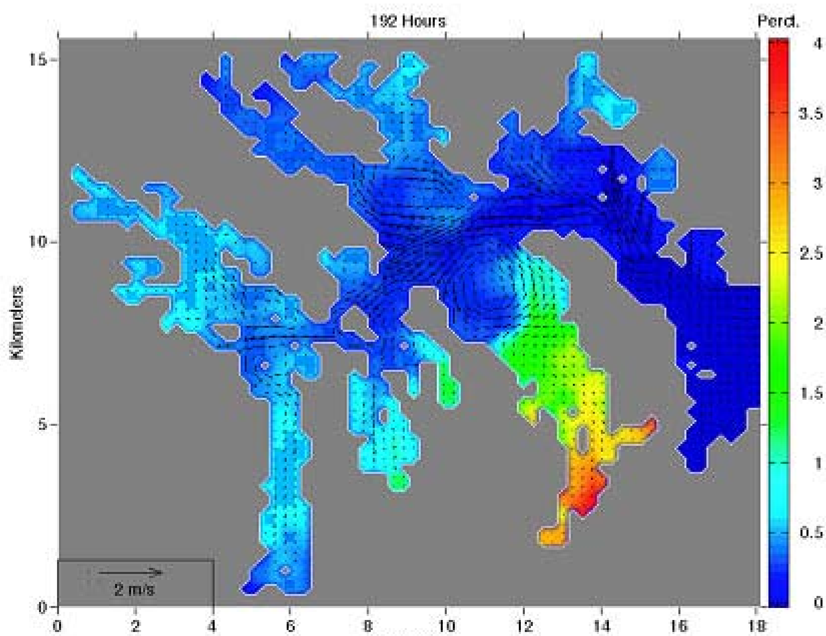
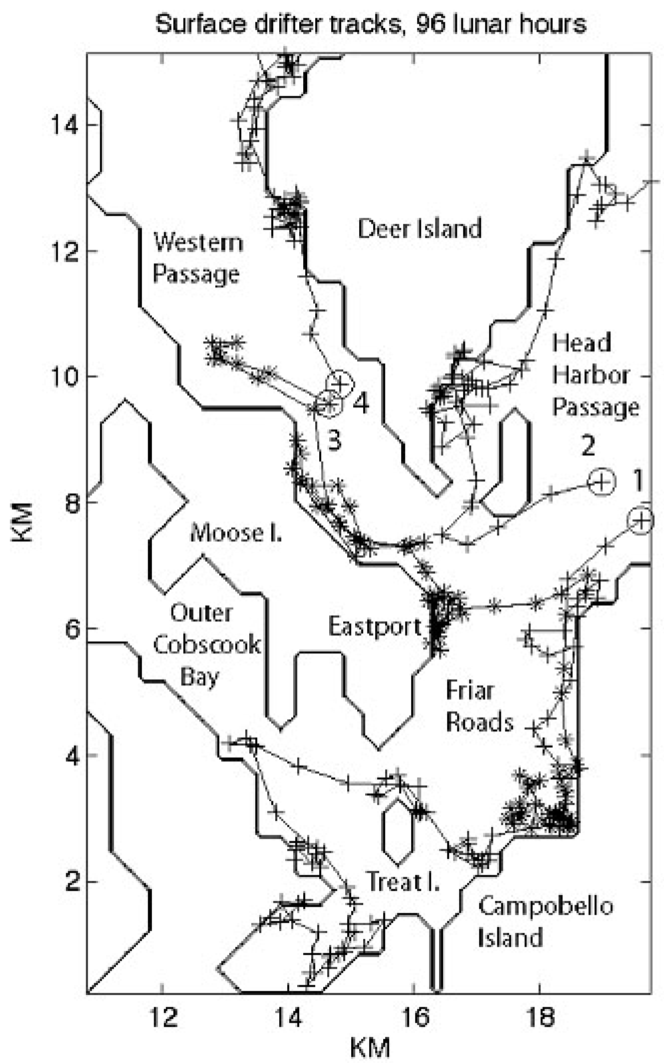


Figure 6. Model surface drifters tracked for eight tidal cycles in the passages connecting Passamaquoddy and Cobscook bays. Circles mark the release points. Symbols mark time intervals in lunar hours along the track lines. The neutrally-buoyant drifters were released simultaneously near the time of maximum flood in Head Harbor.



THE TIDAL-STREAM ENERGY RESOURCE IN COBSCOOK-PASSAMAQUODDY BAYS: A FRESH LOOK AT AN OLD STORY

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Abstract

With a mean tidal range of 5.5 meters, the Cobscook-Passamaquoddy archipelago has long been regarded a promising site for tidal-power development. Modern, low-head turbines allow power extraction primarily from the kinetic energy of the tidal stream, rather than the potential energy of an impounded basin, eliminating the need for expensive and elaborate systems of dams, locks and gates. Although the available power levels are much less in streaming applications, the resource may still be significant and accessible in areas with strong tidal flows, because the available power follows the *cube* of the current speed. The much lower costs per installed kilowatt and the relatively minor environmental impacts warrant a fresh look at the tidal-stream resource.

Circulation models indicate that the peak power resource in narrow straits such as Letete Passage and Lubec Narrows exceeds 10 kw per square meter of installed turbine aperture. Modern helical turbines have efficiencies of about 30 percent, so in those locations a moored installation with 30 m^2 of aperture could produce about 0.1 megawatt during each of the four peak flow intervals in a tidal day, and perhaps a factor of two greater during spring tides. An installation with the "footprint" of a large aquaculture site could produce peak power levels approaching one megawatt. Lower levels are available in deeper, less restricted regions, such as Western and Head Harbor passages and parts of Friar Roads. Pathways between small islands and headlands where flow speeds exceed about 2 m s^{-1} (about 4 knots) offer a tidal-power potential that could be tapped at relatively low cost and with minimal impact on the environment, fisheries and navigation.

Background

In 1912, an experienced hydraulic engineer, Dexter P. Cooper, visited Campobello Island with his new bride, whose family maintained a summer home on the island. At the time, Cooper was in charge of construction of a large hydroelectric dam on the Mississippi River, so the idea of extracting power from Passamaquoddy tides came to him readily. Cooper spent the rest of his life advocating an international tidal-power project in which Passamaquoddy Bay was to be the "high" pool and Cobscook Bay the "low" pool. The project required massive construction of dams, locks, fishways and articulated gates to provide continuous one-way flow through a powerhouse separating the two pools (Figure 1). In Cooper's original design, the installed generating capacity was to be 300 MW, with room for expansion to 500 MW. Trites (1961) describes the operation of the two-pool plan. Subsequent estimates, based on more efficient horizontal-axis turbines, indicated a peaking capacity of 1,000 MW, comparable to a modern nuclear plant (Udall 1963).

Cooper's project was never completed, mainly because of concerns about potential damage to fisheries, enhanced freezing of harbours, and lack of a ready market for the power. At that time, transmission grids were limited, and a local source of "firming" power had to be identified to fill in the valleys of a tidal plant output, which follows the moon's orbit and not the 24-hour demand cycle. In 1935, federally-funded construction began on a smaller, US-only plan under the Works Progress Administration. The work stopped abruptly in 1936 due to funding constraints, but several small dams were completed, one of which supports the current roadway connecting Moose Island and Eastport with the mainland (Figure 1). There have been numerous studies and attempts to revive the project since then, but no further construction has resulted. With modern power grids, the peaks from a tidal plant could be absorbed at any time, eliminating the need for a separate firming facility, but the old issues of environmental impacts, drastic changes in the tidal regime, and navigational complications seem even more compelling today.

The Energy Resource

To illustrate the significant difference between the tidal-stream and tidal-barrage resource, consider a vertical section of 120 m width and 5 m depth in the ocean, with a water flow of 1 m/s perpendicular to the section (Figure 2). The power available from the kinetic energy (P_{KE}) of the flow is proportional to the rate at which mass crosses the section times the velocity squared, which for the situation illustrated is about 0.3 MW. Helical turbines have efficiencies of 30 percent or greater (Gorban et al. 2001), so in principle about 0.1 MW could be extracted. Of course, in a tidal regime the flow reverses during the cycle, so the actual power available from such an installation would exhibit prominent peaks at times of maximum ebb and flood currents.

Now imagine a dam or barrage to be constructed across the section, and suppose the maximum tidal height difference or "head" from one side to the other to be 5 meters. The power available from the potential energy (P_{PE}) of the impounded water is proportional to the rate at which mass crosses the section times its vertical drop, further multiplied by the acceleration of gravity, as shown. For the same aperture as before, the peak power available is about 30 MW, or two orders of magnitude greater than that from the KE resource.

This simple example shows why tidal power concepts have historically used dams and gates to trap water at high tide, allowing it to fall through turbines as the level outside the dams drops. In regions such as Passamaquoddy, with a tidal range of 6 m or more, clearly the PE resource greatly exceeds the KE (streaming) resource. However, in constricted passages, tidal currents may exceed 1 m/s by a considerable amount, and since P_{KE} follows the *cube* of the flow speed a more careful look is warranted. Figure 2 also shows that the ratio of P_{KE} to P_{PE} per unit aperture varies inversely as the tidal range but directly as the square of the flow speed. The P_{PE}:P_{KE} peak power ratio is plotted in Figure 3 for tidal ranges from 1 m to 5 m and flow speeds up to 5 m/s. The stars (on Figure 3) show the ratio available at three sites in the Passamaquoddy region, based on estimates of flow speeds from model calculations, measurements or pilot information. For the locations shown, the highest peak KE resource available is about one-tenth the PE resource. For a 5 m tidal range, a flow speed of slightly greater than 3 m/s (about

6 knots) is required for the streaming resource to rise to 10 percent of what would be available from a tidal barrage system. According to the NOAA Coast Pilot, currents can exceed this level in Lubec Narrows and Letete Passage.

Model calculations show that the available peak power density exceeds 10 kilowatts per square meter of aperture in Lubec Narrows (Figure 4). The peaky nature of the power density is evident, with higher values at ebbs than at floods (the Coast Pilot also notes that ebbing currents are stronger than floods in the narrow passage). The coastal model (Hess 2000) provides current and other information in the full Cobscook-Passamaquoddy region, and at finer horizontal resolution (about 60 m) in the outer part of Cobscook Bay. (See Brooks 1992 for details about an earlier version of this model and its application to Cooper's tidal-power plan). Figure 5 shows an example of the streaming resource at the time of maximum ebb currents in the outer Cobscook area; note the high values of peak power density near Lubec Narrows and somewhat lower values elsewhere in the domain. The figure is a single frame from a movie that shows the distribution of the pulsating power density in outer Cobscook Bay for a full tidal cycle. This movie and another for the full Passamaquoddy region can be viewed at http://cobscook.tamu.edu/review/.

Measurements from a long-term buoy in outer Cobscook Bay (http://www.gomoos.org) show current speeds of about 1.5 m/s, generally consistent with the model results. The buoy location is near the center of the channel, just west of Broad Cove, where several large aquaculture net-pens are moored. The estimated peak power density at this location and several others, including Lubec Narrows and Letete Passage, is shown in Figure 6. In the highest flow regimes, it appears that a barged installation, comparable in surface footprint to a typical net-pen, could produce about 0.1 MW during each of the four peak flow intervals in a tidal day, using efficient helical turbines (http://www.gcktechnology.com/GCK/; Gorban et al. 2001). Other possible applications, such as installations in causeway openings or in swinging or lifting structures in narrow passages come easily to mind. These, and other flow pathways between small islands and headlands offer, a tidal-power potential that possibly could be tapped at relatively low cost and with minimal impact on the environment, fisheries and navigation.

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Figure 1. The two-pool plan and powerhouse for the International Passamaquoddy Tidal Power Project (IJC 1961)

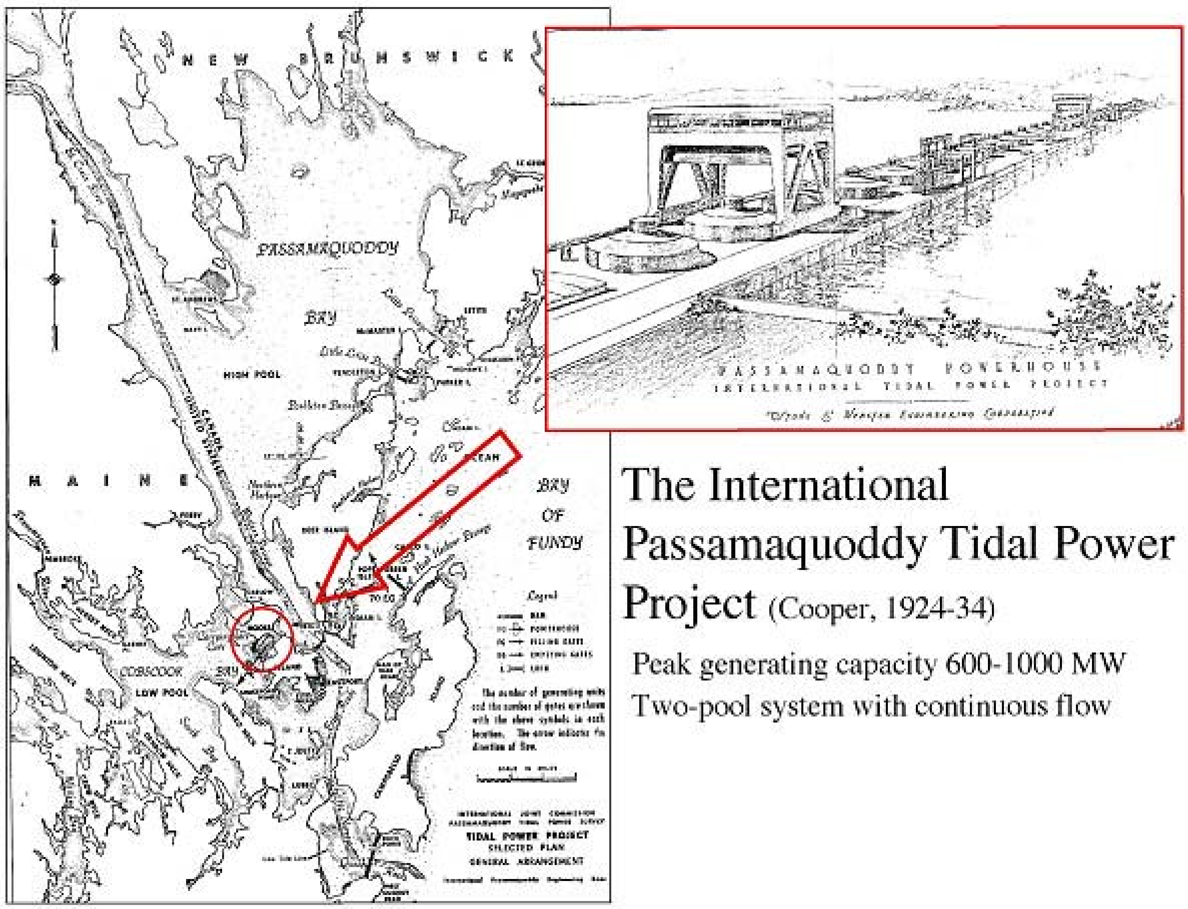


Figure 2. A comparison of power available from tidal-stream versus tidal-barrage systems

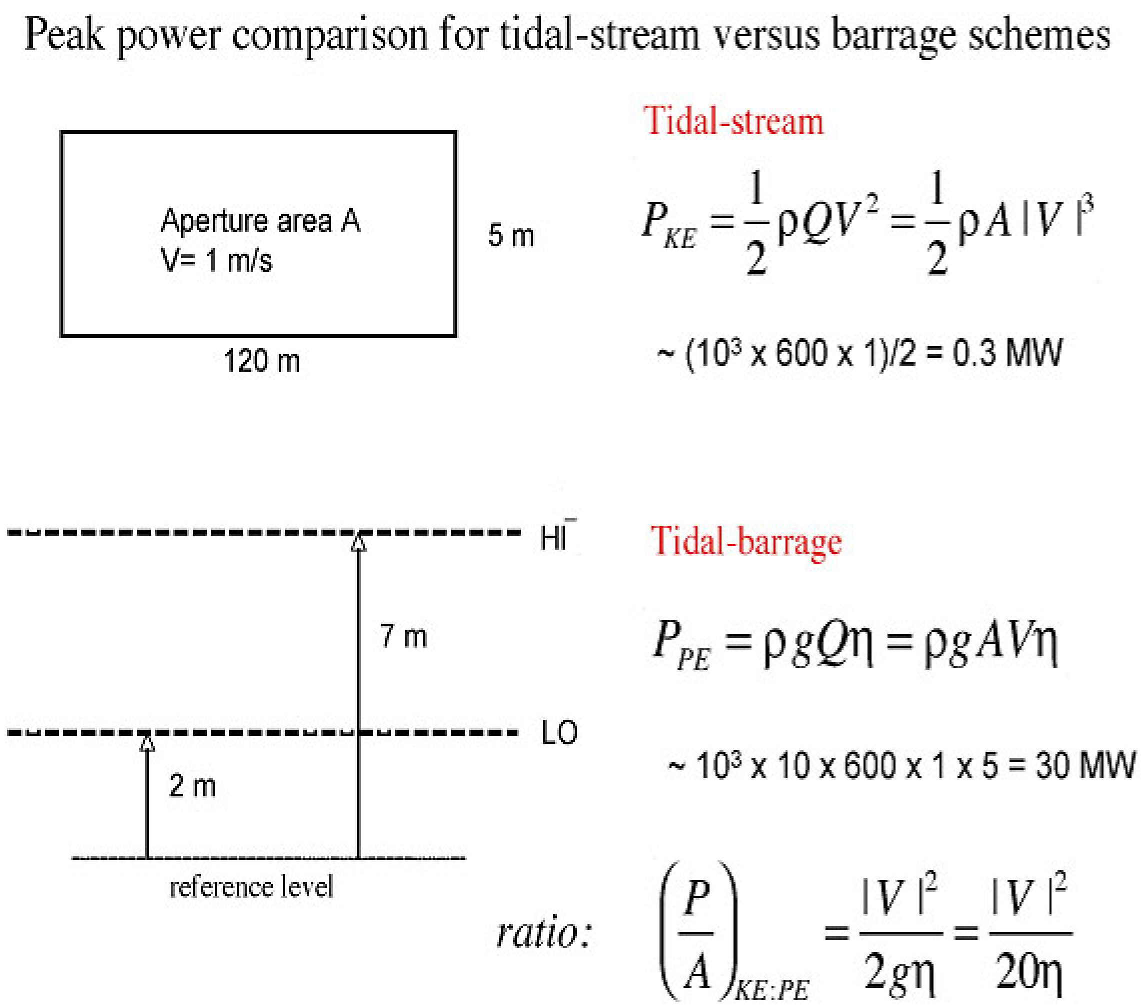


Figure 3. Peak power ratio (PPE/PKE) for barrage vs. streaming applications, for tidal ranges 1-5 m and current speeds 0-5 m/s. Note log scale. Stars indicate locations in Passamaquoddy-Cobscook region (see Figure 6).

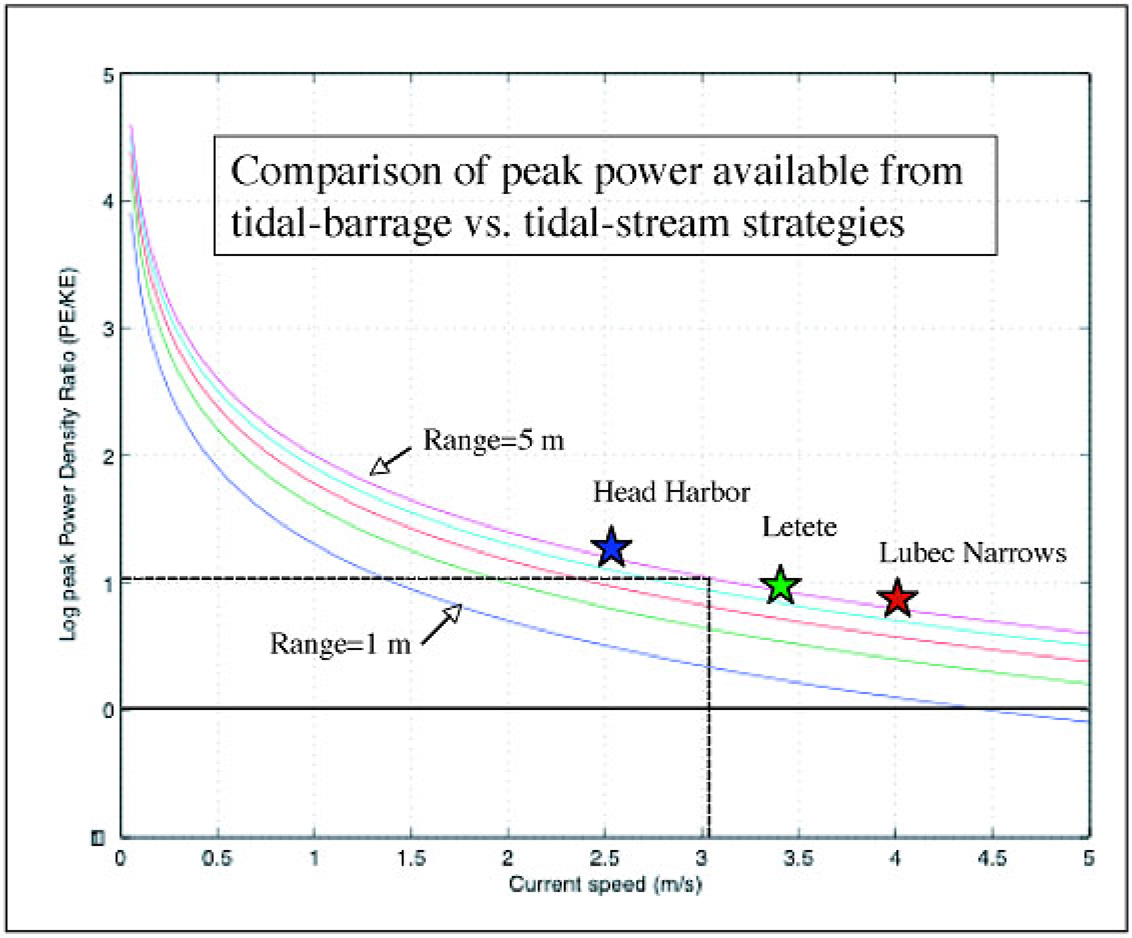


Figure 4. Power density (kw/m^2) in Lubec Narrows, from model calculation

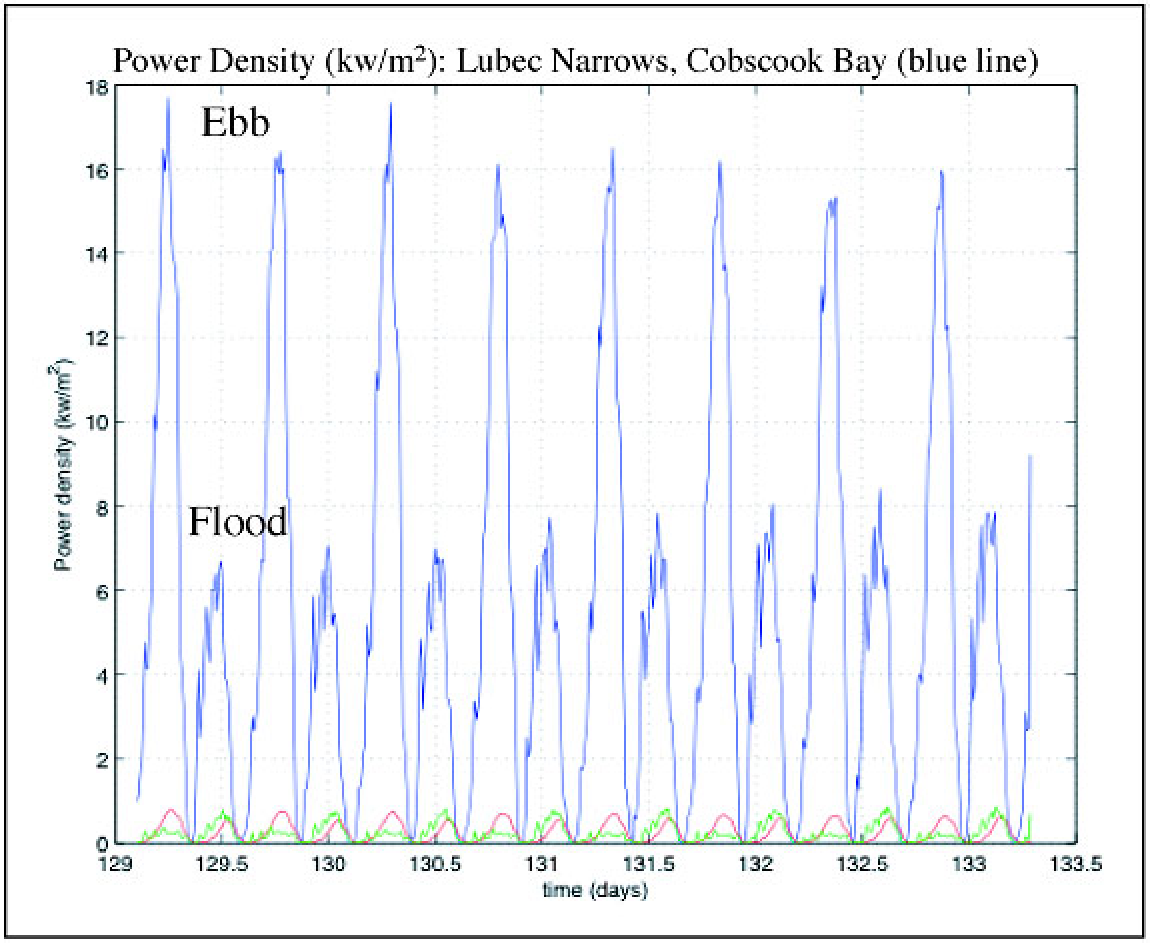


Figure 5. Available power density in outer Cobscook Bay near maximum ebb. Note log scale.

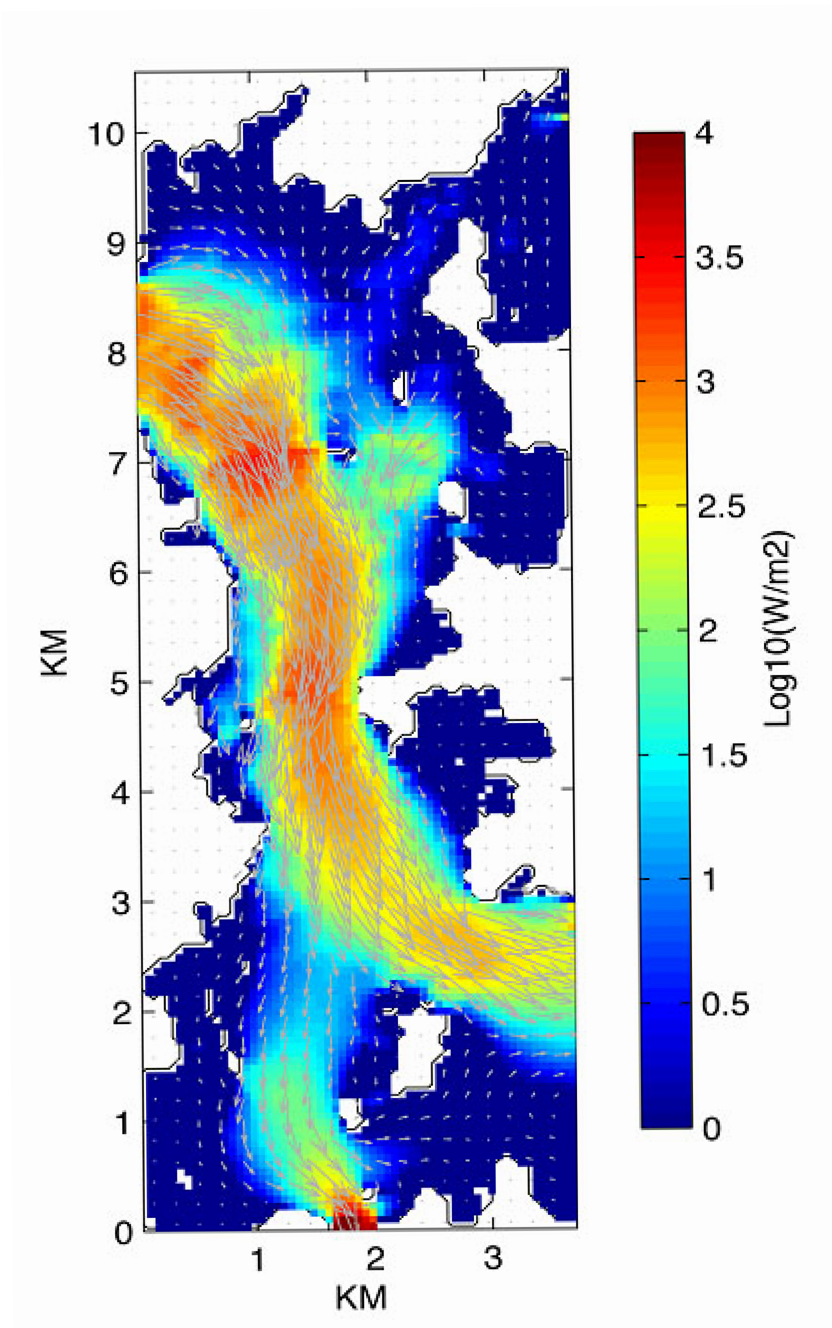
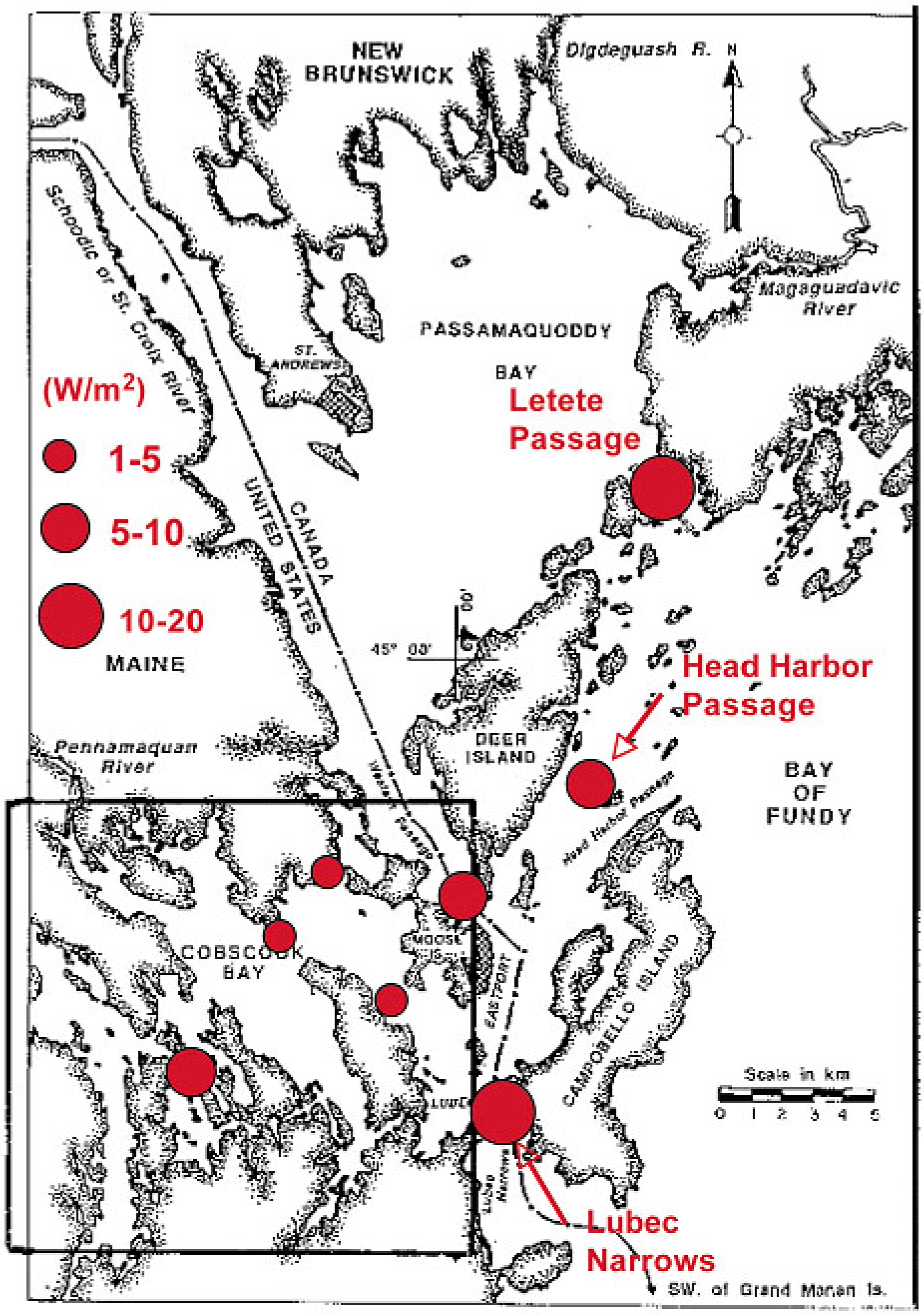


Figure 6. Estimates of peak power density available at several sites in Passamaquoddy-Cobscook region. Power density is shown in legend, as W/m^2 (W=watts).



NUTRIENT SOURCES AND DISTRIBUTIONS IN A MACROTIDAL ESTUARY IN THE QUODDY REGION[1]

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Abstract

The nutrient distribution in the highly productive, macrotidal Cobscook Bay, located in the northern Gulf of Maine, was investigated through a series of spring-neap cruises during the spring, summer and fall of 1995. Sampling design included three five-station transects at major constrictions in the Bay and 21 peripheral stations in the principal coves and sub-embayments. Results indicate that Cobscook Bay is nutrient rich throughout the year and is potentially eutrophic. Plots of salinity against nitrate show that this is a totally natural circumstance brought about by an abundant supply of nutrients, most importantly nitrate, from the adjacent Gulf of Maine. Predictive nutrient algorithms fitted with a hydrodynamic model emphasize the high nitrate water entering the Bay from the seaward end and diminishing in concentration with distance from the mouth. The plant biomass produced is heavily grazed, resulting in high ammonium concentrations from excretion and regeneration. The high ammonium concentrations, and its incomplete re-utilization by the phytoplankton, strongly suggest that plant biomass is controlled by grazing. In other words, despite a high natural nutrient loading, natural grazing processes serve to limit the accumulation of plant material and potential eutrophication. Comparing all potential nitrogen fluxes indicates that man-made contributions are not significant to the overall nutrient budget of Cobscook Bay, although they may have local impacts.

Introduction

The same nutrients, nitrogen and phosphorous, that are important for healthy growth of land plants are also essential for the growth of marine plants. In the lighted, upper portion of the sea, nitrogen may be available for plant growth as nitrate and ammonium, sometimes referred to as combined inorganic nitrogen. However, during the summer months it frequently becomes exhausted, while other nutrients do not; so nitrogen is often considered the “limiting nutrient” (Ryther and Dunstan 1971). By limiting, we mean that adding more nitrate or ammonium will cause an increase in plant growth rate and quantity (biomass), whereas adding other nutrients will cause little response. For this reason, in marine systems, study of combined inorganic nitrogen can tell us a lot about the health and productivity of a water body.

There is often a great deal of public concern about nutrients in both fresh and salt water. They are, however, essential for marine life and healthy productive waters. Virtually all life in the oceans depends on a supply of nutrients to promote plant (phytoplankton and macro-algal) growth. Herbivorous animals depend on the plants for their nutrition and become prey and food for larger animals. In the big picture, the amount of protein nitrogen that can be removed from a natural system, and this applies collectively to seaweed harvesting, shellfish digging and dragging, fishing, migratory bird feeding, and a host of other activities, cannot exceed the supply of combined inorganic nitrogen to it without depletion and, ultimately, detriment. Some of the most productive fisheries in the world are found in regions that have high natural rates of nutrient supply and high nutrient concentrations. The anchovy and similar fisheries of upwelling regions, such as the coast of Chile, are good examples, where high nutrient concentrations have direct economic value.

A frequent cause of concern when dealing with nutrients is that they may be present in excess. When this happens plant biomass increases dramatically and the process is called eutrophication. Eventually, biomass may reach such high concentrations that night-time respiration can use up all the dissolved oxygen in the water, causing anoxia that results in mass mortality of plants and animals alike. Generally, the problem leading to anoxic events is one of scale, that is, there is an enormous amount of nutrient producing activity, which is frequently human, and a limited, often inadequately flushed, receiving water to absorb the nutrients. Anoxic events are actually quite rare and limited geographically. They can occur naturally, but they can also occur as a result a variety of human activities. These include sources such as collected sewage discharge (Hudson Estuary/New York Bight), agricultural fertilizer, and animal feed that are allowed to enter coastal waters without proper safeguard.

It is important to remember that high nutrient concentrations can be natural, do not necessarily lead to eutrophication, and can have tremendous ecological and economic value (Garside et al. 1978). Cobscook Bay is such a case.

Background

We are interested in the distribution of nutrients in Cobscook Bay because they can tell us a lot about how the Cobscook Bay ecosystem works. Our study obtained samples from many locations within the Bay, twice in May, twice in July, and in October and November of 1995. We chose these sample times to allow us to observe the start of the growing season for marine plants, its peak in the summer, and its decline in the fall. We hoped to see the nutrient distributions before plants started to use them, as they consumed them, when they were most utilized, and then as use declined and ceased.

One problem with studying a region like Cobscook Bay is that a large volume of water moves in and out of the Bay on each tide on extremely strong currents. Indeed, tidal currents reach 2 m/sec as a volume equal to the outflow of the Mississippi River passes through the narrow passages of Cobscook Bay on each ebb and flood tide (Brooks et al. 1999). A sample taken at a particular location, half an hour previously came from water that is now miles away, and a sample taken from the same location now is from water that was elsewhere when the previous sample was taken. It too will be far away half an hour from now, and all the time water is mixing and changing as a result. In other words, trying to relate nutrient concentrations to geographical locations is not very meaningful unless we could sample all locations at the same moment, which is not possible. What we often do in estuaries is relate nutrient and other distributions to salt content, or salinity, which varies from 0 at the river inflow to 32–33 ppt in the coastal sea. Mixing of fresh and sea water in the estuary provides waters with a range of salinities and related properties in between (Ketchum 1955). Instead of plotting measurements against geographical location or mile point along the estuary, we plot graphs of the measurements from a sample against the salinity of the same sample.

The reason for this way of looking at things is that properties that enter with fresh water will distribute with it, with higher concentrations in fresher water in the Bay, and those that enter from the sea will have higher concentrations in saltier water. In fact, if only mixing affects the concentration of a property, then concentration should be proportional to salinity, forming a straight line between the freshwater concentrations and the saltwater concentration on the graph (Ketchum 1951). We may have only a general idea of where water with a particular salinity is in the Bay at any time, depending on the tide, but we can know what its properties such as nutrient concentration should be, and depending on its distribution with salinity, where the property originated. Often we find that the distribution is not proportional to salinity, which tells us that other processes have affected concentration, either removing or adding to what we would expect (Ketchum 1955). With nutrients, this can tell us a lot about processes such as uptake and regeneration.

Methods

Water samples for nutrient analysis were collected during a series of hydrographic cruises in Cobscook Bay in 1995. The three-day cruises were centered around the extremes of the spring-neap tidal cycles in spring (May), summer (July), and fall (October and November), i.e. six cruises. Stations consisted of three five-station transects across the main flow axis of the prominent constrictions that separate Cobscook Bay into sub-basins (Figure 1), and 21 peripheral stations generally situated in the center of subtidal areas of the principal coves and sub-embayments. The transects were sampled at high and low water in an effort to obtain synoptic sections of physical, chemical and biological conditions across these constrictions. Peripheral stations were occupied at irregular times between high and low tides. Portions of the inner bays were inaccessible because of their shallowness. See Phinney et al. (2004) for detailed information on station locations.

Station activities related to nutrient chemistry and the development of the algorithm for the prediction of nutrient distribution included a Seabird SeaCAT19 CTD profile of temperature and salinity to within one meter of the bottom and collection of water samples with a Niskin bottle, one meter from the surface and one meter from the bottom.

Water samples were vacuum (10 cm Hg) filtered through Whatman GFF glass fiber filters into 20 ml sample vials and frozen. Samples were thawed immediately prior to analysis at the Bigelow Laboratory. Analysis for nitrate (and nitrite, ammonium, phosphate and silicate) was done on a five-channel continuous flow analyzer. The continuous flow analyzer is of our design, and runs chemistries adapted from Strickland and Parsons (1972). Although samples do not always preserve well for some analyses, they do for nitrate, which is our principal interest here. Precision was ± 0.05 μg-at. N l^{-1} (Glibert et al. 1991).

Predictive algorithms relating nitrate concentrations to the temperature/salinity distribution were developed using the step-wise multi-variate polynomial regression techniques developed and described in Garside and Garside (1995).

A complete table of data is available in paper and digital format in Garside et al. (2004).

Results and Discussion

Spring and Summer

Nitrate is plotted against salinity in the spring (May points marked 1 and 2) and summer (July points marked 3 and 4)(Figure 2). There are differences between the two distributions, which we expect, but both show a rapid decline of nitrate with decreasing salinity. What this indicates is that the source of nitrate is in waters with the highest salinity, in other words the sea water end. In the spring, the concentrations are generally higher than in the summer, and greater than zero because plant growth is just starting, and nitrate is not used entirely or as quickly as it is in the summer. Salinities are lower than in the summer because freshwater run-off is higher in the spring, causing slightly more dilution of the sea water. However, the general pattern in both cases is unequivocal evidence that nitrate enters Cobscook Bay from the seaward end, and the distribution is dominated by this source.

A second feature of this distribution is that, in both spring and summer, nitrate would be depleted before salinity reached zero (Figure 2). This further reinforces the conclusion that the ocean, and not the rivers, provide the nitrate distribution in Cobscook Bay. It also tells us that nitrate is being utilized within the Bay by plants, since if it were not, nitrate concentrations would decline much more gradually with salinity, reaching low values only when salinities approach zero.

There are several other lines of evidence that suggest that the coastal sea is the source of nitrate. A much more complicated analysis of the nitrate and temperature/salinity data allow us to create equations that can be used to predict nitrate from temperature and salinity (Garside and Garside 1995). Since we have hydrodynamic models that can predict the distribution of salinity and temperature (Brooks et al. 1999), these models can also be used to describe nitrate distribution. Results (Figure 3) indicate high nitrate water entering the Bay from the seaward end and diminishing in concentration into the bays and towards the rivers.

A second line of evidence can be obtained by comparing the potential nitrogen fluxes from other candidate sources with the nitrate transported in and out of the Bay on the tide each day (Table 1). These calculations show that all the other likely candidate sources of nitrogen to Cobscook Bay combined only represent about three percent of the nitrogen that is transported by the tide each day as nitrate, and five percent of what is utilized each day in the growing season by plants. Thus, although local impacts of the other sources cannot be discounted in the bigger picture, only tidal exchange of nitrate is comparable to plant utilization of nitrogen, and the smaller sources are insignificant.

Ammonium is excreted by animals that consume plants, and also by bacterial breakdown of nitrogen-containing organic matter (Glibert et al. 1988). It is used preferentially over nitrate by most marine plants, and is also oxidized quite rapidly by bacteria to nitrate. As a result, it is important in phytoplankton nutrition, and its presence tells us about recent herbivory and recycling. In ocean waters, its presence often indicates that plant production and herbivorous grazing are closely balanced, and this is observed as the ecosystem matures in the summer.

The distribution of ammonium in Cobscook Bay in the spring and summer is shown in Figure 4. Unlike nitrate, ammonium is distributed quite randomly with respect to salinity in both the spring and the summer. Since ammonium is produced by regenerative processes and is relatively short lived, this strongly suggests that the ammonium is being regenerated within Cobscook Bay. What is most surprising is that ammonium concentrations are almost as high in the spring as they are in the summer. High concentrations in the summer and fall would be expected because the herbivore populations have had a chance to respond to the available plant food, and grow to match the supply. This is normally not the case in the spring. The implication is that at least some of the herbivore population is already in place in the Bay and starts to consume plankton as soon as they grow in the spring. This scenario is consistent with large populations of filter feeding animals that are resident in the Bay, such as clams, mussels and scallops.

This pool of nitrogen can be put in the same perspective as the other fluxes calculated above:

Ammonium tidal exchange (2 uM NH_4 in the Bay): 14.9 metric tons N per day

that may be lost if ebbing water is not returned on the next flood. Coincidentally, this helps balance the nitrogen budget for the Bay (not the purpose of this exercise) but more importantly, this flux is a factor of ten or more larger than any originating from current human activities, based on inputs from agriculture and sewage (Table 1).

Fall

In the fall, we see nitrate utilization continuing into October (points labelled 5) and the distribution is still similar to summer conditions (Figure 5). By November, however, nitrate uptake ceases or is very low and nitrate concentrations are both high and almost uniform over the salinity range sampled (points labelled 6). Despite the high nutrient concentrations there is reduced light to support plankton and algal growth, and phytoplankton populations decline, while fixed algae respire more than they photosynthesize, which has implications for nitrogen regeneration.

Ammonium distributions in October are very similar to those in the summer, and for the same reasons: herbivores effectively crop the phytoplankton and regenerate ammonium within the Bay (Figure 6). The same distribution persists into November, but primary production has been inferred to have decreased, based on the nitrate distribution, and so the source of this ammonium must be different, at least in part.

Nutrient data alone are insufficient to elucidate the source of the regeneration that continued high ammonium concentrations imply. However, by the fall there are large reservoirs of organic nitrogen in seaweeds and algal mats. These break down and are grazed, resulting in direct regeneration and a continued supply of particles for filter feeders. In fact, for a variety of reasons other than the nutrient distribution, it seems very likely that grazing on fixed algae is at least as important as filter feeding on phytoplankton in the regeneration of nitrogen as ammonium, throughout the growing season and into the fall (see Campbell 2004; Vadas et al. 2004).

The Ultimate Source of Nitrate?

A final comment on where the nitrate comes from, when much of the Gulf of Maine surface water is nutrient depleted throughout the summer, is in order. High nitrate concentrations build up in deeper waters where the products of excretion, death and decay accumulate and the nitrogen they contain is oxidized eventually to nitrate. In the absence of sufficient light this nitrate cannot be utilized until physical processes bring it to the surface where there is light, photosynthesis, plant growth, and nutrient uptake. This occurs annually throughout the Gulf when winter cooling causes deep convection, water column overturn, and mixing, providing a nutrient supply supporting phytoplankton growth when days lengthen in the spring. Mixing is the key. Over much of the Gulf, the spring warming results in warm, nutrient-depleted water at the surface separated by a thermocline from colder, nutrient-rich water below (Hopkins and Garfield 1979). Nutrients and high production are short-lived in the surface layer.

In the Bay of Fundy two circumstances contribute to mixing of nutrients to the surface throughout the year. In moving from the Gulf into the Bay of Fundy, tidal currents are compressed and accelerated by both a narrowing channel and shoaling of the bottom. At some point, the increasing turbulence from increasingly faster currents acting on the bottom provides enough energy to destabilize the water column and break the thermocline. Cold nutrient rich water is mixed to the surface and it is this water that acts as a source of nutrients to Cobscook Bay. The large volume tidal exchange of the Bay throughout the year serves as the local transport mechanism (Brooks et al. 1999).

Conclusion

Cobscook Bay is nutrient rich throughout the year and is potentially eutrophic. This is a totally natural circumstance brought about by an abundant supply of nutrients, most importantly nitrate, from the adjacent Gulf of Maine. These nutrients promote phytoplankton and fixed algal growth, and the biomass produced is heavily grazed, resulting in high ammonium concentrations from excretion and regeneration. The high ammonium concentrations and its incomplete re-utilization by the phytoplankton strongly suggest that plant biomass is controlled by grazing. In other words, despite a high natural nutrient loading, natural grazing processes serve to limit the accumulation of plant material and potential eutrophication. At least at the time these measurements were made, man-made contributions were not significant to the nutrient budget of the Bay, although they may have significant local impact. Consequently, the nutrient status of Cobscook Bay has probably changed little since the development of macrotidal ranges, approximately 7,000 years BP (Scott and Greenberg 1983).

Acknowledgements

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Table 1. Comparison of potential daily, tidal nitrogen fluxes, as nitrate, in and out of Cobscook Bay each day

Nitrate tidal exchange (5uM NO_3 source in spring)[1]	70.0	metric tons	N	per day
Nitrogen consumed by plants (400gC$m^{-2}y^{-1}$ over 6 months)[1]	40.2	“	”	“
Nitrogen in salmon feed (1994/5 data) [2]	1.2	“	”	“
Total nitrogen in freshwater run-off [2]	0.9	“	”	“
Total nitrogen in rain and dust fallout [2]	0.2	“	”	“
Sewage nitrogen (10,000 people max.)[3]	0.01	“	”	“

Data from this[1] or other personal studies[3]

[2] Data provided by Dan Campbell, US Environmental Protection Agency

Figure 1. Map of Cobscook Bay, Maine showing the locations of the principal transects for the study

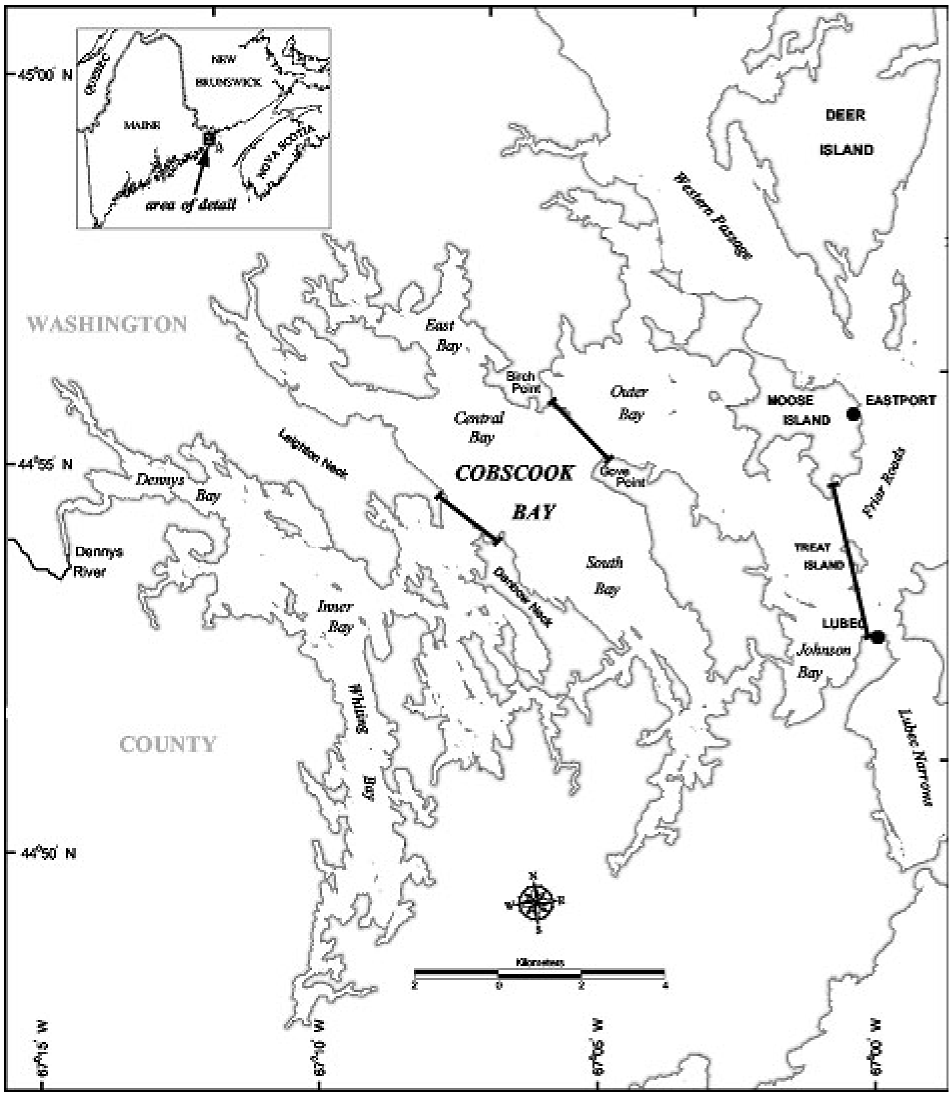


Figure 2. The relationship between nitrate and salinity in the spring (May points labelled 1 and 2) and summer (July points labelled 3 and 4). Points labelled 1 and 4 represent neap tides; 2 and 3 spring tides.

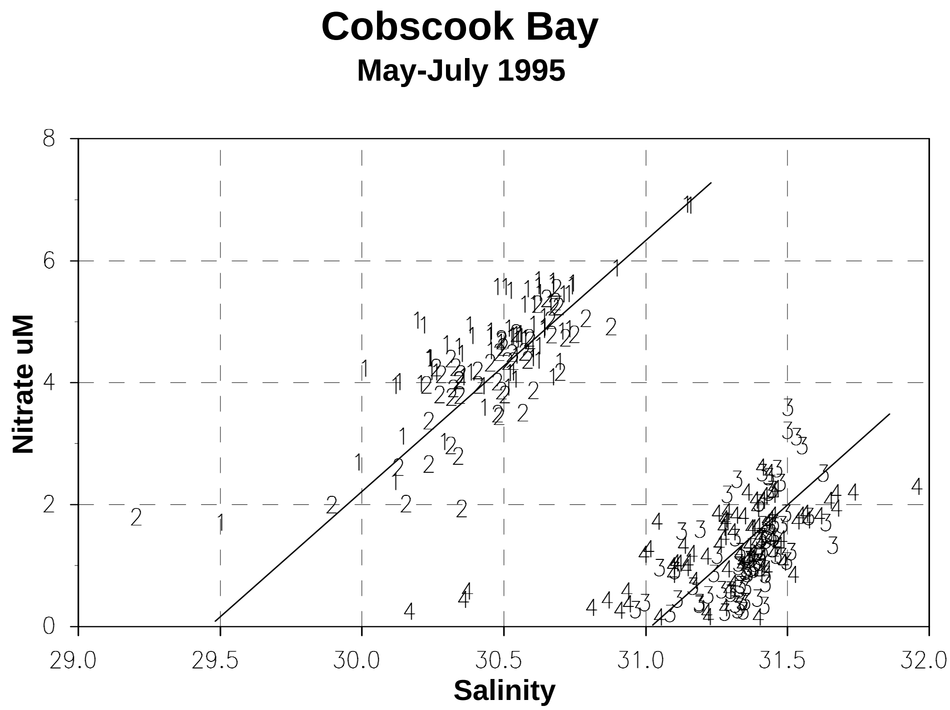


Figure 3. Spring nitrate distribution in Cobscook Bay, determined by predictive algorithms and the three-dimensional numerical circulation model (Brooks et al. 1999)

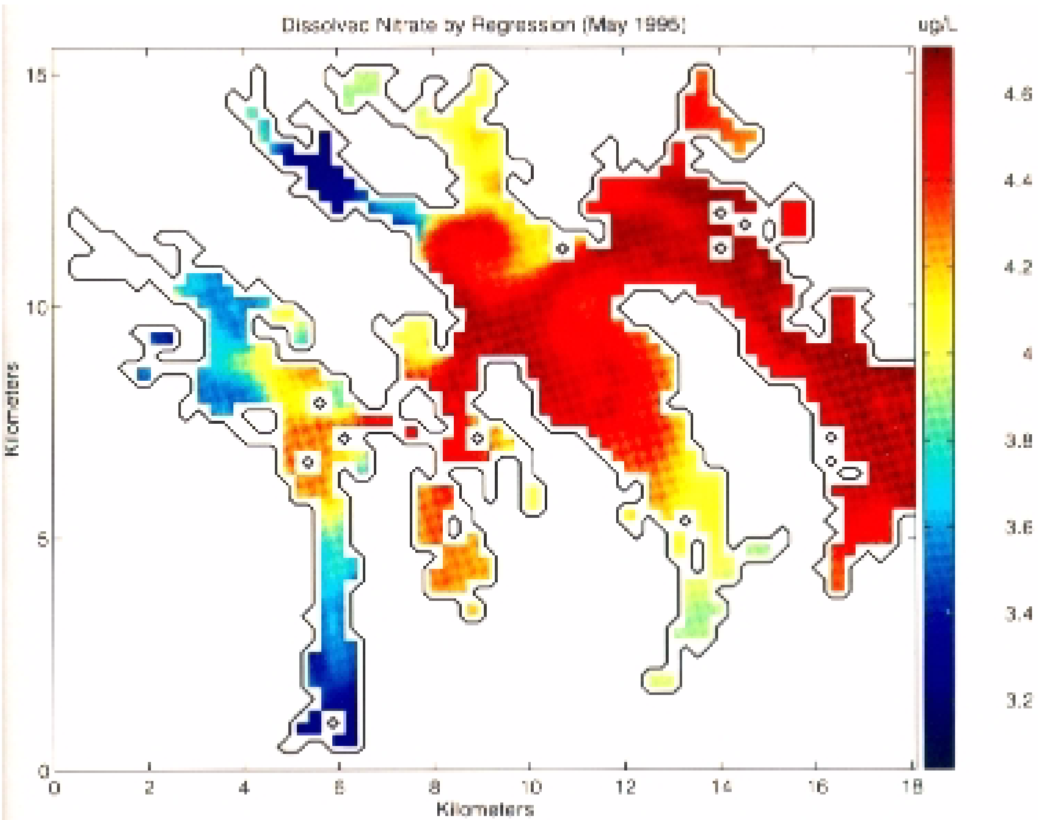


Figure 4. The relationship between ammonium and salinity in the spring (May points labelled 1 and 2) and summer (July points labelled 3 and 4). Points labelled 1 and 4 represent neap tides; 2 and 3 spring tides.

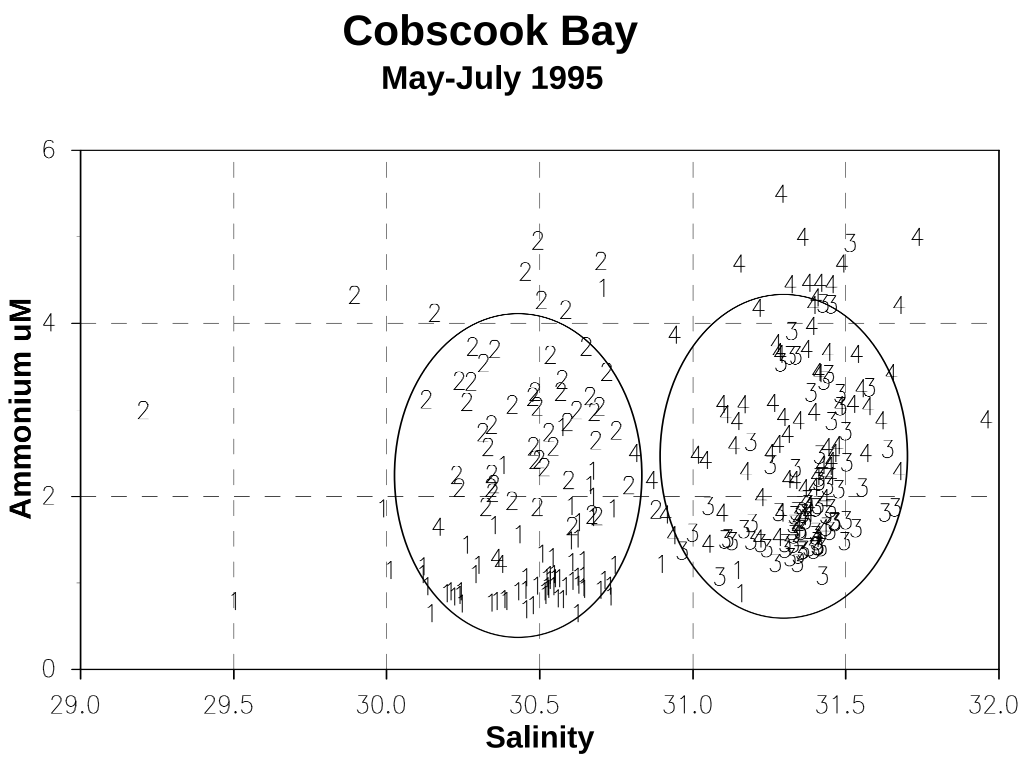


Figure 5. The relationship between nitrate and salinity in the fall (October points labelled 5 and November points labelled 6)

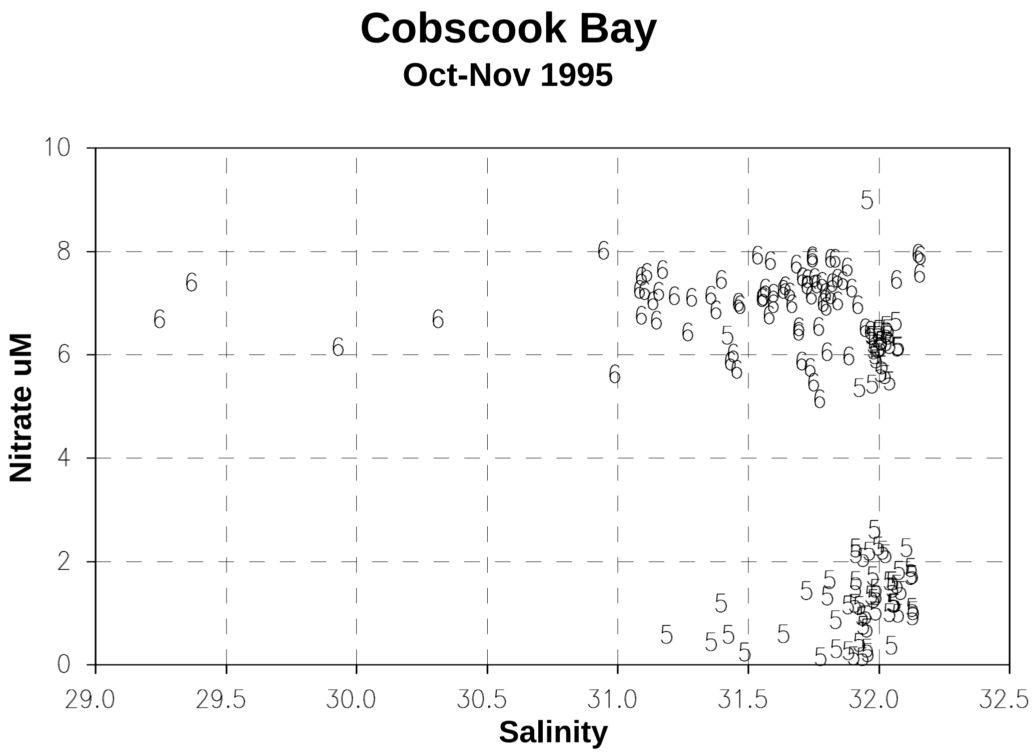
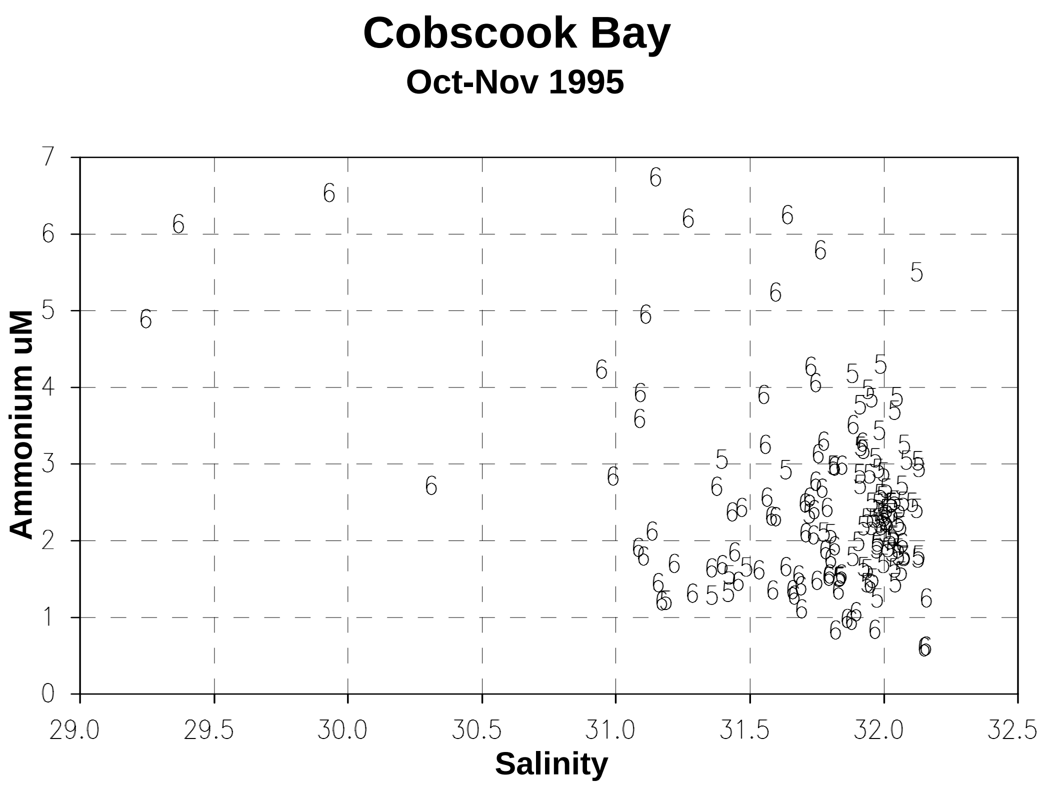


Figure 6. The relationship between ammonium and salinity in the fall (October spring tide points labelled 5 and November neap tide points labelled 6)



MACROPHYTE PRODUCTIVITY IN COBSCOOK BAY

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We estimated annual and seasonal productivity for a representative group of macrophytes in Cobscook Bay (eastern Maine, USA) during 1995-1996. We delineated sites according to presumptive flow regimes represented by protected embayments/coves and headlands, and measured spatial and temporal variation in biomass and productivity for the fucoid, *Ascophyllum nodosum*, the kelp, *Laminaria longicruris*, the red alga, *Palmaria palmata*, the green alga, *Ulva* spp., and the marine angiosperm, *Zostera marina*.

Highest productivity estimates for *Ascophyllum* occurred at one of the high flow sites (14.9 kg wet · m^{-2} · yr^{-1} or 894 g C · m^{-2} · yr^{-1}). Turnover rates for *Ascophyllum* ranged from 29 to 71 percent, indicating that the biomass of this alga is turning over approximately every two years. About 60 percent of the standing biomass is added to detrital pools contributing large amounts of energy for secondary consumers. Rockweeds in Cobscook Bay are among the most productive, cold-water, intertidal assemblages and are contributing large amounts of carbon to this system. We estimated that 1,060 hectares of the Bay was in rockweed production. Based on the average annual productivity (594 g C · m^{-2} · yr^{-1}) at two sites, total rockweed production in Cobscook Bay is estimated to be 6.3 x 10^9 g C · yr^{-1}.

We estimated kelp production near the sublittoral fringe at three sites. Highest productivity estimates for *Laminaria* was 942 g C · m^{-2} · day^{-1}. Growth in these fringe stands was comparable to subtidal kelps, but productivity was slightly lower, likely due to lower stand densities, and possibly stress from aerial emergence during low tides. We estimated that 75 hectares of the Bay was in *L. longicruris* production yielding 3.34 x 10^7 g C · $year^{-1}$.

Productivity of intertidal red and green algae was estimated at four coves and three headlands across two-three tidal levels. Generally, maximum biomass values for both groups occurred in the low intertidal. Mean maximum biomass for *Palmaria* was 564.2 g dry wt · m^{-2}, or 169.4 g C · m^{-2} · yr^{-1}. We estimate that 212 hectares of the Bay was in *Palmaria* production. Total areal productivity for this red alga is 1.2 x 10^9 g dry wt · yr^{-1} or 3.6 x 10^8 g C · yr^{-1}. Mean maximum biomass values for foliose green algae was 362.1 g dry wt · m^{-2}, or 109 g C . m-2 . yr^{-1}. We estimate that 916 hectares of the Bay was in foliose green algal production, therefore, total (areal) production by these macrophytes is 3.0 x 10^9 g dry wt · yr^{-1} or 9.0 x 10^8 g C · yr^{-1}.

Productivity of intertidal stands of *Zostera marina* was estimated at three soft-bottom sites. Leaf initiation and elongation rates showed a strong seasonal pattern, with highest rates occurring from June through September and lowest rates occurring from November to April. Productivity at one site ranged from 0.095 g dry wt · m^{-2} · day^{-1} from November to January to 1.215 g dry wt · m^{-2} · day^{-1} in August. At Mahar Cove, rates ranged from 0.176 g dry wt · m^{-2} · day^{-1} in March and April to 1.490 g dry wt · m^{-2} · day^{-1} in August. Average annual productivity ranged from 0.481 to 0.784 g dry wt · m^{-2} · day^{-1}. The length of time for plants to fully turn over their leaves at the two sites ranged from 50.5 to 56.7 days, or an average of 6.4 to 7.2 turnovers per year. These turnover rates are comparable to those in other locations in the northeast United States and the Canadian Maritimes. The estimated area of subtidal eelgrass in Cobscook Bay was 466 hectares. We estimate that total (intertidal + subtidal) eelgrass production in Cobscook Bay ranges from 3.3 to 5.3 x 10^8 g C · $year^{-1}$.

LATE 20TH CENTURY QUALITATIVE INTERTIDAL FAUNAL CHANGES IN COBSCOOK BAY, MAINE

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Abstract

Late 20th century changes in the intertidal distributions of macroinvertebrates within five sample sites in the Cobscook Bay, Maine, region were evaluated by comparisons with qualitative baselines, some as old as 35 years. These baselines were generated by the Maine State Planning Office Critical Areas Program (CAP) (1970–1987), which recognized the unique distributions of macroinvertebrates and high diversity of intertidal communities in Cobscook Bay that had attracted many zoologists, dating back to the early 1800s. The sample sites were Critical Invertebrate Areas registered by CAP between 1968 and 1976. None of the sites had been re-examined for at least 20 years, and all but one had been evaluated at least twice prior to this study. Many species, including those whose presence was used to designate habitats as critical, were common or abundant in original site descriptions but rare or absent in 2002. The dramatic change in community composition, away from species typical of hard bottoms to established mussel beds, suggests a faunal shift has occurred. The principal driving force that produced this change is proposed to be disturbance from increased sedimentation that altered intertidal habitats. Potential sources of this disturbance, and possible cascades that followed, are discussed.

Introduction

Cobscook Bay, Maine, is exceptional because of the extreme tidal range that characterizes this macrotidal estuary and creates an ecosystem with biodiversity comparable to that at lower latitudes (Trott and Larsen 2003). Postglacial changes in climate and ocean circulation, superimposed on the large tidal amplitude contributed to the assemblage of unique communities found there (Bousfield and Thomas 1975). However, compared to estuaries similar in size and commercial importance, such as Chesapeake Bay, general awareness of this ecosystem is poor in spite of its distinctiveness. Cobscook Bay, a rock-framed macrotidal estuary, is both the furthest east and the only boreal estuary on the eastern coast of the United States. Even though Cobscook Bay serves as the sink for two rivers, the amount of fresh water entering the bay is negligible (Campbell 2004), and differentiates it from many macrotidal estuaries, which often receive substantial river input (Gleizon et al. 2003). All the water entering the innermost region of the Bay, formed by confluence of Whiting and Dennys bays, must enter through a single narrow opening restricted by an island. All processes occurring in the inner Bay that are dependent on mixing with offshore waters rely on this single input.

Cobscook Bay shares a history with a few locations in the United States, since Eastport, Maine, was where the United States Fish Commission established its second research station, after recognizing the decline of fisheries on the eastern US coast in the mid-1800s. For decades before this, the intertidal communities of Cobscook Bay had drawn zoologists to this remote region. The highly diverse macroinvertebrate fauna of Cobscook Bay is documented by a rich historical chronology that spans 162 years of collection records because of this attention (Trott 2004). Information of this kind is rare and useful in establishing species distributions and general knowledge of geographic ranges. It provides, however, no hint of relative abundance of the benthic community that inhabits intertidal rocky shores and mudflats. With the exception of Larsen and Gilfillan (2004), no quantitative information from systematic sampling in Cobscook Bay has been published, and even then their study sampled exclusively subtidal commuities.

One focus of historical ecology is the examination of long-term changes in communities. These studies are difficult, since pre-existing databases are required to make time series comparisons. Surveys of marine benthic communities are few, especially in North America. Long-term changes have been best studied in northern Europe, where ecological investigations of marine communities have more commonly surveyed community composition (e.g., Buchanan 1963; Ford 1923; Kühne and Rachnor 1996). Subsequent studies have revealed interesting changes in community composition and biogeography (Bamber 1993; Shillabeer and Tapp 1989; Tyler and Shackley 1980). The rarity of benthic community surveys in North America makes them attractive for investigating community change and for comparison with studies from the northeastern Atlantic.

Five specific locations in the Cobscook Bay region were the focus of qualitative, ecological assessments of intertidal macrobenthic invertebrates in the 1970s and 1980s, as were other noteworthy invertebrate communities along the coast of Maine (Maine State Archives). These evaluations were conducted as part of the Critical Areas Program (CAP) of the Maine State Planning Office that operated officially from 1970 to 1987, and aimed to identify rare and unique features throughout the state. Many publications resulting from CAP documented ecologically significant regions of the state of Maine and the fauna found within these special locations (Doggett et al. 1978; Gilbert 1977a, b; Speel 1978; Weiss 1980). Because of their qualitative nature, measuring changes using the databases produced by these studies is difficult, though highly attractive, since such location specific historical records are rarely available. Detailed site sketch maps, land owner information and tax maps, site descriptions, evaluations based on CAP criteria, species lists, and observations are available for most critical invertebrate areas. For some species, relative measures of their abundances, based on unit effort for particular localities, also exist.

During the past six years of field studies in Cobscook Bay, many intertidal species once easily found, according to previous investigators and local knowledge, were rarely or never seen by the author and his colleagues who had sampled Cobscook Bay years before he began ecological studies there. The purpose of this investigation was to measure change, if any, in intertidal communities with assemblages of invertebrates that originally attracted attention to each Critical Invertebrate Area. These were a group of species selected by their inclusion in previous CAP records, which included, but was not limited to, the circumboreal prosobranch gastropod, *Margarites helicinus*, the Arctic bivalve, *Mya truncata*, and the northern Atlantic brachiopod, *Terebratulina septentrionalis* (see Table 1). Within Cobscook Bay, the ecological significance of the Critical Invertebrate Areas rested on the spread of many cold-water species from subtidal into the shallow intertidal zone. This expansion of vertical range is possible because of special physical oceanographic and meteorological conditions of this boreal macrotidal estuary that create cooler intertidal environments. The high species diversity, and the unusual southern distribution of Arctic species, made these Critical Invertebrate Areas located outside of Cobscook Bay ecologically significant. The qualitative baselines, generated for each Critical Invertebrate Area in Cobscook Bay and vicinity, served as reference points to measure changes in invertebrate distributions, community structure and diversity. This study marks another point in the timeline for each Critical Invertebrate Area in the Cobscook Bay region.

Methods

All five locations of this study were sampled in July to coincide within one month of the original historical reference data, marked by dates that ranged from June through August, on field evaluation forms obtained from the Maine State Archives. The duration of the quadrat sampling interval at each site ranged from 40 to 50 minutes. Each transect, later described, was sampled synoptically within a single low tide period by a team of three. Additional data recorded included tidal amplitude, air and seawater temperatures, weather conditions, and general observations of the sample site for evidence of disturbance and features identified in previous reports.

Faunal Sampling Methods

Location of Study Areas

The five study areas selected for evaluation were all in the Cobscook Bay region (Figure 1). Three areas were situated within the inner bay complex: Crow Neck and Wilbur Neck both located in Dennys Bay, and Outer Birch Island located in Whiting Bay. The two remaining areas, Gleason Point and West Quoddy Head, are located north and south, respectively, of the entrances to Cobscook Bay. Gleason Point borders Passamaquoddy Bay, and West Quoddy Head projects into Grand Manan Channel.

Sample Site Selection

Reconnaissance surveys of each documented location were conducted as part of a pre-selection process for positioning sample transects. The primary goal was to locate one or more “target species” with distributions particular to each sample site (Table 1). Target species were not indicator species. Target species is a term created for this study. These species were considered ecologically significant among the set of those referenced from each site in Critical Area Program Field Evaluation Forms for any of three reasons: (1) a historical record more extensive than a listing in critical area field evaluations only, (2) a recognition of uniqueness in geographic distribution by the Critical Area Program that was used in the decision on registering an area, and (3) available estimates of the relative density of these species made at the time of site evaluation. A secondary goal was to construct a qualitative species list of all species encountered in the process of searching for target species. Each mission began an hour before low water, and its focus progressed from coarse, large-scale sweeps to fine, small-scale probing while moving towards the low water mark and following the falling tide. Maps contained in the original reports (Maine State Archives) were used for orientation to the specific designated regions within each specific location. These included navigational charts and both topographic and hand drawn maps. In all instances, hand drawn maps were used as the final reference to locate target species. They indicated landmarks, and other physiographic features, illustrated sufficiently to find the exact locations reported. Other supporting materials contained within each file, i.e. descriptions, correspondence and evaluation forms, also aided in this process.

Upon completion of a reconnaissance survey, two outcomes were possible based on presence/absence of target species: either (1) the target species was found and its distribution marked for assigning the boundaries of the sample transect, or (2) the target species was not discovered. In outcome 1, a sample transect was located within the boundaries of the Critical Invertebrate Area indicated by its large-scale delineation on topographic maps and navigational charts. In outcome 2, the boundaries of the sample transect were selected according to the distribution of non-target species found during reconnaissance that often corresponded to significant features of the physical environment. The rationale for following this selection method was based on the prediction that locations qualitatively characterized to have high species diversity would generate the best ecological inventory to compose a baseline update for an area. For example, at Gleason Point the gaper clam, *Mya truncata,* was not found within the boundaries of the archived, hand-drawn map from the Gleason Cove Critical Area file (Maine State Archives). A transect was, therefore, located within Gleason Cove in an area adjacent to Gleason Point that formed a natural boundary where the greatest numbers of different species were found during the reconnaissance survey.

Faunal Transects

Quadrat sample transects were oriented as a 50 m^2 band (50 x 1 m) parallel to the low waterline with a width overlapping the low intertidal-high subtidal fringe exposed at low water. This stratum had the highest probability of coinciding with the greatest densities of target species. Approximately 30 minutes before the time of low water, the endpoints of the 50 m long transect were anchored with markers and the distance, divided into thirds, marked in turn. Approximately 20 min before the time of low water, a 1 m distance, perpendicular to the transect and extending in the direction of the falling tide was marked at each endpoint and each intra-transect marker. At Crow Neck, Wilbur Neck, and Gleason Point, sampling effort and tide permitted a second sample transect (50 x 1 m), that extended the initial one to give a total sample transect area of 100 m^2. It was positioned slightly higher (<1 m) than the original stratum, given the rise in tide.

Faunal Transect Quadrat Samples

Thirty replicate 0.1-m^2 quadrats, 10 per each third of the 50 m^2 transect area, were sampled without replacement. Quadrat selection was not truly random. A quadrat sampler was blindly tossed forward from an end of a subdivision, with no intent towards distance or lateral direction, provided it fell within the transect boundaries. This action was repeated until the opposite end of the subdivision was reached. Sampling continued if <10 quadrat samples were taken before reaching the end of the subdivision, by facing towards the area just sampled and repeating this procedure. Overlap between quadrats was avoided by marking the position of each sampled quadrat with golf tees. A subsequently selected quadrat that overlapped, to any degree, a previously sampled quadrat was discarded and re-selected. When a second sample transect was added, 60 total replicate quadrats were sampled.

The presence of all macrobenthic epifaunal invertebrates was recorded before disturbing the quadrat by turning over rocks and cobble in search of additional species. Macroalgae were intensively searched for target species. Only target species were quantified, by counting the number of individuals within a quadrat, using adaptive cluster sampling.

Faunal Transect Adaptive Cluster Samples

Many sample locations had been evaluated as ecologically significant, and registered on the basis of the presence of species like the smooth top shell, *Margarites helicinus*, and the brachiopod, *Terebratulina septentrionalis*, that have patchy spatial distributions. An adaptive cluster sampling design (Thompson 1990) was implemented to estimate mean densities for these epifaunal species, since populations that are highly clumped are best sampled by this method. Briefly, it dictates that when a randomly selected quadrat contains a species of interest, additional quadrats are non-randomly added to the borders of the original quadrat. These ‘neighborhood quadrats’ initially have one side in common with the original quadrat and are examined for the targeted species. Neighborhood quadrats are added until ‘edge quadrats’ result, i.e. quadrats that are empty. When only edge quadrats are obtained, the sampling for that cluster stops. Adaptive cluster sampling is not effective for infaunal species and is inappropriate for dispersed species.

Faunal Transect Benthic Substrate Samples

Ten substrate samples were taken from the quadrats along the initial 50 m transect. These quadrats were selected prior to sampling by randomly choosing quadrat numbers (1–30) from a table of random values (Zar 1996). All substrate was removed with a scoop within the selected 0.1 m^2 quadrat until anoxic sediments were reached (~ 2–6 cm), or a volume of 2.3×10^3 cm^3 was collected, whichever came first. Substrate samples were processed in entirety on the day of collection. They were sieved through 2.0 and 1.0 mm screens sequentially in the laboratory. Material retained on the screens was sorted with the aide of 50x dissecting microscopes. All organisms were identified to the lowest taxon practical, most often the species level. Invertebrates were transferred into fingerbowls after separating any predators (i.e. crabs), relaxed with a 7 percent filtered seawater solution of $MgCl_2$ for 24 h in refrigeration, then fixed with 10 percent formalin. Fixed samples were labelled with location, sample and quadrat number, and date before archiving. Archived samples were transferred into 70 percent ethanol for permanent storage after 6–8 weeks.

Faunal Transect Sample Data Analysis

Species richness was estimated using the nonparametric jackknife estimate at each location for a simple measure of diversity (Heltshe and Forester 1983). This estimate is based on the observed frequency of rare species in the community. Data from quadrats and substrate samples were used to calculate separate species-richness estimates. As already described, mean densities for target species with clumped distributions were estimated using adaptive cluster sampling statistics (Thompson 1990). Whenever possible, current baseline information was compared with qualitative historical reference data collected during previous ecological assessments.

Habitat Characterization

Habitat Mapping Transects

Sample sites were characterized to habitat type using semi-quantitative methods, described by Brown (1993) for a classification system of marine and estuarine habitats in Maine as applied to benthic habitats. Since examples of each habitat type defined by this classification system included some of the current sample sites, the utility and accuracy of this scheme could be tested. It also created a new baseline for future reference. Habitat mapping included more intertidal area than what was sampled for fauna, since the entire vertical slope of the intertidal zone was surveyed along a line transect positioned perpendicular, not parallel, to the shore. The width of the intertidal zones exposed at low tide ranged from 35 to 80 m, with tidal variation that ranged from –0.46 to 2.4 m.

All five locations were mapped using a procedure modified from Bailey et al. (1993). A habitat mapping transect was established, starting at a georeferenced permanent marker at spring high water that extended to the low water mark, bisecting perpendicularly the horizontal faunal sample transect. The compass heading for the transect was recorded from the georeferenced marker to be used for roughly re-establishing the transect line in future mapping studies. The slope of the intertidal zone along the transect line was determined by measuring the change in elevation at 10-m intervals.

Habitat Mapping Transect Quadrat Samples

A 1-m^2 quadrat was sampled down slope at each 10-m interval by dividing the quadrat and collecting data from 0.25-m^2 subsamples. The percentage cover of every macroalgal species that occupied at least 5 percent of a subquadrat was estimated by visual assessment. The substrate was exposed and a visual scan used to estimate the percentage area comprised of each sediment type, i.e. mud, sand, gravel, cobble, boulder and rock, as defined by Brown (1993). Macroinvertebrates within the 1-m^2 quadrat were noted. At West Quoddy Head, Wilbur Neck and Crow Neck, each 0.25-m^2 subquadrat was digitally photographed twice: (1) after estimating percent macroalgal cover, and (2) after estimating percentage of each substrate type. The purpose of photo documentation was to provide a quantitative reference for each mapped 1-m^2 quadrat for future comparisons.

Results

Habitat Characterization

Habitat classification agreed, in part, with descriptions given in the intertidal subsystem of Brown (1993) that listed some of the Cobscook Bay Critical Invertebrate Areas as typical for defined habitats (Table 2). West Quoddy Head substrate was classified as rock and differed from the published predominant substrate type of boulder, but energy level, i.e. partially exposed, was the same. This result indicates that the characterization of substrate type is highly dependent on the position of habitat mapping, sample transect oriented perpendicular to the tide line. Gleason Point (mixed-coarse: semi-protected) and Wilbur Neck (mixed-coarse and fine: protected) agreed with published descriptions for these locations. Outer Birch Island and Crow Neck were not directly comparable to published classifications, since they were not listed as example sites for any intertidal habitat classifications in Brown (1993). However, both sample sites fall into the defined categories for exposure based on their substrate composition.

The level of accumulated fine-mud sedimentation that occluded normal interstices among boulders and large cobble at the inner bay complex Critical Invertebrate Area sample sites was substantial. Extensive patches of macroalgae, specifically *Laminaria* beds, described in correspondence and illustrated on maps in archived files, were no longer present at these locations. The surfaces of rock, shell and algae, were coated with a veneer of fine mud that strongly adhered and resisted removal by washing. In some sample locations this condition was extreme, particularly Wilbur Neck, producing anoxic conditions just millimeters below the surface.

Extensive beds of mussels were found at both Crow Neck and Wilbur Neck. One large mussel bed at Crow Neck extended along the sides to the point of the North by Northeast rock spit bordering a tide pool. This landform was once exposed, bare, current-swept rock and boulder according to Weiss (1980). Mud was not included in the geological description of the rock spit at Crow Neck. Layers of mussel shells underlie extensive mussel beds at Wilbur Neck, representing previous surface levels. At both locations, mussel beds were coated with a veneer of fine mud.

Mussels were not reported to occur at Wilbur Neck by the original critical area evaluation. They are listed only in the revised species list for Crow Neck (Weiss 1980), and not the original lists from the field evaluation forms completed in 1968, 1970, 1975–1977 (Maine State Archives). The appearance of mussel beds could be relatively recent, since the extensive detailed description of Crow Neck in the critical area report includes a specific focus on the North by Northeast rock spit fauna and never mentions mussel beds. Mussel beds were unlikely to be routinely overlooked. This idea is supported by the inclusion of *M. edulis* in the description of the West Quoddy Head Critical Invertebrate Area (Doggett et al. 1978; Maine State Archives).

Species Composition and Community Structure

Bryozoa, Porifera, and Ascidiacea, taxa that contain species that are epifaunal suspension feeders, consistently formed a minor proportion of representative phyla across all sample sites, or were sometimes absent (Figure 2). Cnidaria, epifaunal sit-and-wait predators, were also a minor segment of the community at all locations. Molluscs dominated in number of species present (37 to 51 percent) at all sample sites except Outer Birch Island, where samples contained nearly equal proportions of molluscs, polychaetes and echinoderms, comprising 24, 28 and 24 percent of the macroinvertebrate fauna, respectively. Species area curves suggest that further sampling would not raise considerably the number of species at Crow Neck, Gleason Point, and Wilbur Neck, while at Outer Birch Island and West Quoddy Head, 30 replicate quadrat samples were insufficient to collect all species (Figure 3).

Differences in jackknife estimates of species richness (Figures 4a, b) paralleled closely the number of species found in quadrat and substrate samples at each site (Figure 3), although species historically present were under-represented in samples from all sites (Figures 5–7). For example, Crow Neck had the highest species richness, but notably only 33 percent (13 out of 31) of species previously identified as ecologically significant to this sample site were found (Figure 7). Gleason Point, West Quoddy Head, Outer Birch Island and Wilbur Neck formed a group with nearly equal estimates of species richness.

Mussels were clearly dominant at Crow and Wilbur Necks and occurred in 60 and 95 percent of quadrats, respectively. They were present in 23–47 percent of quadrats sampled at the remaining sites. Mussels and the gastropod, *Littorina littorea,* were the only species ubiquitous in occurrence in all transects at all sample sites.

Distribution of Target Species

The sea stars, *Solaster endeca* and *Crossaster papposus,* were not found at any sample site, although they were historically present intertidally at Crow Neck, as were all targeted species (Figure 7). In total, just 6 of the 12 target species reported to occur at Crow Neck were observed. Only a single Neptune whelk, *Neptunea lyrata decemcostata,* the only one found among three targeted in this study, was discovered during reconnaissance at Outer Birch Island.

No gaper clams, *Mya truncata,* were found at Gleason Point, registered as a Critical Invertebrate Area based on the intertidal distribution of this species (Table 3, Figure 5a). Gleason Point reconnaissance found *Mya arenaria* that had misshaped, deformed shells formed during growth in the coarse cobble/gravel/sand substrate (Table 2). Their initial appearance was similar enough to be confused with *M. truncata* and casts doubt on the report that this species occurred at Gleason Point (see discussion). A gaper clam was found live under rocks at Outer Birch Island and in only one substrate sample taken from Crow Neck (Table 1). When shells of this species were counted in substrate samples, the same distribution among sample sites was obtained. Only one sample from Outer Birch Island and three from Crow Neck contained shells of *M. truncata*. This distribution was consistent with historical records (Figures 6a, 7).

Brachiopods, *Terebratulina septentrionalis*, were found live infrequently at two of the five sample sites during post quadrat sampling reconnaissance surveys only: Crow Neck and Outer Birch Island (Table 1). A shell of this species was found in one sediment sample taken from West Quoddy Head. The distribution of *T. septentrionalis* at West Quoddy Head and Outer Birch Island was not documented previously (Figures 5b and 6a, respectively). Quantitative population densities were not estimated, since this species did not occur within quadrats at any sample location. They were discovered at Crow Neck and Outer Birch Island only with intense, intentional, directed searching when time permitted, i.e. at the end of the field season when quadrat sampling at all sites had been completed. *T. septentrionalis* was found on the undersides of only two out of eight large boulders at Crow Neck; one boulder had 11 lampshells attached to its underside and another 16. This patchy distribution was similar to historical documentation on the occurrence of this species in the Crow Neck Critical Invertebrate Area (Table 3). On Outer Birch Island, only a single *T. septentrionalis* was found, attached to the underside of a boulder. It was photographed and marked for future reference.

Five target species were found within sample transects at various locations, but their abundance was not quantified using adaptive cluster sampling (Table 2). Three were infaunal bivalves found in sediment samples, i.e. the suspension feeding *Musculus discors*, *M. niger* and *Astarte* complex, and the fourth was the gastropod *Lacuna vincta*, a grazer, that did not have a clumped distribution. To summarize, eight of the 12 target species selected for study were found among the five Critical Invertebrate Area sample sites. However, only one of these, *Margarites helicinus*, was found in quadrat samples with distributions appropriate for estimating population density using adaptive cluster sampling.

Margarites helicinus

Abundance of *Margarites helicinus* differed markedly from documented qualitative estimates by Gilbert (1977a) that scored smooth top shells as “abundant” at Wilbur Neck (Table 3). Differences in densities among these sites were most apparent when the total number of snails, counted using adaptive cluster sampling was compared. Within 50 m^2 sample transects, totals ranged from 2 at Wilbur Neck to 320 at West Quoddy Head. Mean density among sites broke into two groups according to broad geographic location: (1) greatest outside Cobscook Bay; West Quoddy Head, and (2) lowest inner Cobscook Bay; Outer Birch Island, Wilbur Neck and Crow Neck (Table 4). The occurrence of this species within sample sites followed patterns documented in historical reference data, with the exception of Gleason Point where it was absent, and West Quoddy Head where it was found (Figures 5–7). Among sample sites, *M. helicinus* was present in all transects except at Gleason Point (Table 1).

Smooth top shells were found associated most frequently with the macroalgal fucoid, *Fucus evanescens*, a species common to quiet harbours, though occasionally found on more exposed points, near or below low tide (Taylor 1976). At West Quoddy Head, *M. helicinus* was associated with a more diverse assortment of algae that included the red, *Porphyra miniata.*

Discussion

Faunal diversity of the Critical Invertebrate Areas in the Cobscook Bay region, specifically those in the inner bay complex, was remarkably poor compared to the rich, diverse communities expected from historical baselines generated by the Critical Areas Program. This was most apparent at Crow Neck that had the best historical record (1968–1980) of all study locations for comparison with quadrat samples. Fewer than half of the documented, ecologically notable species were found in quadrat and substrate samples from Crow Neck in the present study. While not directly comparable, because subtidal communities were studied, no change was seen over a similar time frame among three stations also located in the Quoddy region (Wildish and Pohle 2005). These St. Croix stations, located in neighboring Passamaquoddy Bay, were sampled in 1974 and 2000 where no or few anthropogenic influences were present.

The absence of target species selected for study at sample locations, where these species were distributed historically, is evident also from qualitative comparisons of densities. Changes in abundance of at least one target species is reflected by the diminished presence of the smooth top shell, *Margarites helicinus,* now a minor part of the intertidal communities of the inner bay complex Critical Invertebrate Area sample sites. The first reports describing the density of this species were based on a qualitative measurement relating effort to abundance, i.e. the number of individuals found at low tide on a walk through the intertidal zone (Gilbert 1977a). Based on this relative measure of abundance, Wilbur Neck had an 'abundant' population of snails (>25 snails found at low tide) that were also 'common' (10–25 snails found at low tide) on Outer Birch Island (Table 3). Twenty-five years later, the Wilbur Neck populations have dwindled to rare and infrequent occurrences requiring intensive sampling to find any snails, e.g., the two snails found during the present study. Differences in abundance from the historical record are underscored by the nearly equal effort in search times for both field studies. In the present study, smooth top shells were most abundant at West Quoddy Head, which suggests seasonality in reproduction cannot explain the observed low population densities within Cobscook Bay. Insufficient sampling is a doubtful cause for low estimates, although species area curves indicate Outer Birch Island was under sampled, but West Quoddy Head was also undersampled.

A similar interpretation of abundance of the brachiopod, *Terebratulina septentrionalis*, another target species, is problematic. Since they were absent in quadrat samples, population densities were not estimated with adaptive cluster sampling. Brachiopods were found during intensive searches directed at finding this species at Crow Neck post faunal transect quadrat sampling. The patchy distribution of *T. septentrionalis* matches descriptions written as long as 26 years previous (Speel 1978; Weiss 1980) and resembled the clumped spatial pattern that characterize brachiopod distributions in general (Noble et al. 1976). Any reasonable population estimates of this species would require disruptive sampling that could damage this habitat extensively, a concern already raised by Weiss (1980). For this reason, adaptive cluster sampling was not executed after discovering brachiopods.

The gaper clam, *Mya truncata*, was not found at Gleason Point that Gilbert (1977b) registered as a Critical Invertebrate Area because of the occurrence of this species. Our second survey completed one year after this present study, and directed at the exact area marked in her hand drawn archived map, did not find any *M. truncata* again. In a letter, Gilbert (Maine State Archives, File 371) raised the possibility that she could have mistaken *M. arenaria* for *M. truncata* during the field evaluation that the registration of Gleason Point rested on (Table 3). Her doubts of the initial identification of this species were expressed in this letter to Hank Tyler, Senior Planner, after finding "lots of truncated *Mya arenaria*" at Gleason Point in August 1977. Environmentally induced resemblance in shell form between these two species can result in similarities that require examination of the pallial sinus and hinge tooth as differentiating characters (Foster 1946). The results of our two surveys, combined with Gilbert's questionable identification, casts reasonable doubt on the presence of *M. truncata* at Gleason Point.

Gaps in the historical record of faunal distributions within critical areas are less likely the result of inadequate sampling effort than absence of species from these sample sites. Sampling effort can be defined by the amount of time invested in search of species at a location. Most historical critical area evaluations were conducted during a single visit during one low tide. This is comparable to the initial sample site reconnaissance employed in this study. If the number of observers searching is considered, in addition to sampling time, then sampling effort was greater in the present investigation, i.e. three observers versus two at most in critical area evaluations. The added blocks of time (40–50 min) represented by quadrat sampling of transects during this re-evaluation accents its greater sampling effort.

Species area curves convincingly illustrate adequate sampling at most locations, making sampling error an unlikely explanation for species absence (Figure 3). Intentional searches outside of sample transects did produce positive records for only two species, *Neptunea lyrata decemcostata* and *Terebratulina septentrionalis*, pointing out that the chance effects of sample transect overlap with natural distributions of particular species can result in false scores of species absence. Reconnaissance prior to sampling for positioning sample transects was intended to reduce this possibility. Species distributions can be influenced by natural fluctuations in abundance, both seasonally and inter-annually, and were given consideration *a priori* to sampling. Pronounced seasonal variation is known to occur in subtidal habitats in Maine, with the highest number of species found during the summer months (Ojeda and Dearborn 1989). The possibility that changes in distributions could result from seasonal reproduction and recruitment of target species was minimized by sampling protocols. To maintain congruency with reference to time, locations were sampled in the same season and within 30 days from the month when each critical area had been evaluated. The presence of target species at some locations and absence at others sampled within weeks of each other supports the idea that seasonal reproduction and recruitment was not a contributing factor to the observed changes in species distributions. To reduce the chance that species presence was the result of a random set of larvae, recently settled animals were excluded from quadrat observations by including only individuals easily seen, i.e. distinguishable to the naked eye. This increased the chances that only established populations were recorded and also reduced the chance that density estimates would be inflated.

Inter-annual variations in occurrence could be argued as an explanation for the absence of target and other species, since this study was conducted over only one summer season. Some account for this can be made indirectly by considering longevity of some of the target species, since only adult, established populations were surveyed. Gaps in the presence of species among previous critical area evaluations could address the likelihood that inter-annual variability accounts for their absence in this study. Among target species not found in quadrat samples, longevity is unknown but might be estimated from congeners and related species. *Musculus niger* could have a life span similar to the 2–5 years for *M. discors* (Tyler-Walters 2001) and, likewise, *Mya truncata* to *Mya arenaria* with a life span of 10–20 years (Tyler-Walters 2003). Among the Buccinidae (*C. stimpsoni*, *N. lyrata decemcostata*), *Neptunea antiqua* is known to live up to 10 years and considerably older in colder waters (Pearce and Thorson 1967). Longevity for species of sun stars or the brachiopod, *T. septentrionalis,* could not be found, although, respectively, *Asterias rubens* can live 7–8 years (Budd 2001) and the brachiopod *Neocrania anomala* from 5–10 years (Jackson 2000). Many of these target species were recorded during all previous critical area evaluations made at intervals of 2 to 10 years for up to 12 years. This persistence suggests that inter-annual variability during these years was not a major factor influencing the presence of target species.

Most species historically present were not found during the present investigation 22 years after their last recorded appearance. Did they actually disappear or is this a result of interannual variability? To help answer this, found target species need to be considered, and the two rediscovered in the present study have longevities of 2–5 years for *Musculus discors* (Tyler-Walters 2001) and <1 year for *Lacuna vincta* (Jackson 2003). Both species were recorded by evaluations 22 years earlier, and *L. vincta* twice by earlier evaluations made four years apart. While inter-annual variability can influence species occurrence, it does not seem to account for species absences in this study. If it were a major factor determining presence or absence of persistent fauna, then the rediscovery of these two species with such short life spans would be less likely.

Other components of the sampling design also reduced possible confounding influences on species density estimates from movement of individuals within sample transects. Many of the species selected for study are motile, which could potentially result in inaccurate estimates of species densities if data collected on different days were combined. This error was reduced by sampling transects synoptically within one low tide interval, which also matched the time frame used for relative abundance estimates in historical evaluations (Gilbert 1977a). Without doubt, explanations for species absence based in natural variation of seasonal abundance and inter-annual variation cannot be eliminated totally without annual, long-term seasonal monitoring lasting for many years (Davidson 1934; Lacalli 1981). In spite of this limitation, surveys similar to this investigation can be valuable in assessing changes in species distributions (Cohen et al. 1998).

What has happened in the last 20 years that caused the decline in diversity of species historically present intertidally, and the faunal shift observed in this study? One idea worth exploring is the possible effects of disturbance resulting from siltation of suspended sediments which could have produced the coatings of fine mud found covering surfaces of algae and rock. Changes in substrate characteristics resulting from siltation can have a direct effect on community composition through recruitment. Invertebrate larvae that actively select habitats for settlement may not prefer surfaces modified by sediment deposition (Butman and Grassle 1992; Crisp 1976; Pawlik 1992; Woodin et al. 1998) and will not recruit, while larvae of other species that do prefer this habitat will settle and replace the former. Once established, new colonizing species can enhance sedimentation through bioresuspension and biodeposition (Rhoads and Young 1970; Graf and Rosenberg 1997) and further inhibit colonization of previously established fauna. Increased suspended sediments can also decrease the survivorship of sessile, filter-feeding fauna including ascidians, bryozoans and sponges (Bakus 1968; Naranjo et al. 1996; Turk and Risk 1981; Zühlke and Reise 1994). These phyla were minor components of the intertidal communities surveyed by this study.

Patterns of sedimentation in Cobscook Bay must have been altered if siltation is a reasonable explanation for the observed change in faunal composition. Present day community composition is characterized by the absence of species historically distributed intertidally, and now dominated by mussels. Mussel beds cause significant siltation and modification of substrates in two ways. They increase sedimentation of suspended solids through hydrodynamic effects that result from turbulence created in the benthic boundary layer by the physically rough form of these aggregates (Butman et al. 1994; Fréchette et al. 1989). In addition, sediment composition can change from biodeposition of feces and pseudofeces by mussels and modify diversity through benthic macrofaunal succession (Dittmann 1990; Mattsson and Lindén 1983).

Mussels were not reported at Wilbur Neck and for Crow Neck earlier than 1980, but were found by this survey to be ubiquitous and often dominant species among all sample sites in Cobscook Bay. Greater abundance of mussels could have enhanced siltation, and recent work on the species composition of mussel beds in Cobscook Bay might help to explain population changes. Mussel beds in Cobscook Bay are of mixed species composition of *Mytilus edulis* and *M. trossulus* and their hybrids (Rawson et al. 2001, 2003). Frequencies of *M. trossulus* in mussel beds can vary from approximately 97 percent at Gove Point to 46 percent at West Quoddy Head (Rawson et al. 2001). In Newfoundland, Toro et al. (2002) found this species becomes mature at smaller sizes, has a higher reproductive output, and spawns over a much longer period of time (late spring to early autumn) than *M. edulis* (2–3 weeks in July). If reproductive capacity of *M. trossulus* is also high in Cobscook Bay, the combined effects of increased recruitment events facilitated by removal of grazers known to decrease mussel recruitment, e.g., *Littorina littorea* (Bertness et al. 1999; Petraitis 1987), might explain the current patterns of greater distribution and abundance of mussel beds. Massive recruitment of *Mytilus edulis* has occurred across a 125-km-long coastline in the southwest Gulf of Maine in 1995 (Witman et al. 2003). Recruitment on this scale has not been documented in the northern Gulf of Maine but, since the 1995 event, increased mussel recruitment has been reported at two offshore sites in the Gulf of Maine (Harris et al. 1998) and during the summer of 2000 in Long Island Sound, Narragansett Bay, and Isles of Shoals, Gulf of Maine (see Witman et al. 2003).

Mussel beds might be considered unexpectedly persistent, in spite of possible heavy predation by the invasive European green crab, *Carcinus maenas*. Green crabs were found by the present study to be very abundant in Cobscook Bay, and mussels are commonly eaten by this species (Bertness et al. 1999). Mussel clumps can also increase habitat availability for recruiting green crabs, with known impacts on community trophic structure and faunal diversity (Thiel and Dernedde 1994). A positive feedback between recruitment of mussels and green crabs would eventually limit mussel populations through increased predation, quite opposite of what was observed by the present investigation. However, the lower energy yield of *M. trossulus* mussels that contain less meat (Freeman et al. 1994) could make them less preferable prey for green crabs that maximize energy in their diet by selective predation (Elner and Hughes 1978). If green crabs can discriminate between the two species of mussels based on sensory cues, the current species composition of mussel beds (Rawson et al. 2001) could also be the result of selective predation on more energetically profitable *M. edulis,* and not solely a result of higher recruitment of *M. trossulus*. In addition, since predation by green crabs on periwinkles is well known (Lubchenco and Menge 1978, Trussell 1996), an increase in this predator's abundance would indirectly facilitate mussel recruitment by removing these grazers from intertidal communities (Petraitis 1987).

Sources of suspended solids in Cobscook Bay are worthy of examination if siltation facilitated by mussel beds has contributed towards changing intertidal communities. Potential sources of input are rivers and streams, erosion due to rising sea level, and sources outside of Cobscook Bay, i.e. Passamaquoddy Bay, upper Bay of Fundy. The most parsimonious explanation for sources of suspended sediments would not require the examination of inputs of particulates from various sources outside Cobscook Bay, but would rely instead on resuspension from within the Bay. Expansive plumes of sediments stirred up by scallop-dragging vessels are evident in aerial photographs in Brooks et al. (1997). The intensity of dragging for scallops has historically been high because Cobscook Bay was one of the most productive scalloping areas on the Maine coast. The suspension of large amounts of sediment from urchin dragging in autumn attenuates light enough to make Cobscook Bay light limited in respect to phytoplankton production (Phinney et al. 2004). Dredges used to harvest sea urchins undoubtedly create similar plumes.

The degree of resuspension of sediments from dragging for scallops and sea urchins would be cumulative and vary according to fishing intensity, although the duration and overlap of open season for each fishery would contribute additional combined affects. Licencing regulations control the number of boats dragging for each species and are more stringent on urchin than scallop draggers. New licences for urchin dragging have been issued by lottery since 1998, but the licencing of scallopers is unrestricted. Unlimited licencing has resulted in startling numbers of scallop boats appearing on opening day, with more than 200 scallopers working the Bay for the first two weeks of the season in 1989, and 178 boats appearing on opening day in 2001 (DMR, personal communication). Fewer boats were seen since 2001, due to changes in regulations that have made dragging less profitable for large boats working the Bay from outside the region. Currently, nearly 100 people in towns neighbouring Cobscook Bay are licenced to drag or dive for scallops. While fewer boats harvest sea urchins than scallops, because of regulated licencing, the duration of open season for urchin dragging was much longer prior to 2004 and overlapped the shorter six-month scallop season. When this fishery first started in earnest during 1987, urchin dragging had no closed season, i.e. harvesting was year round. The first season restriction was imposed in 1993, closing the fishery for nearly three months, and then for approximately five months in 2003. Currently, the open season for 2004–2005 is only 45 days. Fishing effort for urchins is difficult to reconstruct because of the methods by which catch data were collected, but during the 2002-03 season, of the 48 draggers licenced, 37 fished the Bay at least ten times.

Increased amounts of suspended sediments, with redistribution dependent on circulation patterns in the Bay (Brooks 2004; Kelley and Kelley 2004), could result in the deposition observed at all of the inner bay complex, Critical Invertebrate Area sample sites. The decrease in predator populations rather than the increase observed by Witman et al. (2003) following massive recruitment of mussels could be the difference between sedimentation patterns within a bay complex versus an exposed open coast where transport away from the shore can take place. Sediments are more likely to remain within the Bay because of long residence times (Brooks 2004) and be trapped by mussel beds. In addition, the adhering veneer of fine sediment coating all surfaces at the inner bay locations could be created by biostabilization of the resuspended silt by microphytobenthos (Friend et al. 2003; Stal 2003). Elevated standing stocks found within the inner bay (Phinney et al. 2004) where residence time increases (Brooks 2004) would enhance this process. Removal of herbivorous snails by predation and the commercial fishery for *Littorina littorea* would eliminate the growth-limiting effects of grazing on microphytobenthos and associated biofilms. Over time, veneers of fine sediment, such as those found during this study, would coat surfaces normally cleared by grazing snails.

The influence of sedimentation of solids suspended through commercial dragging activity on community diversity in Cobscook Bay deserves further study. Inhibition of recruitment of historically important species on substrates altered by sedimentation in the Cobscook Bay ecosystem must be a concern if the diversity of species historically present is to be conserved. The paradigm suggested as an explanation for the observed faunal shift is based on the cumulative effects of hydrodynamically facilitated sedimentation by *M. trossulus*/*M. edulis* mussel beds of 'recent' appearance and trapping of suspended solids on biofilms. Predation by green crabs may have indirectly accelerated these processes in two ways: (1) by reducing the abundance of blue mussels, *M. edulis,* and (2) reducing the abundance of grazing gastropods. Commercial harvest of periwinkles, *L. littorea*, would contribute towards the latter. Considerable changes in seascapes would be the overall result, with loss of habitat for species found in the previously unique intertidal communities of Cobscook Bay and potentially some currently harvested, commercial species such as scallops. The destabilizing effects of siltation and altered species recruitment could explain at least some of the significant changes in community structure observed over the past 20 years in Cobscook Bay.

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Table 1. Target species assigned ecological significance in historical reference information for the five Critical Invertebrate Area sample sites in the Cobscook Bay, Maine region. The current distribution of each species is indicated by presence (+) or absence (–) for each sample site. Critical Invertebrate Areas were registered based on the presence of the species that abbreviations appear next to.

Species	West Quoddy Head	Gleason Point	Outer Birch Island	Wilbur Neck	Crow Neck
Margarites helicinus (BI, WN)	+	-	+	+	+
Colus stimpsoni (CN)	-	-	-	-	-
Neptunea lyrata decemcostata (CN)	-	-	+ [1]	-	-
Lacuna vincta (CN)	+	-	-	+	+
Astarte complex (CN)	-	+	-	-	+
Mya truncata (GP)	-	-	+ [+]	-	+ [+]
Musculus discors (CN)	+	+	+	-	+
Musculus niger (CN)	+	-	-	-	-
Priapulus caudatus (CN)	-	-	-	-	-
Terebratulina septentrionalis (CN)	[+]	-	+ [1]	-	+ [1]
Solaster endeca (CN)	-	-	-	-	-
Solaster papposus (CN)	-	-	-	-	-

Abbreviations: Gleason Point (GP); Wilbur Neck (WN); Outer Birch Island (BI); Crow Neck (CN); shell [+]; [1]observed during post quadrat sampling reconnaissance.

Table 2. Habitat classification of the five Critical Invertebrate Area sample sites in the Cobscook Bay, Maine, region according to the Brown (1993) habitat classification system of benthic intertidal habitats in marine ecosystems.

Sample Site	Substrate (%)						Brown Classification
	Rock	Boulder	Cobble	Gravel	Sand	Mud	
West Quoddy Head	61	16	11	3	10	0.4	Rock: Partially-exposed
Wilbur Neck	0.25	28	20	35	2	15	Mixed-coarse and fine: Protected
Crow Neck	1	4	4	51	0	40	Mixed-coarse and fine: Semi-protected
Birch Island	43	17	21	15	0.31	4	Mixed-coarse: Semi-protected
Gleason Point	0	35	23	24	18	0	Mixed-coarse: Semi-protected

Table 3. Locations and the relative abundance of macroinvertebrate species at the five Critical Invertebrate Area sample sites in the Cobscook Bay, Maine, region on which registration of each area was based on (Maine State Archives).

Sample Area	Species	Common Name	Faunal Affinity	Relative Abundance
Outer Birch Island[1]	*Margarites helicinus*	Smooth Top Shell	epifauna	common (10 - 25 snails found at low tide)
Wilbur Neck[1]	*Margarites helicinus*	Smooth Top Shell	epifauna	abundant (> 25 snails found at low tide)
Gleason Point[2]	*Mya truncata* ?	Gaper Clam	infauna	large, healthy population but questionable ID
West Quoddy Head[3]	high species diversity area	Species complex	epi- and infauna	no data
Crow Neck[4]	*Terebratulina septentrionalis*	Lampshell	epifauna	rare to moderately common, patchy*

[1]Gilbert 1977a; [2]Gilbert 1977b; [3]Doggett et al. 1978; [4]Weiss 1980. *one isolated patch with high density of 100/m^2 (Weiss 1980)

Table 4. Mean densities (mean ± 95 percent confidence interval) per quadrat ($0.1m^2$) of smooth top shells, *Margarites helicinus*, determined by adaptive cluster sampling in 50 m^2 transects at the five Critical Invertebrate Area sample sites in the Cobscook Bay, Maine region (N = total number of snails counted within each transect)

Location	N	Mean Density
Outer Bay Complex		
West Quoddy Head	320	$0.61 \pm 2.77 \times 10^{-1}$
Gleason Point	0	0.0
Inner Bay Complex		
Birch Island	17	$0.08 \pm 7.99 \times 10^{-4}$
Crow Neck	6	$0.02 \pm 2.34 \times 10^{-2}$
Wilbur Neck	2	$0.01 \pm 2.03 \times 10^{-3}$

Figure 1. Cobscook Bay, Maine region indicating Critical Invertebrate Area sample sites

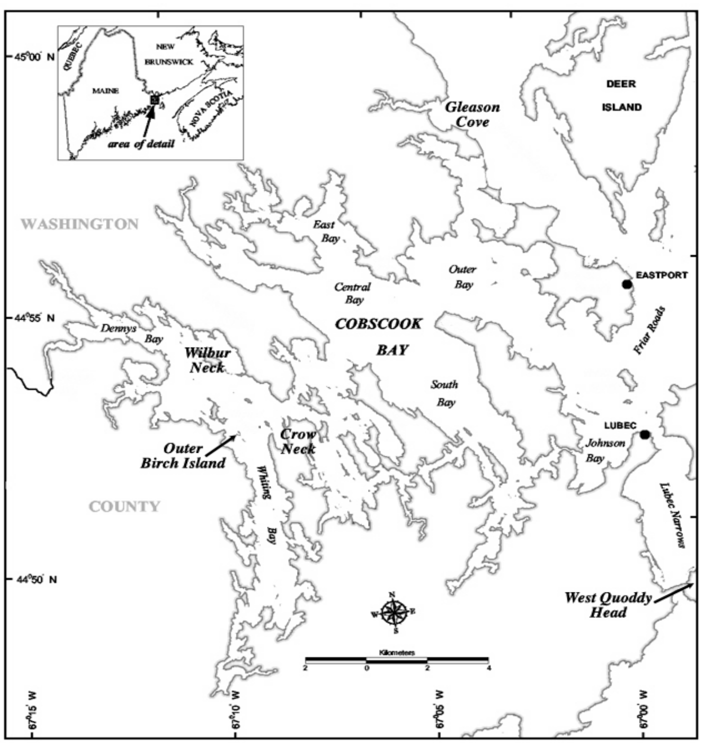
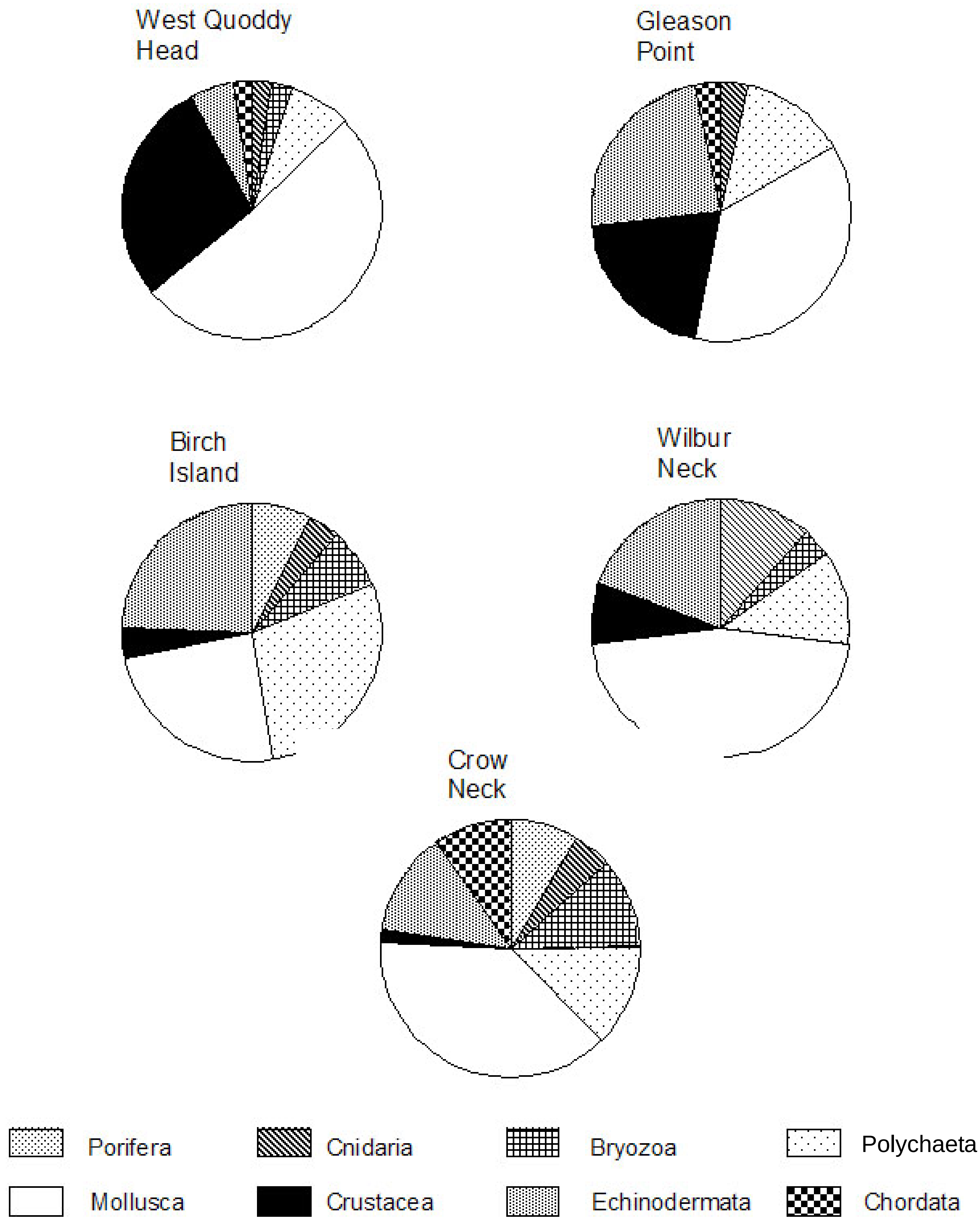


Figure 2. Community composition by percentage contribution of major phyla represented at each Critical Invertebrate Area sample site in the Cobscook Bay, Maine, region



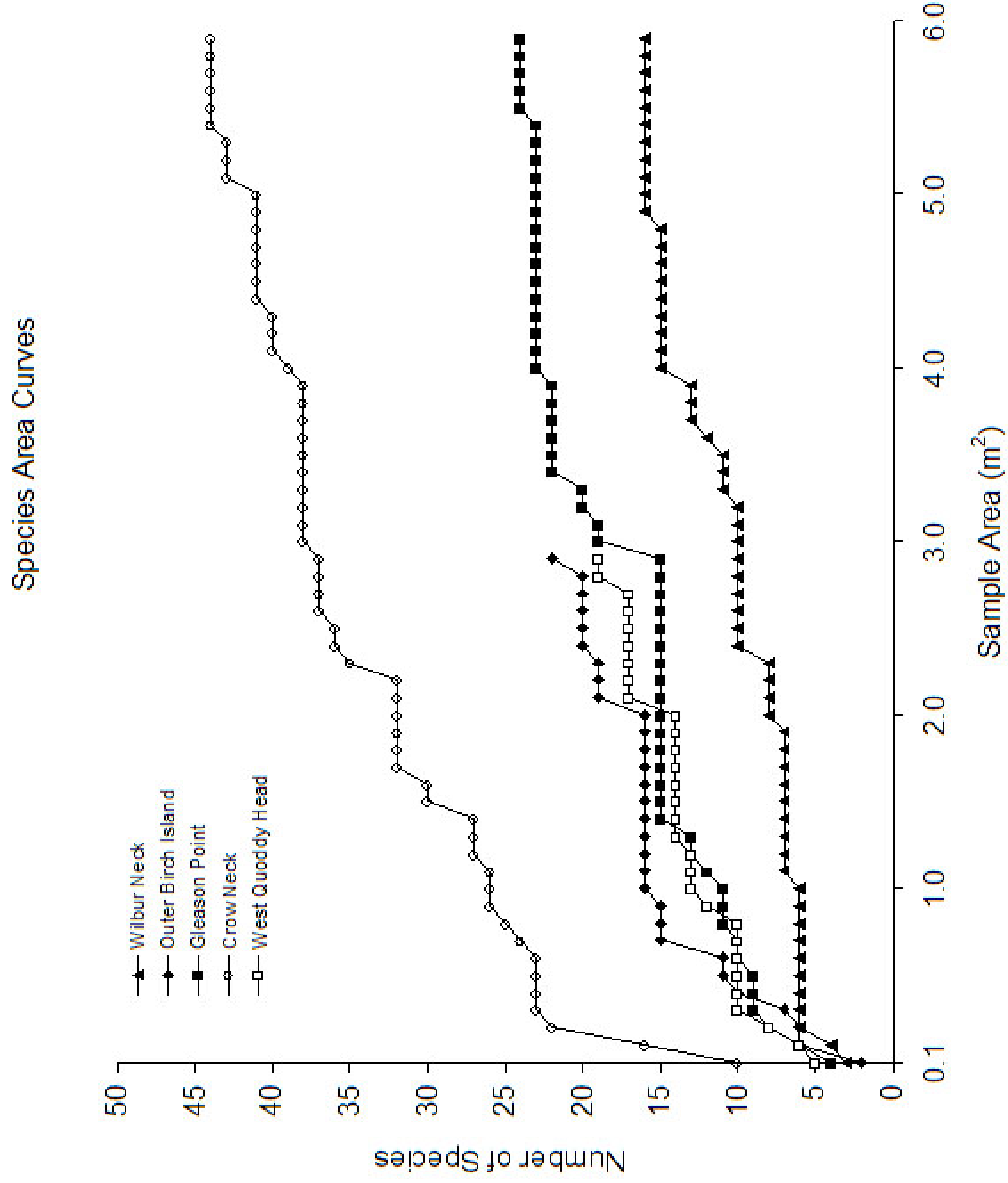
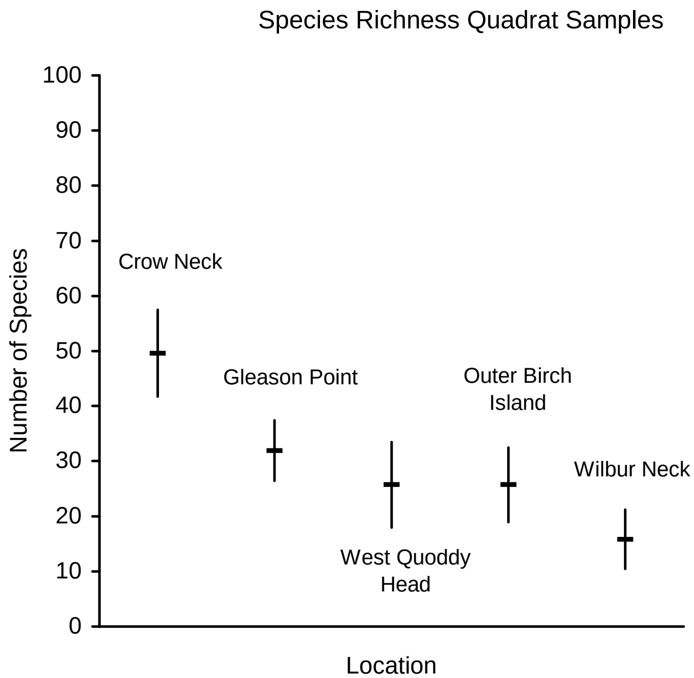


Figure 3. Species-area curves for the five Critical Invertebrate Area sample sites in the Cobscook Bay, Maine, region

Figure 4. Species richness of (a) quadrat samples, and (b) substrate samples from the Critical Invertebrate Area sample sites in the Cobscook Bay, Maine, region

a)



b)

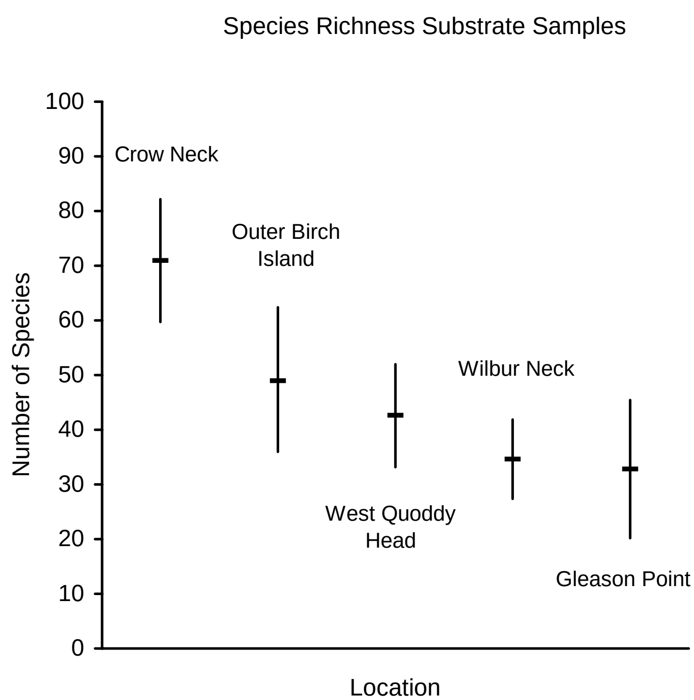
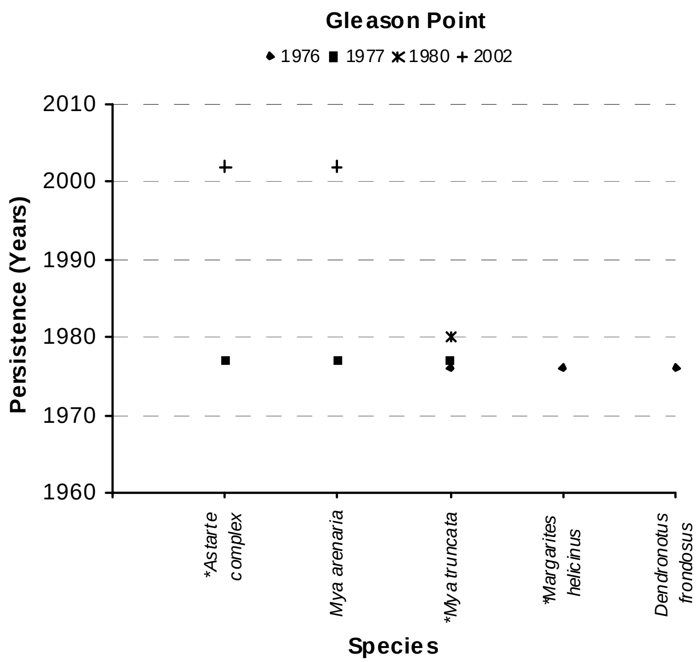


Figure 5. Historical records of target species (*), including those identified in previous Critical Invertebrate Area evaluations at (a) Gleason Point, and (b) West Quoddy Head, outside Cobscook Bay, Maine

a)



b)

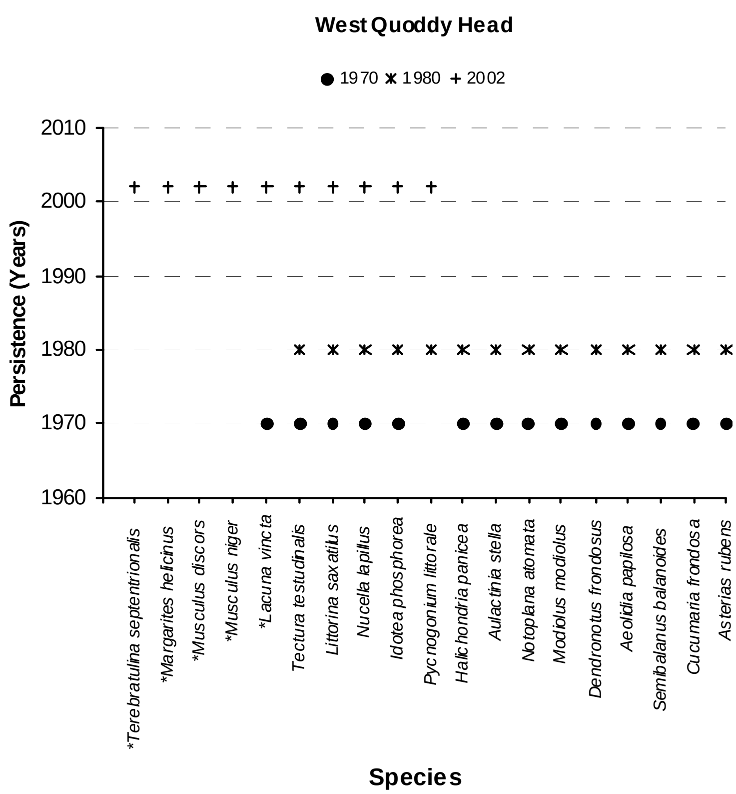
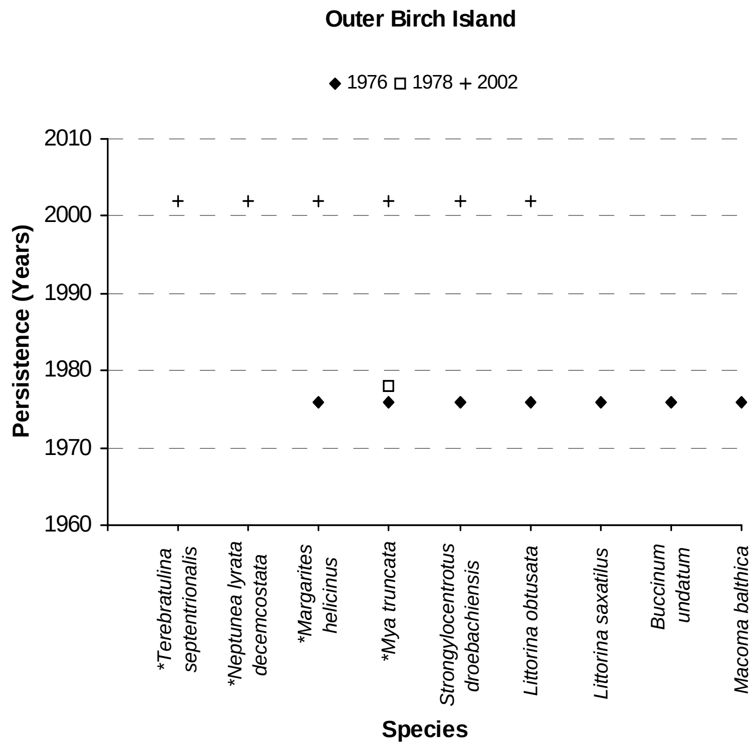


Figure 6. Historical records of target species (*), including those identified in previous Critical Invertebrate Area evaluations at (a) Outer Birch Island, and (b) Wilbur Neck, inner Cobscook Bay, Maine. Shells not included.

a)



b)

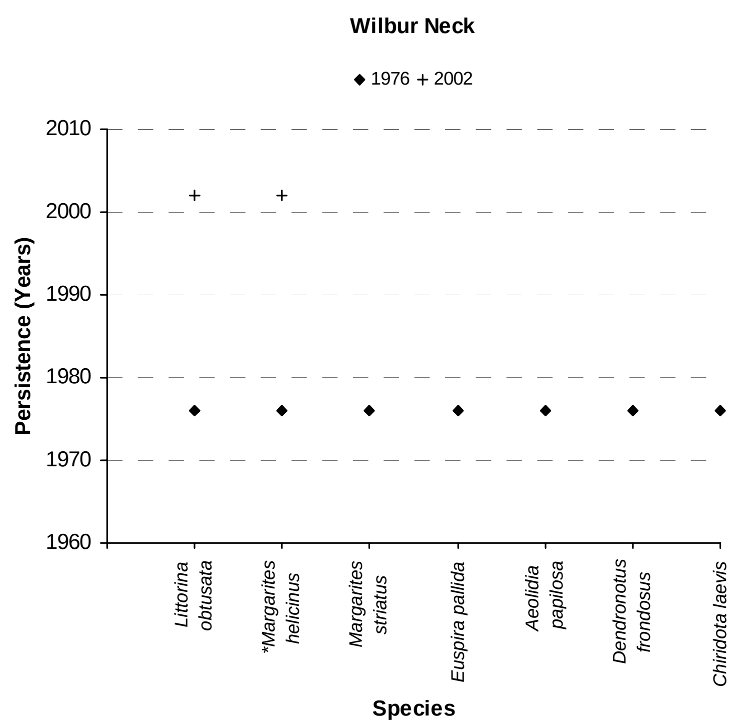
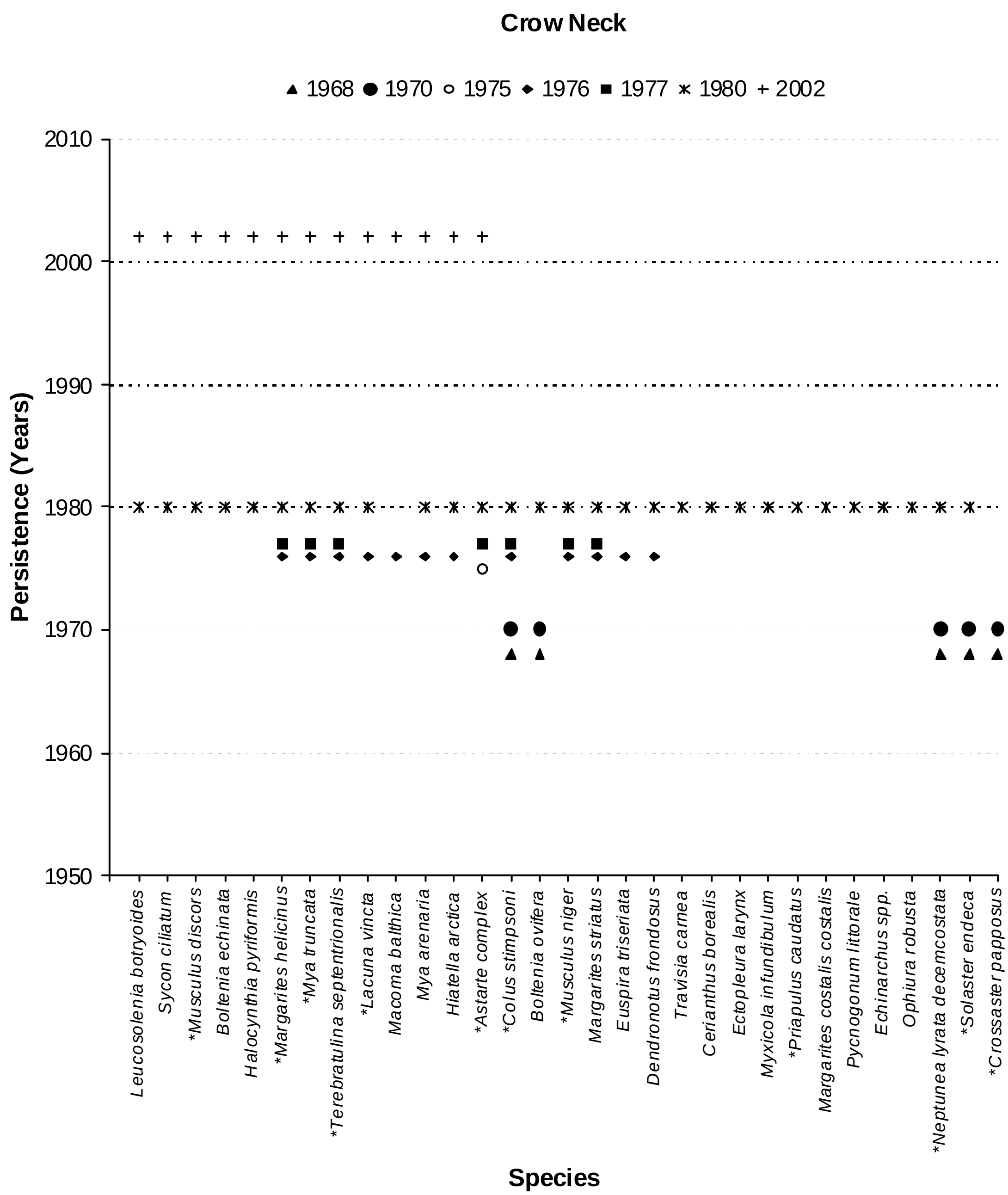


Figure 7. Historical records of target species (*), including those identified in previous Critical Invertebrate Area evaluations at Crow Neck, inner Cobscook Bay, Maine



BIODIVERSITY AND OBSERVATIONS ON THE SUBTIDAL MACROBENTHOS OF COBSCOOK BAY, MAINE

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Abstract

Cobscook Bay, a boreal, macrotidal embayment in the northeastern Gulf of Maine, is noted for its species richness and has been the site of extensive natural history investigations. Early zoologists recognized the remarkable biodiversity, and a significant portion of the collection and taxonomic description of North American marine fauna, was centered in this region. This early work will be summarized briefly. In spite of this level of investigative activity, however, no quantitative surveys of the subtidal, macroinvertebrate communities of Cobscook Bay exist. We present the results of a 1975 limited benthic grab survey of outer Cobscook Bay, an area of recent salmon aquaculture and port development. The 11-station survey resulted in the identification of 172 taxa. Densities ranged from 870 to 12,970 m^{-2}. Multivariate and qualitative analyses clearly dissected the station set into sandy cove stations and gravel channel stations. Cove stations were characterized by burrowing and tube-dwelling infauna while channel station fauna was epifaunal. Community distribution is controlled by strong tidal currents and resulting sharp geological discontinuities. Because 70 percent of the Bay bottom is floored by gravel, the epifaunal community characterizing the channel stations may be the most representative of the Bay. The grab sampler certainly underestimated large filter feeders that may be important in the nutrient budget of the Bay. Future surveys need to be more extensive, and use a combination of sampling methods to quantitatively describe all components of the community.

Introduction

The Gulf of Maine ranks among the world's most productive and rich marine ecosystems. Many of the Gulf's most remarkable examples of dynamic physical processes, species richness, and natural abundance are concentrated in the northern Gulf of Maine around the mouth of the Bay of Fundy. The region contains North America's only boreal, macrotidal estuaries, which include some of the least impacted estuaries in the United States. Cobscook Bay is a preeminent example of such an estuary.

The biodiversity of Cobscook Bay was recognized early and much of the Northwest Atlantic invertebrate fauna was first described from here (e.g., Verrill 1871; Webster and Benedict 1887). In subsequent decades, Cobscook Bay became a collecting destination for professionals and student groups, which has produced a solid qualitative database of the macroinvertebrates (Trott 2004). Additional information on invertebrates was generated during investigations related to fisheries, tidal power development, oil refinery proposals, and salmon aquaculture monitoring (Larsen and Webb 1997). Nevertheless, no quantitative investigations of the subtidal macrobenthos of Cobscook Bay are available in the published literature. In this communication, we present a brief overview of the biodiversity of the region followed by the results of a 1975 preliminary macrobenthic sampling survey in outer Cobscook Bay. The stations occupied are in the precise location of subsequent salmon aquaculture operations and port development (Sowles and Churchill 2004).

Physical Environment

Cobscook Bay is located in extreme eastern Maine on the US-Canadian border near the mouth of the Bay of Fundy (Figure 1). Together with Passamaquoddy Bay and the enveloping islands, the area is known as the Quoddy region. Cobscook Bay is a rock-framed, glaciated, tidally-dominated estuary (Kelley and Kelley 2004). The large tidal range, with a mean value of 5.7 m, is a dominating ecological forcing function. Fresh water input is small, <1 percent of the intertidal volume, whereas the tidal flow over the narrow outer portion of the Bay where our study area is located, is equivalent to the mean outflow of the Mississippi River over the duration of both the ebb and flood tides (Brooks et al. 1999). Peak current speeds are on the order of 2 m/sec. Mean depth of the outer bay is about 30 m, with pockets to about 45 m. The well-mixed nature of the tidal waters results in moderated seasonal ranges of temperature and salinity. Mean temperature variation is less than 10^{o}C, while salinity variation is only about 1 ppt (Shenton and Horton 1973). More information on the Cobscook Bay region can be found in the comprehensive bibliography of Larsen and Webb (1997).

Brief Observations on Biodiversity

The eastern Gulf of Maine and the Quoddy region have long been known for their high species richness (Stimpson 1853). Deep, early and continuing interest in the region is evidenced by the establishment of the St. Andrews Biological Station, the Huntsman Marine Science Centre, and the Friedman Field Station of Suffolk University. In addition, generations of university classes have made annual pilgrimages to the region. On the United States side of the border, much of the northeastern marine fauna has been described from specimens collected in Cobscook Bay. Fully one third of the invertebrate specimens formerly housed in the collection of the Marine Biological Laboratory at Woods Hole, MA, were from Cobscook Bay (Larsen and Doggett, unpublished).

The US President appointed a Commissioner of Fish and Fisheries in 1871 at the direction of Congress. The purpose was to investigate the diminution of fisheries. The Commissioner assembled a multidisciplinary team of America's most eminent scientists who, after an initial year of investigation in the Woods Hole region, began the first significant US investigation of the Cobscook area in 1872. This effort established the species richness of the area and lead to the description of many species new to science.

A principal contributor to the US Fish Commission efforts in the Cobscook vicinity was A. E. Verrill. Verrill was a Maine native who became the first professor of zoology at Yale University. He was a prolific naturalist who described species ranging from hydroids to the giant squid. He also was quick to recognize the biodiversity of the Quoddy region and in 1871 he wrote: "The number and variety of marine animals that can be collected at low water within a few minutes walk of Eastport is really surprising to persons accustomed to collecting on other parts of the coast. Even under and among the lofty wharves a very respectable collection may be made, including at least 200 species, and representing nearly all the classes." Further early evidence comes from H. E. Webster and his colleagues who, in the 1870s and 1880s, dedicated their efforts to describing the annelid worms of the east coast of the United States. These worms usually dominate benthic communities in terms of numbers of species and individuals. The Eastport area proved to be the most diverse area, even though less time was spent collecting here than in the other regions. In just six weeks, Webster and Benedict (1887) found more annelid families, genera, species, and species new to science than were found in Virginia, New Jersey, and the Woods Hole region (Table 1).

More recently, compilations of invertebrate species lists by Linkletter et al. (1977), Trott (2004), Larsen and Doggett (unpublished), and others, indicate that roughly 1,500 benthic species occur in the Quoddy region. This is nearly twice the number of species found in the Chesapeake Bay (M. Wass, personal communication). Indeed, one may be able to make the case that, in terms of benthic invertebrates, the Quoddy region is the richest area in the western North Atlantic, north of the tropics.

Other evidence adds insight about the species richness of the region. Bousfield (personal communication 9/28/79) believes that about 100 macroinvertebrate species are unique to the area. This is indeed a high figure, but considering the high total number of species found, the fact that only 100 species are unique supports the conclusion that the species richness is high because so many widely distributed species populate the area, rather than because it is a pocket of endemism.

The Quoddy region is also notable because normally subtidal species can be found living intertidally. Bousfield and Laubitz (1972) mention 15 such species and data of Larsen and Doggett (unpublished) show that 98 species can be found in the intertidal east of Mt. Desert Island, most notably in Cobscook Bay, which are only found subtidally elsewhere. This phenomenon has attracted many collectors to the area who seek an efficient, inexpensive way to gather a large number of boreal and subarctic species for museum and university collections. The significance of some of these occurrences has been formalized as part of Maine's Critical Areas Program (Reports available from the Maine State Planning Office, Augusta, ME).

Several populations of marine invertebrate species in Cobscook Bay and the eastern Gulf of Maine exhibit giantism, i.e. attain unusually large size. Among these species are starfish, brittlestars, tunicates and sea urchins. The best known example is the common periwinkle that is heavily harvested in Cobscook Bay because its unusually large size, 2–3 times normal, makes it more marketable.

The convergence of high biodiversity, unusual ecological distributions and phenomena, and high productivity raises questions about the environmental forcing functions that established and maintain this seemingly unique ecosystem. An interdisciplinary, multi-institutional research program entitled "Developing an Ecological Model of a Boreal Macro-tidal Estuary: Cobscook Bay, Maine," funded by a grant from the A.W. Mellon Foundation to The Nature Conservancy, was undertaken to begin to address these questions. Initial results will be available soon in a special issue of the *Northeastern Naturalist* (Special Issue 2. In press).

Survey Methods

Eleven stations, located in the vicinity of Broad Cove, Shackford Head and Deep Cove in the eastern portion of outer Cobscook Bay, were sampled in 1975 with a 0.1 m^2 Smith-McIntyre grab (Figures 1 and 2). Multiple casts of the grab were often required to obtain the planned two replicates per station because of the coarseness of the sediments and/or bedrock outcroppings. In spite of this effort, only one sample was recovered successfully from Stations 23 and 31. A small subsample was removed from the first grab at each station for use in sediment analyses. The contents of the grab samples were sieved on a 1.0 mm screen. The residue was fixed in a five percent buffered formaldehyde solution and later transferred to 70 percent ethanol. Surface water samples were taken for temperature and salinity determinations at Stations 29 and 32 at slack low water.

In the laboratory, the sediment grain size distributions were determined using nested series sieves based on the Wentworth scale. Particles in the silt and clay size range were negligible.

All organisms were removed from the sample residue, identified to the lowest practical taxonomic level using a low-powered dissecting microscope, and counted. Oligochaetes and colonial species were not treated quantitatively. Statistical analyses were completed with the aid of PRIMER software (Clarke and Warwick 1994) and standard diversity formulas (Margalef 1958; Pielou 1970).

Results

Abiotic Factors

Sediments ranged from very fine sand to granule, with a marked gradient from the inner cove stations to the main tidal channel (Table 2). Sediments at the four stations in interior of Broad and Deep Coves, i.e. stations 22, 29, 32 and 33, consisted of 79 percent or higher fine and very fine sands (Table 1, Figure 2). The outer stations along the tidal channel, 23, 25, 26, 27, 28 and 31, all were dominated by granule-sized particles, i.e. gravel and cobble. Station 24, with the sediment grain size mode in the medium sand class, was the only station not dominated by sediments on the ends of the observed grain size spectrum. Low water surface temperature and salinity measured at station 29 in Broad Cove were 12.5^{o} C and 31.98 ppt, respectively. Corresponding values at station 32 in Deep Cove were 11.0^{o} C and 31.95 ppt.

Species Composition

One hundred and seventy-two taxa from 12 phyla were identified from the 20 grab samples; 142 of them were identified to the genus or species level (Table 3). Annelids were the most diverse group with 59 putative species, followed by arthropods and molluscs with 47 and 44 taxa, respectively. Complete faunal data can be found in Larsen (2004).

Cluster Analysis

The dendrogram, based on a group-average sorting classification using the Bray-Curtis similarity measure on square root transformed species data, resulted in branching revealing a clear-cut spatial pattern (Figure 3). The primary dichotomy (A) separated stations into those in the tidal channel, stations 23, 24, 25, 26, 27, 28 and 31, and those in the coves, stations 22, 29, 32 and 33. Dichotomy B segregated station 26A, the only channel replicate containing no *Spirorbis borealis* (Larsen 2004), from the other channel stations. All other channel samples exhibited similarities in the 40-60 percent range. Dichotomy C separated station 29, containing the finest sediments, from the three mixed sand cove stations. Finally, both Deep Cove stations were separated from the outer, homogenous Broad Cove station 22 by dichotomy D. The sensitivity of the analysis was further reflected by the pair-grouping of replicates of five of the nine multiple replicate stations, i.e. stations 22, 24, 29, 32 and 33.

The biological relationships amongst the 20 samples were investigated further using a non-metric multidimensional scaling (MDS) ordination with the Bray-Curtis similarity measure calculated on square root transformed abundance data. The two-dimensional MDS ordination produced distinct separation of channel stations, 23, 24, 25, 26, 27, 28, 31, and cove stations, 22, 29, 32 and 33 (Figure 4), thus matching the cluster analysis results. The agreement of the classification and ordination was further reflected by the outlying positions of samples 26a, 29a and 29b. The goodness-of-fit of the two-dimensional ordination was measured by calculating a stress value. The observed stress value of 0.09 "corresponds to a good ordination with no real prospect of misleading interpretation" (Clarke and Warwick 1994). ANOSIM confirmed the strength of the analysis and yielded a Global R value of 0.577 at a significance level of p <0.2 percent.

One hundred and four putative species were found at the four cove stations, and 135 were identified from the seven channel stations (Table 3). Thirty-eight and 68 species were limited to the cove and channel stations, respectively, and 66 species were common to both areas. Fifty-three taxa were limited to a single station. Cnidarians, bryozoans and echinoderms, with the exception of the brittle star *Ophiura robustus*, were found only at channel stations. Other species which were found exclusively or more abundantly at the channel stations include the chitons *Lepidopleurus cancellotus* and *Puncturella noachina*; the limpet *Acmaea testudinalis*; the jingle shells *Anomia aculeata* and *A. simplex*; the cockle *Cerastoderma pinnulatum*, the gastropod *Margarites costalis*; and the scaleworms *Harmothoe imbricata*, *H. extenuata* and *Lepidonotus squamata*; the serpulids *Hydroides dianthus*, *Spirorbis borealis* and *S. spirillum*; the pycnogonids *Achelia spinosa*, *Nymphon hirtipes* and *Phoxochilidium* sp.; and the epifaunal pericarids *Aeginina longicornis* and *Melita dentata*. Few numerically important species were limited to, or had their centers of abundance at, the cove stations. These included the isopod *Edotia triloba*, the amphipods *Haploops spinosa*, *Leptocheirus pinguis* and *Unciola irrorata,* and the deposit feeding polychaete *Nephtys bucera*.

Community Structure

The numbers of species, density, informational diversity, and numerical dominance were measured at each station (Table 4). Numbers of species per station ranged from 28 to 70, with a mean of 50. Lowest number of species occurred at station 29, the most inshore station in Broad Cove that also exhibited the finest sediments (Table 2). The two single sample channel stations also exhibited below average numbers of species. The most species rich stations were located in Deep Cove.

Abundance ranged between 870 and 12,970/m^2, with an overall mean of 3,730 individuals/m^2 (Table 4). Lowest density was found at station 27. The other six channel stations exhibited similar densities, with a mean and standard deviation of 2,792 ± 497. The highest densities occurred at the outer cove stations, 22 and 33, which exhibited densities of 12,970 and 6,880 individuals/m^2, respectively. Unpaired t-tests indicated that there were no statistically significant differences for any of the community parameters between the cove and channel stations.

Discussion

This first published quantitative account of the subtidal benthos of the macrotidal Cobscook Bay is remarkable for the sharp faunal contrasts revealed over relatively short distances. Two distinct benthic communities, one occupying the cove stations and the other located at the channel stations, are clearly defined by both multivariate and qualitative analyses.

The four nearshore stations located in Broad Cove and Deep Cove are characterized by various grades of sand and are dominated by burrowing or tube-dwelling infauna. The highest densities encountered occur at the outer of the cove stations (stations 22 and 32) that have slightly coarser sediments, than the more landward inner stations (Tables 2 and 4). The outer, coarse-bottomed stations in the tidal channel have high species richness, with 135 taxa identified from only 12 grab samples. All channel stations are numerically dominated by epifaunal, filter feeding tube-worms of the genus *Spirorbis*. A study of the feeding habits of three coexisting chiton species in Deep Cove also emphasizes the epifaunal nature of the community (Langer 1983).

Cobscook Bay is a rock-framed, tidally-dominated estuary and the community distribution mirrors the geological parameters of the sites and the underlying physical forcing functions. Cobscook Bay is subject to a semi-diurnal M-2 tide with a mean range of 5.7 m (Brooks et. al. 1999). The relatively large tidal range combined with the shallow nature of the Bay results in the exchange of 38 percent of the high tide volume on each mean tide, which produces currents of up to 2 m/sec (Brooks 2004). These high tidal flows winnow out fine, landward-derived sediments and result in gravel being the most abundant seafloor material in each arm of the Bay (Kelley and Kelley 2004). Overall gravel and rock account for 70 percent of the subtidal bay bottom with 90 percent of the outer bay, 54 percent of the middle bay and 83 percent of the inner Bay being floored by gravel (Kelley and Kelley 2004). Kelley and Kelley (2004) also note the abrupt changes between the fine, landward sediments and the dominant gravel. The origin of the sandy sediments is the eroding bluffs at the interior of the coves, and the grain size increases toward the main tidal channel (Kelley and Kelley 2004).

The linkages between the physical and biological attributes are unusually clear in this energetic estuary. Overlying the modeled currents on the station map demonstrates the relationships between currents, sediments and fauna (Figures 5 and 6). The inner cove stations (29, 32) have the lowest current levels and the finest sediments most recently eroded from the bluffs. The outer cove stations have higher currents, slightly coarser sediments, and highest faunal densities. All cove stations are dominated by infaunal species. The channel stations (23, 24, 25, 26, 27, 28 and 31) experience high currents, are characterized by granule-sized sediments (Table 2, Figure 6) and are dominated by filter-feeding epifauna. Given that 70 percent of the Bay is floored by this sediment type (Kelley and Kelley 2004) and the very minor freshwater input that results in only very narrow ranges of temperature and salinity throughout the Bay (Brooks et al. 1999), the epifaunal community described in the vicinity of Shackford Head may be the most extensive subtidal community in the Bay. Further exploratory sampling is indicated.

The Smith-McIntyre grab is not ideal for sampling the coarse sediments occurring in the Bay; no sampler is ideal (Holme and McIntyre 1984). Larger and motile macrofauna may be missed or underestimated by the grab, and thus the exploratory results presented here are incomplete. This may be significant because a remarkable feature of the Cobscook Bay ecosystem is the degree that ammonium plays in the nutrient budget (Garside and Garside 2004). These authors conclude that the tidal exchange of ammonium is up to 14.9 metric tons per day. Furthermore, the seasonal pattern of ammonium in the Bay's waters, high in the spring and fall when primary production is low, indicates that the principal source of the ammonium must be regeneration by long-lived filter feeders and grazers. Since the gravel community described here covers 70 percent of the Bay bottom (Kelley and Kelley 2004), it seems likely that some component of the community would be involved in the regeneration process. The numerically dominant filter feeders identified in the present study are the serpulid worms *Spirorbis borealis* and *S. spirillum*. It has been reported that small, epifaunal suspension feeders, including spirorbid polychaetes, occurring in high densities may constitute filtering capacities on the same order of magnitude as macro suspension feeders (Lemmens 1996; Lemmens et al. 1996). Using filtering rates given by Dales (1957) and areas and volumes provided by Kelley and Kelley (2004) and Brooks et al. (1999), it can be estimated that these small spirorbids filter 1.55×10^5 m^3/tide, i.e. much less than one percent of the tidal prism. More likely candidates, suggested by Garside and Garside (2004), are the sea scallop, *Placopecten magellanicus*, and blue mussel, *Mytilus edulis*, which filter 2.1L $g^{-1}h^{-1}$ (Bacon et al. 1998) and 2.0 L $g^{-1}h^{-1}$ (Newell et al. 1989), respectively. Dredge sampling reveals that the highest densities of *P. magellanicus* in the State of Maine occur in Cobscook Bay (Schick et al. 2004). Although density figures for *M. edulis* in Cobscook Bay are not available, a commercial dragging fishery does exist, indicating high abundance. These species, however, would not be adequately sampled by a Smith-McIntyre grab. Future work needs to be focussed on the larger filter-feeders and grazers to get fuller understanding of the functional components of the ecosystem.

Cobscook Bay stands apart from other Maine estuaries and embayments because of the coarse nature of the bottom sediments. Although deposits of sand and gravel do occur along the Maine coast as a result of the reworking of glacial sediments, glaciomarine muds are probably predominant in most areas (Belknap et al. 1987). It is our experience that the interior of Maine estuaries are characterized by mud and sand, and even sawdust, bottoms (Larsen 1979; Larsen et al. 1983; Larsen and Johnson 1985; Shorey 1973; several unpublished data sets). For this reason, as well as the small number of sand samples involved, comparisons of the present results with previous studies are of little value. Likewise, investigations of rock and cobble substrates in the region have used different methodologies making comparisons inappropriate (Logan et al. 1983; Scheibling and Raymond 1990).

In conclusion, the distribution of macroinvertebrate communities of Cobscook Bay are closely linked to hydrographic and geological attributes. The subtidal areas of the outer Cobscook Bay are characterized by infaunal and tube-dwelling species in the protected sandy coves and a rich epifaunal community in the extensive current-swept channel areas. The latter areas comprise 70 percent of the subtidal areas of the Bay, which is unusual for a Maine estuary. It also suggests that filter-feeding components of this community may play an important role in the nutrient budget of the Bay that is characterized by high levels of ammonium (Garside and Garside 2004). While these implications are intriguing, this study is preliminary and limited in spatial coverage and in the adequacy of the sampling gear. Future surveys need to be more extensive and use a combination of sampling methods to quantitatively assess all components of the community. The cove stations, however, provide a good benchmark with which to evaluate the affects of subsequent aquaculture and port development.

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Table 1. The number of annelid families, genera and species found along the US East Coast. Numbers of genera and species new to science are in parentheses (Derived from Webster and Benedict 1887)

Locale	Families	Genera	Species
Virginia	23	49(4)	59(22)
New Jersey	23	50(2)	57(14)
Cape Cod	25	70(3)	90(16)
Eastport	29	89(7)	111(26)

Table 2. Grain size distributions at 11 stations in Cobscook Bay, sampled in 1975

	% Dry Weight			
Station #	Granule	Coarse/Very Coarse Sand	Medium Sand	Fine/Very Fine Sand
22	4	4	3	89
23	100	0	0	0
24	4	19	46	31
25	59	20	12	9
26	62	26	9	5
27	41	24	23	10
28	48	13	26	13
29	0	0	0	100
31	72	12	4	12
32	1	2	2	95
33	5	9	7	79

Table 3. List of subtidal macrobenthic invertebrates collected at 11 stations in outer Cobscook Bay in 1975. Species listed in alphabetical order within higher taxa.

Phylum	Species	Number of Occurrences at: Cove Stations	Channel Stations
Porifera	*Polymastia robusta* (Bowerbank, 1816)		1
	Porifera sp.		1
Cnidaria	Actiniaria sp.		1
	Drifa glomerata (Verrill, 1869)		1
	Hydrozoa		5
	Metridium senile (Linnaeus, 1767)		1
Nemertea	Nemertea	4	3
Priapula	*Priapulus caudatus* Lamarck, 1816	2	
Bryozoa	Bryozoa		6
Brachiopoda	*Terebratulina septentrionalis* (Couthoy, 1838)		1
Mollusca	*Anomia simplex* d'Orbigny, 1842		2
	Anomia squamula Linnaeus, 1758		3
	Astarte borealis (Schumacher, 1817)	2	
	Astarte castanea (Say, 1822)	1	
	Astarte undata Gould, 1841	2	2
	Astyris lunata (Say,1826)	2	2
	Bivalve sp. juv.		1
	Buccinum ciliatum (Fabricius, 1780)		2
	Buccinum polaris Gray, 1839	1	2
	Calliostoma occidentale (Mighels and Adams, 1842)		1
	Cerastoderma pinnulatum (Conrad, 1831)	3	7
	Clinocardium ciliatum (Fabricius, 1780)	1	
	Colus pubescens (Verrill, 1882)	2	
	Crenella decussata (Montagu, 1808)	2	4
	Crepidula fornicata (Linnaeus, 1758)		2
	Cyclocardita borealis (Conrad, 1831)	3	2
	Cylichna alba (T. Brown, 1827)	3	1
	Euspira immaculata (Verrill, 1880)	2	2
	Hiatella arctica (Linnaeus, 1767)	1	1
	Lepeta caeca (Müller, 1776)		2
	Lepidopleurus cancellotus (Sowerby, 1839)		7
	Lyonsia arenosa (Müller, 1842)	4	
	Macoma balthica (Linnaeus, 1758)	1	
	Margarites costalis costalis (Gould, 1841)		5
	Margarites sp.	1	2
	Musculus discors (Linnaeus, 1767)	1	
	Musculus niger (Gray, 1824)	1	2
	Mya arenaria Linnaeus, 1758	1	2
	Mytilidae sp. juv.		2
	Neptunea lyrata decemcostata (Say, 1826)		1
	Nucula delphinodonta Mighels and Adams, 1842	2	1
	Nucula proxima Say, 1822	3	1
	Onoba mighelsi (Stimpson, 1851)	1	1

cont'd

Phylum, cont'd	Species	Number of Occurrences at: Cove Stations	Channel Stations
	Pandora gouldiana Dall, 1886	*1*	
	Puncturella noachina (Linnaeus, 1771)		4
	Scabrotrophon fabricii (Möller, 1842)		1
	Solariella sp.	1	2
	Tectura testudinalis (Müller, 1776)		4
	Tellina agilis Stimpson, 1857	1	1
	Thyasira flexuosa (Montagu, 1803)	3	2
	Tonicella marmorea (Fabricius, 1780)		1
	Tonicella rubra(Linnaeus, 1767)		3
	Unidentified Gastropod	1	1
	Yoldia sapotilla (Gould, 1841)	3	3
Annelida	Ampharetid sp.	1	1
	Aphrodita hastata Moore, 1905	2	
	Aricidae sp.		1
	Aricidea catherinae Laubier, 1967	2	2
	Brada granosa Stimpson, 1854	1	
	Brada villosa (Rathke, 1843)	1	
	Cirratulid sp.	1	2
	Drilonereis magna Webster and Benedict, 1887		1
	Eteone longa (Fabricius, 1780)	1	2
	Eteone sp.	1	
	Eteone trilineata Webster and Benedict, 1887	1	
	Exogone dispar (Webster, 1879)		2
	Exogone verugera (Claparéde, 1868)	2	1
	Flabelligera affinis Sars, 1829	2	1
	Glycera capitata Örsted, 1843		1
	Harmothoe imbricata (Linnaeus, 1767)	3	7
	Harmothoe sp.	1	2
	Hydroides dianthus (Verrill, 1873)		1
	Lagisca extenuata (Grube, 1840)	1	5
	Lepidonotus squamatus (Linnaeus, 1767)		6
	Levinsenia gracilis (Tauber, 1879)	3	5
	Lumbrineris fragilis (Müller, 1776)	3	3
	Lumbrineris sp.	2	
	Lumbrineris tenuis (Verrill, 1873)	1	
	Maldanid sp.	2	5
	Neanthes diversicolor (Müller, 1776)	1	1
	Nephtyidae	1	
	Nephtys bucera Ehlers, 1868	4	2
	Nepthys sp.	2	1
	Nereis sp.		1
	Nereis zonata Malmgren, 1867	1	2
	Ninoe nigripes Verrill, 1873	3	1
	Oligochaeta	3	5
	Ophelina acuminata Örsted, 1843	2	5
	Owenia fusiformis Delle Chiaje, 1844	3	4
	Paraonis sp.	2	1

Phylum, cont'd	Species	Number of Occurrences at: Cove Stations	Channel Stations
	Pectinaria gouldii (Verrill, 1873)	2	1
	Pectinaria sp.		2
	Pholoe minuta (Fabricius, 1780)	4	7
	Phyllodoce groenlandica (Örsted, 1842)		2
	Phyllodoce maculata (Linnaeus, 1767)	2	1
	Phyllodoce sp.		1
	Polychaete A	1	2
	Polychaete B		2
	Polychaete C		3
	Polycirrus sp.		2
	Polynoidae sp.		2
	Scoloplos ?acutus (Verrill, 1873)	1	
	Scoloplos sp.	4	
	Spionid sp.	4	5
	Spirorbis borealis Daudin, 1800		7
	Spirorbis spirillum (Linnaeus, 1758)		6
	Sternaspis scutata (Renier, 1807)	2	
	Syllidae sp.		3
	Syllis gracilis Grube, 1840	3	6
	Terebellid sp.	4	7
	Travisia carnea Verrill, 1873		1
	Unidentified Polychaete	2	4
Sipuncula	*Phascolion strombus strombus* (Montagu, 1804)	2	1
Arthropoda	*Achelia spinosa* (Stimpson, 1853)		6
	Aeginina longicornis (Kröyer, 1842-43)		5
	Ampelisca macrocephala (Liljeborg, 1852)	3	
	Ampelisca vadorum (Mills, 1963)	1	
	Anonyx lilljeborgi (Boeck, 1871)	4	1
	Caprella linearis (Linnaeus, 1767)		1
	Casco bigelowi (Blake, 1929)	3	1
	Chiridotea tuftsi (Stimpson, 1853)	1	
	Corophium bonelli (Milne-Edwards, 1830)	1	4
	Corophium crassicorne (Bruzelius, 1859)	2	
	Corophium sp.	1	
	Cyathura polita (Stimpson, 1856)	1	
	Deflexilodes intermedius (Shoemaker, 1930)		1
	Dexamine thea (Sars, 1893)	1	
	Diastylis quadrispinosa Sars, 1871	3	2
	Diastylis sp.	4	2
	Edotia triloba (Say, 1818)	4	
	Erichthonius rubricornis Smith, 1873	1	
	Eualus pusiolus (Kröyer, 1841)		1
	Eudorella sp.	1	
	Eusirid sp. A		2
	Eusirid sp. B	1	2
	Gnathia sp.		1
	Haploops spinosa (Shoemaker)	3	

cont'd

Phylum, cont'd	Species	Number of Occurrences at: Cove Stations	Channel Stations
	Harpinia sp.		1
	Hippomedon serratus (Holmes, 1905)	1	
	Ischyrocerus anguipes Kröyer, 1838		1
	Jaera albifrons Leach, 1814		1
	Lafystiidae? Sp.		1
	Lebbeus groenlandicus (Fabricius, 1775)	1	
	Leptocheirus pinguis (Stimpson, 1853)	3	5
	Megamaera dentata (Kröyer, 1842)		5
	Nymphon hirtipes Bell, 1853		2
	Orchomenella minuta (Kröyer, 1842)	4	1
	Orchomenella pinguis (Boeck, 1861)	2	
	Pagurus pubescens Kröyer, 1842		1
	Pandalus montagui Leach 1814	1	1
	Photis sp.	1	
	Phoxocephalus holbolli (Kröyer, 1842)	2	4
	Phoxochilidium sp.		2
	Pycnogonum littorale (Storm, 1762)	1	2
	Spirontocaris phippsii (Kroyer 1841)		1
	Stenopleustes inermis Shoemaker, 1949	1	
	Tanaid sp.		2
	Unciola irrorata Say, 1818	3	3
	Unidentified Amphipod	1	
Echinodermata	*Asterias* sp.		1
	Crossaster papposus (Linnaeus, 1766)		2
	Ctenodiscus crispatus (Retzius, 1806)		1
	Echinarachnius parma (Lamarck, 1816)		2
	Edwardsia sp.		2
	Henricia sp.		3
	Ophuira robusta (Ayres, 1861)	2	7
	Strongylocentrotus droebachiensis (Müller, 1776)		7
Chordata	*Molgula complanata* (Alder and Hancock, 1870)	1	3
	Unid. Stalked Ascidiacea	1	3
Phylum unknown		1	1
TOTALS		**104**	**135**

Table 4. Community parameters and numerical dominance

	Number of Replicates	Number of Species	Density (m^2)	Diversity (H^1)	Numerical Dominance
Channel Stations					
23	1	39	3,380	1.62	*Spirorbis borealis* 68%
24	2	54	2,195	2.32	*Spirorbis borealis* 52%
25	2	59	2,470	2.11	*Spirorbis borealis* 60%
26	2	50	2,460	1.57	*Spirorbis borealis* 70%
27	2	48	870	3.03	*Spirorbis borealis* 28%
28	2	52	3,345	1.55	*Spirorbis borealis* 72%
31	1	29	2,900	1.89	*Spirorbis borealis* 46% *S. spirillum* 23%
Cove Stations					
22	2	54	12,970	1.15	*Unciola irrorata* 80%
29	2	28	1,330	2.34	*Diastylis* sp. 26% *Edotia triloba* 17% *Scoloplos* sp. 15% *Nephtys bucera* 12%
32	2	70	2,235	3.40	*Casco bigelowi* 15%, *Haploops spinosa* 15%
33	2	62	6,880	2.59	*Haploops* sp. 28%, *Leptocheirus pinguis* 18%, *Unciola irrorata* 14%
All Stations	Mean	50	3,730	2.14	
	Min	28	870	1.15	
	Max	70	12,970	3.40	

Figure 1. Map of Cobscook Bay (Box indicates the study area)

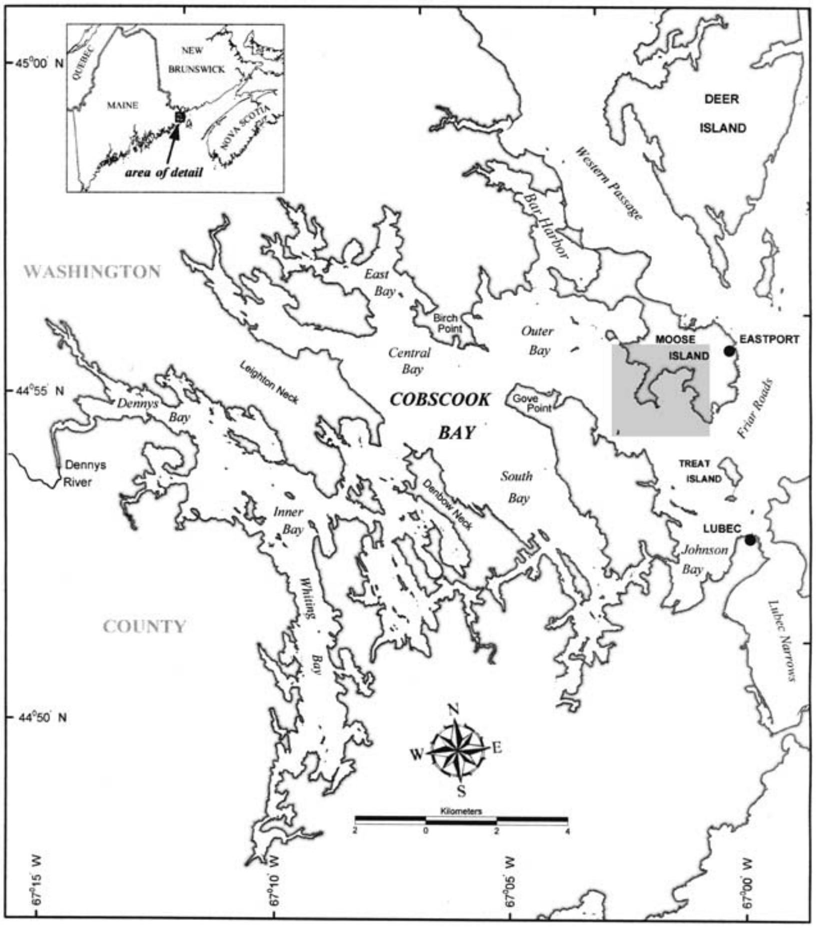


Figure 2. Locations of the 11 subtidal stations sampled in 1975 in outer Cobscook Bay

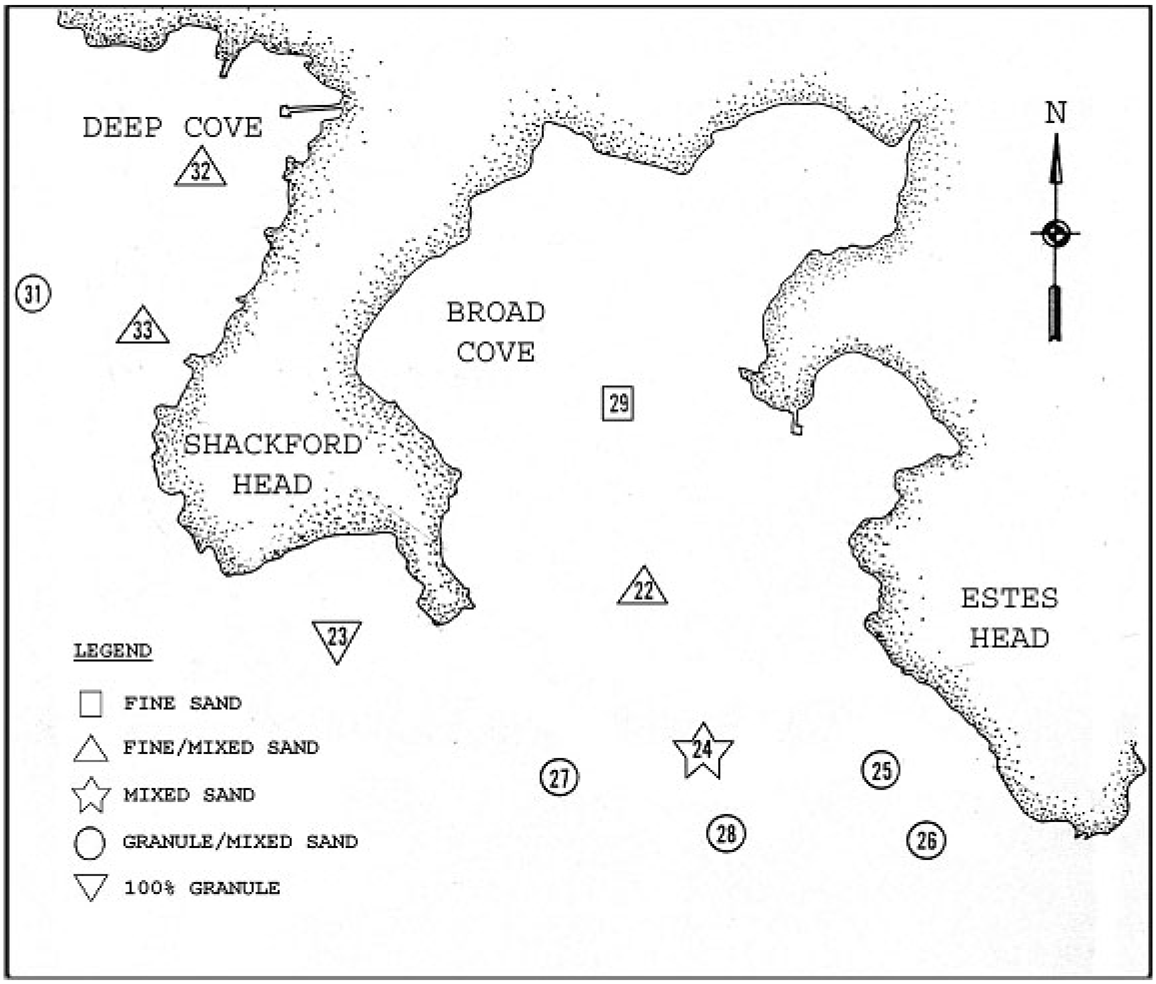


Figure 3. Dendrogram based on a group-average sorting classification using the Bray-Curtis similarity measure on non-transformed species data

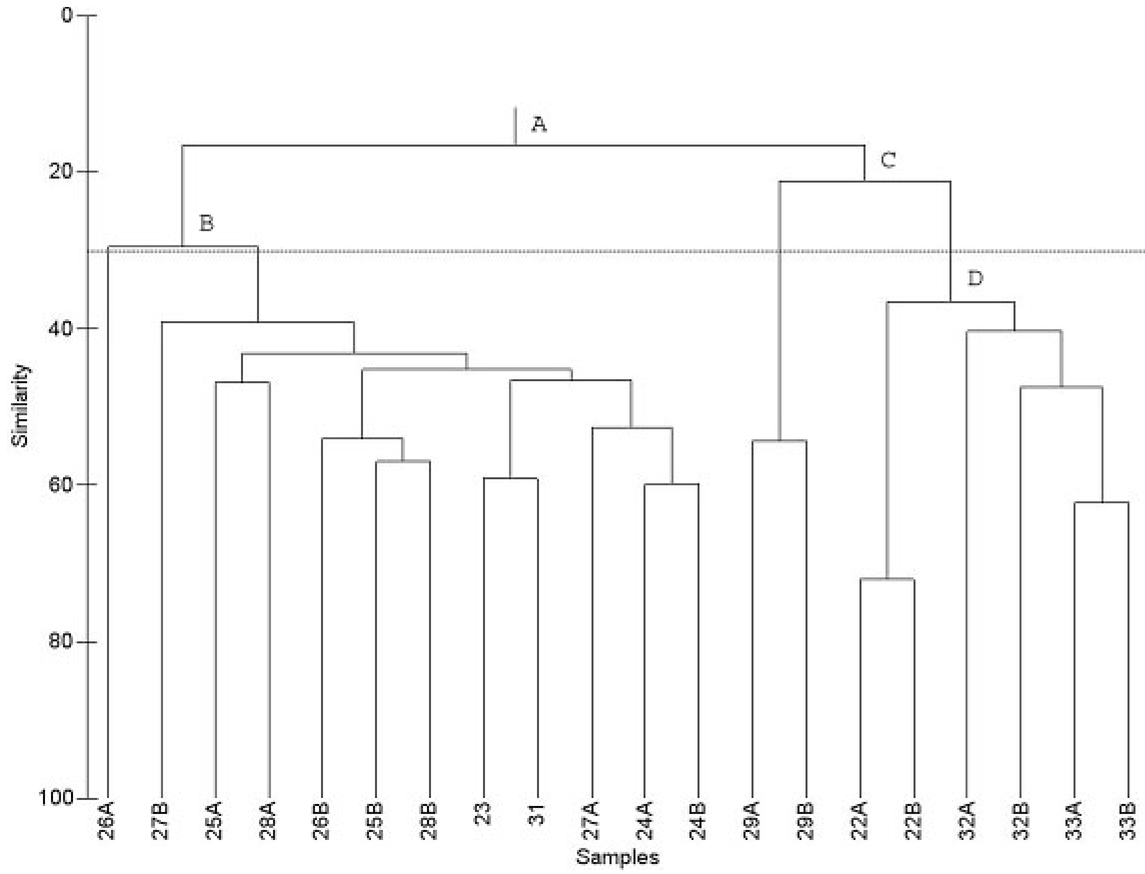


Figure 4. MDS (multidimensional scaling) ordination of the 20 replicate samples based on non-transformed species abundances and Bray-Curtis similarities (stress = 0.08)

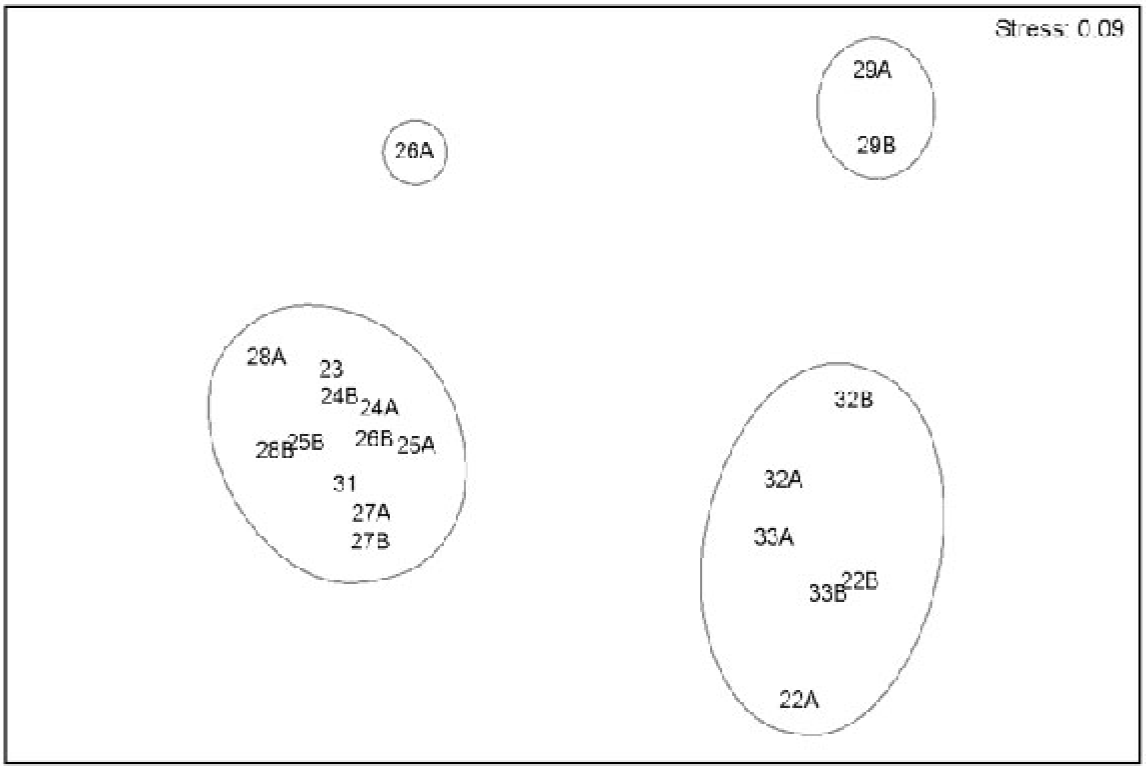


Figure 5. Stations in outer Cobscook Bay overlain on surface currents from hydrographic model simulation. Longer arrows indicate currents of 2 m/sec (Modified from Brooks, et al. 1999)

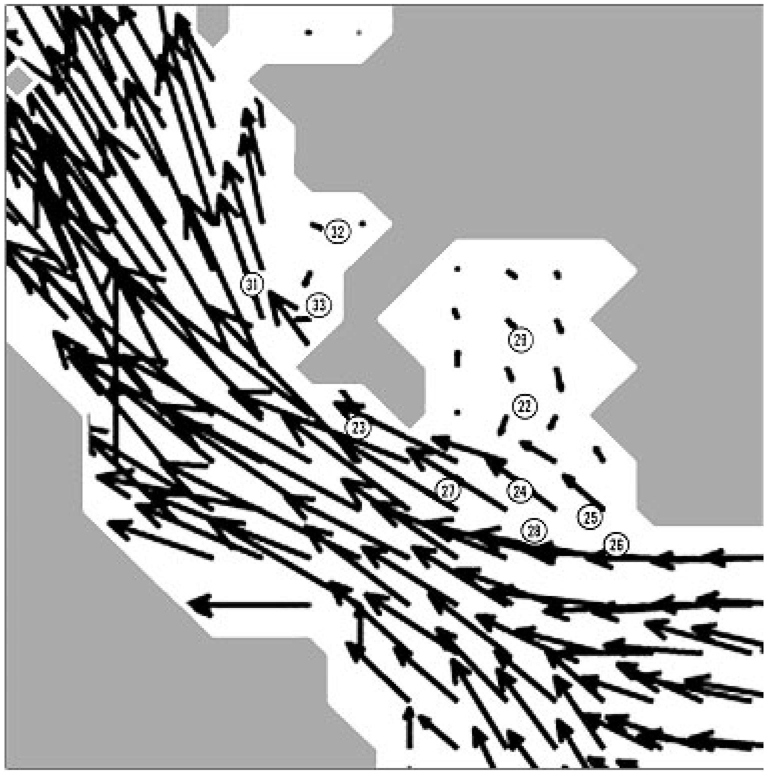
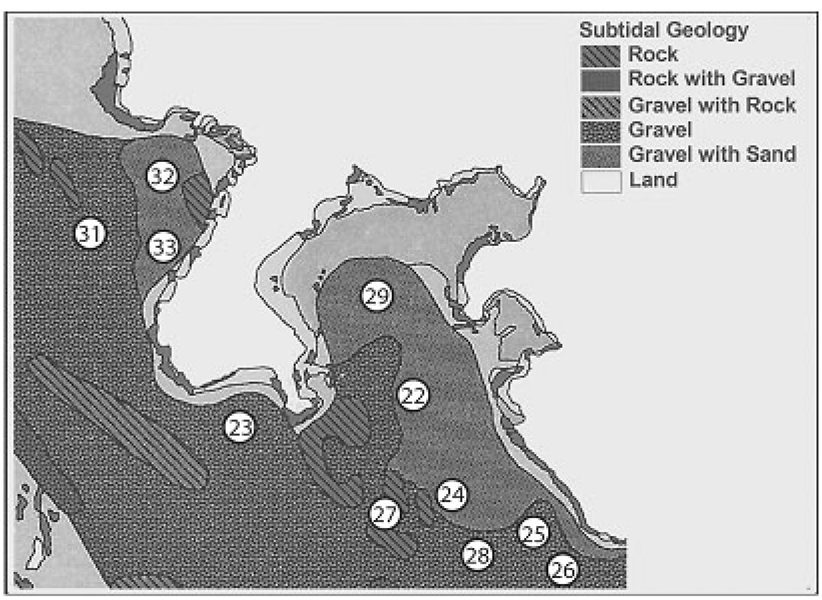


Figure 6. Stations overlain on bottom types (Modified from Kelley and Kelley 2004)



EMERGY ANALYSIS OF THE COBSCOOK BAY ECOSYSTEM

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Abstract

Energy Systems Theory and its derivative methods, Emergy Analysis and Environmental Accounting using emergy, are particularly suited for evaluation of the ecological, economic and social consequences of environmental policy decisions. For these methods to be broadly applied, scientists must document the emergy basis for the products and services provided by ecosystems and economies. In this study, the emergy basis for the Cobscook Bay estuarine ecosystem was documented. Cobscook Bay is a macrotidal estuary that is naturally eutrophic due to new nitrogen supplied from the sea. Plant production is stabilized by benthic macrofauna grazing and phytoplankton production is light limited due to the intense vertical mixing regime. The fucoid algae, kelp, red algae and benthic microalgae are best adapted to use the rich emergy signature of the Bay. Emergy Analysis indicated that primary producers are unable to use the estuary's emergy sources as efficiently as in other estuaries. The additional emergy goes into creating rare physical, geological, and biological structures. Empower density in Cobscook Bay (7.4 E12 sej m^{-2}) is three times the minimum estimate for salmon culture; therefore, salmon aquaculture may be a good human use of the Bay's rich emergy signature. Energy transfer and observations in the Bay indicate that the system is productive and healthy overall, but not without local disturbance in space and time.

Introduction

Scientists and engineers recognize that energy is the source and control of all things (Odum and Odum 1976), but this fact has seldom been taken as the starting point for analyzing environmental systems. In Canada, the ecosystem approach plays a vital role in managing the environment (Wells 2004), but Energy Systems Theory (Odum 1971, 1983, 1994) and its derivative tools such as Emergy Analysis and environmental accounting are not widely known or broadly used to support environmental planning and decision making. Canadians have tended to reinvent Odum's seminal work on the thermodynamic basis for ecosystems, using a somewhat different perspective (Johnson 1981; Kay 1991, 2000), rather than build on the existing body of knowledge produced by Odum and his colleagues. This tendency has produced some very fine research; however, it has also made progress toward using energy-based methodologies in managing the environment more difficult than it might have been if Odum's work had been acknowledged and incorporated into Canadian thermodynamic approaches to ecology.

Odum synthesized knowledge from general systems theory, irreversible thermodynamics and ecology (Odum 1971, 1983, 1994) into a comprehensive approach applicable to all natural phenomena. This methodology provides general explanatory principles, (e.g., the maximum power principle, the energy hierarchy law, the pulsing paradigm) through which the phenomenological universe can be understood and interpreted. Odum realized that energy can be used as a general accounting tool if (1) the transformation of energy underlies all phenomena, and (2) if the energy previously used up directly and indirectly to make any item can be accounted for as energy of one kind (e.g., solar emjoules). Odum's research on the irreversible thermodynamics of ecosystems led to the formulation of a powerful new concept, emergy, which can be used to express all phenomena on a common basis, so that the quantities of different things (e.g. iron, corn, oil, and human labor) are made directly comparable. *Emergy* is the available energy of one kind previously used up directly and indirectly to make a product or service. Its unit is the emjoule. Emergy can use any kind of energy as the common base, for example coal joules, solar joules, etc. However, in evaluating environmental systems, we commonly use solar energy as the base unit. *Solar emergy* is the available solar energy used up to make a product or service in an ecological or economic system. Its unit is the *solar emjoule* (abbreviated *sej*). *Available energy* is energy with the capacity to do work, sometimes called *exergy*. *Empower* is the emergy flow per unit time and *empower density* is the emergy flux per unit area.

Odum's work is important because it provides a powerful alternative value system that gives an objective measure of ecological and economic costs and benefits. At present, we are developing methods to allow the construction of comprehensive income statements and balance sheets for business, industries and institutions which will allow us to document environmental liabilities and determine the true solvency of human enterprise (Campbell 2004a). To successfully accomplish this work the emergy basis for many different kinds of systems must be documented. In this study we documented the physical basis for biological productivity and ecological organization in Cobscook Bay, a macrotidal estuary in eastern Maine.

Methods

Emergy Analysis and Energy Systems methods have been extensively documented elsewhere (Odum 1971, 1994, 1996); therefore only a brief synopsis of these methods will be given here. In summary, the key features of the energy systems approach are: First, consider the energy transformations underlying the system processes and behavior that you want to understand or predict. Second, consider the larger systems that supply energy to and determine trends in the system under consideration. Finally, formulate specific diagrammatic models using the Energy Systems Language (Odum 1994) that represent the key system characteristics and behavior that we need to understand to answer research or management questions. Energy Systems models are constructed, evaluated and analyzed as follows: (1) Develop a detailed description of the system under study using expert testimony, literature sources, and if necessary field studies. (2) Draw a detailed diagram that represents all the known components and processes of the system. (3) Simplify the complex diagram through aggregation of similar components and processes, leaving nothing out so that the model can be disaggregated when more complexity is needed to answer a particular question. (4) Evaluate all sources, storages, and flows shown in the model at a given time. (5) Analyze the network, calculate indices, and compare with other systems.

Using data from others involved in this study (Phinney et al. 2004, Vadas et al. 2004a, 2004b, 2004c; Beal et al. 2004; Larsen et al. 2004), the ecological flows of nutrients and primary production in Cobscook Bay were first documented and then compared in terms of the mass of nitrogen taken up or the quantity of carbon fixed. The fate of this carbon was also examined using the data from others mentioned above, information from the literature, and convenient but reasonable assumptions about its disposition. Next, the mass flows were converted to energy, and the emergy (Odum 1996) used in making a joule of each kind of primary production in the ecosystem was determined.

The relationship between emergy and available energy is expressed in the fundamental equation of emergy analysis: Emergy = Transformity X Available Energy (exergy). *Solar transformity* is the solar emergy required to make one joule of an item, such as an ecological storage or flow. Its units are solar emjoules per joule (sej J^{-1}). The emergy algebra rules given in Odum (1996) were used to determine the transformity of the energy flows in the ecosystem network. Transformity is significant because it is a universal measure of the position of any ecological component or process within the hierarchical structure of its system and within the larger universe of natural processes. Different transformities for the same item are an indicator of the relative efficiency of the production process for that item. The greater the energy flow in the denominator for a given emergy input to the production process (the numerator), the lower the transformity of the item and the higher the efficiency of the production process. For example, the transformity of penaid shrimp produced naturally in the Gulf of Mexico is about 4.0 E6 sej J^{-1}, compared to 1.3 E7 sej J^{-1} for shrimp produced by mariculture in Ecuador's coastal ponds (Odum and Arding 1991).

Results and Discussion

The results and discussion are presented in two sections (1) An evaluation and characterization of ecosystem processes in the Cobscook Bay ecosystem and (2) Emergy Analysis of the ecosystem network. Because of the short length of this paper it is impossible to give all the information and supporting calculations needed to document the results presented here. The reader can find these details posted on the following web site: <http://epa.gov/aed/research/desupp2.html>.

Evaluation of Ecosystem Processes

The following aspects of the ecosystem were documented to determine the carbon and nitrogen flows in the system: (1) new nitrogen inflows; (2) nitrogen required by primary producers; (3) primary production and its fate; (4) the import-export balance of chemical constituents and phytoplankton. The inflows of new nitrogen to Cobscook Bay are shown in Table 1. Seventy-five percent of the annual supply of new nitrogen comes from the sea. Summer nitrate concentrations in Cobscook Bay (~ 2 ì moles l^{-1}) are comparable to those found in the summer in culturally eutrophic estuaries like Narragansett Bay (Nixon 1986). Thus, we have said that Cobscook Bay is a naturally eutrophic estuarine ecosystem. Table 2 gives the nitrogen requirements to support the primary production measured in the Bay during 1995 and 1996. The nitrogen required to support the primary production estimates exceeds the estimated supply of new nitrogen to the Bay. Therefore, some of the annual primary production in the Bay must depend on remineralized nitrogen in the form of ammonia. The ratio of recycled to new nitrogen is low (1.1:1), compared to that found in other estuaries (2:1-8:1, Kemp et al. 1982) and the Gulf of Maine (2:1, Campbell 1986). Table 2 shows that benthic microalgae are the largest users (60%) of nitrogen in the Bay.

Benthic microalgae also account for most of the primary production as shown in Table 3. Phytoplankton is less productive than expected, given the high concentrations of nitrogen in the Bay (Phinney et al. 2004). This condition is probably due to the extreme vertical mixing regime that results in light limiting phytoplankton production. An estimate of the fate of the primary production listed in Table 3 is given in Table 4. Data from Table 4 shows that extensive beds of shellfish feeding on microalgae may also play a role in controlling suspended algal populations. These large and productive shellfish beds support fisheries for scallops, clams, and urchins in the Bay. Table 4 also shows that approximately 1/3 of the primary production or 12,500 MT is exported, 1/3 is taken by suspension feeders and 1/3 is deposited to support benthic deposit feeders. If detritus is exported in proportion to its production, about 45 percent of macroalgal production is exported.

Table 5 gives the balance of several chemical constituents and phytoplankton carbon during each of the sample periods in 1995 (Phinney et al. 2004). In spring and summer, NO_3, NH_4, and SiO_3 (except on July 11) are imported and PO_4 is exported. Phytoplankton is exported in spring and fall and imported in summer when there is a bloom in offshore waters. In October, a net export of NO_3, NH_4, SiO_3, PO_4, and phytoplankton C was observed. At this time, the Outer Bay was a source of NO_3 for both the Inner Bay and Friar Roads (outside the Bay). Also at this time, urchin dragging was ongoing along the North Shore of the Outer Bay where the highest NO_3 concentrations were also found. This circumstantial evidence, combined with the use of weather records to eliminate winds as a source of re-suspension, indicates that urchin dragging probably elevated concentrations of chemical constituents in the Outer Bay, leading to a large net export of all chemical constituents at this time.

By November, high concentrations of NO_3 and PO_4 are present in Friar Roads leading to a net import of these substances. Ammonium concentrations declined more rapidly outside than inside the Bay, resulting in the largest net export of NH_4 at this time. In November, the highest concentrations of SiO_3 are found in Central and South Bay where scallop dragging had begun. Winds do not appear to be related to the high SiO_3 concentration in November; thus circumstantial evidence indicates that the turbidity observed at that time was due to scallop dragging. Trott (2004) presented evidence that the species composition of benthic communities in the Inner Bay was altered from the seventies and early eighties to 2002, perhaps from the chronic effects of increased sedimentation. In light of these observations it would be prudent to further investigate the relationship between dragging, sedimentation and faunal change in the Bay.

Emergy Analysis of Cobscook Bay

Emergy Analysis of the Cobscook Bay ecosystem network consisted of three elements: (1) Documentation of the Bay's energy and emergy signatures; (2) tracing the emergy basis for primary and secondary productivity in the Bay; and (3) comparing the results to data from other estuarine ecosystems. The energy signature of Cobscook Bay (Figure 1) is dominated by solar energy and shows two distinct peaks in the middle of the spectrum of transformities. One peak in the range of 24,300 to 30,000 sej J^{-1} is created by tidal and wave energy; a second peak at 50,000 sej J^{-1} is produced by the chemical potential energy of fresh water in rivers. These two peaks are also present in the emergy signature (Figure 2), which shows the relative ability of each energy source to do work in the system. The emergy signature shows a third peak, corresponding to the nitrogen received in seawater moving back and forth each day with the tide. The emergy flow received in the new nitrogen (NO_3) contained in seawater is large. However, only a small fraction (10 percent) of this emergy is captured by the estuary as a net flux of NO_3-N into the system (Figure 2, patterned bar). The total new nitrogen entering the estuary each year (25.76 E+5 kg-N y^{-1}) was determined by adding the net new nitrogen supplied by tidal exchange to the nitrogen added by freshwater inflow, salmon culture, and wet and dry deposition from the atmosphere. The emergy base for the Cobscook Bay ecosystem (7.64 X 10^{20} sej y^{-1}) is comprised of the emergy inputs in the tides, waves, and the emergy of the cross boundary flows, i.e. chemical potential energy in fresh water and the new nitrogen entering the estuary from the sea, salmon culture, rivers and the atmosphere.

The results of the emergy analysis of the Cobscook Bay ecosystem network are shown in Figure 3, where the emergy base for the various energy flows in the network is given in the circular symbols arrayed around the edge of the system boundary in order of increasing transformity. The transformity of any network flow can be obtained by dividing the emergy required for the pathway (in bold) by the energy flowing on the pathway (in italics). The most efficient primary producers in Cobscook Bay have transformities of 10^5 sej J^{-1}, compared to 10^4 sej J^{-1} in other estuaries (Odum 1996). This difference is carried through into the grazing and detritus food chains, but it disappears by the time energy transfer reaches the top carnivores. Brown algae (fucoids and kelp), red algae, and benthic microalgae are most effectively using the emergy available from the Bay's emergy inflows. Phytoplankton has a higher than expected transformity, which is much higher than the intertidal algae and, therefore, it is less efficient in using the emergy inputs to the Bay, probably because of light limitation.

Emergy Analysis of the Cobscook Bay ecosystem network indicated that primary producers are unable to use the estuary's emergy sources as efficiently as in other estuaries. The additional emergy goes into creating rare and unusual physical, geological, and biological structures in the environment. Many of these unique features of the Bay are derived from processes using the available energy in its large tides. For example, tidal mixing cools the surface waters in summer, resulting in an extremely foggy environment that protects intertidal creatures from desiccation and may support the development of a diverse and sometimes giant intertidal fauna; swift tidal currents account for rare hydrologic features such as reversing falls and whirlpools, and scour has produced an unusually large expanse of hard bottom in the central channels of the estuary (Kelly and Kelly 2004); a large tidal exchange volume and strong vertical mixing result in high nitrate concentrations in the estuary for most of the year.

The renewable empower density in Cobscook Bay (7.4 E12 sej m^{-2}) is one of the highest we have measured and it is equivalent to that required for intensive Tilapia culture in Mexico (Brown and

Bardi 2001). It is three times the minimum estimate for salmon culture made by Odum (2000): therefore, salmon aquaculture may be a good human use of the Bay's rich emergy signature.

Analysis of energy transfer and productivity in the trophic network of the Bay indicates that the system is productive and healthy overall. However, problems were observed in a number of areas. Human activities in the Bay alter water column properties during the urchin and scallop seasons (Phinney et al. 2004), degrade benthic communities below and adjacent to salmon pens (Heinig and Bohlin 1995), regularly overfish commercial populations of shellfish (Dow and Baird 1960, Ellis and Waterman 1998, urchin landings data, M. Hunter, pers, comm.), and may be responsible for long term loss of benthic biodiversity in the Inner Bay (Trott 2004). The negative effects of these human activities should be quantified in emergy terms, so that the environmental liabilities (Campbell 2004) incurred as a result of the loss of empower in the natural ecosystem can be compared to the concomitant empower gains in the economy. Such comparisons should be made in the future as an aid to planning and decision making for the Cobscook Bay and for the Bay of Fundy as a whole.

Acknowledgements

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Table 1. Annual supply of new nitrogen entering Cobscook Bay

Nitrogen Source	N inflow (kg N y^{-1} X 10^5)
Runoff from the watershed	2.47
Salmon aquaculture	3.67
Wet and dry deposition from the atmosphere	0.72
Net influx of NO_3-N in tidal exchange	18.90
Total new N inflows	25.76

Table 2. The nitrogen required to support annual primary production in 1995 and 1996

Primary Producer	N needed (kgN y^{-1} X 10^5)
Phytoplankton	14.8
Benthic microalgae	32.6
Fucoid algae	5.3
Green algae	1.0
Red algae	0.6
Kelp	0.2
Eelgrass	0.1
Total nitrogen required	54.6

Table 3. Annual net primary production in Cobscook Bay in 1995 and 1996

Primary Producer	Primary Production (kgC y^{-1} X 10^6)
Phytoplankton	8.8
Benthic microalgae	19.5
Fucoid algae	6.3
Green algae	1.1
Red algae	0.8
Kelp	0.5
Eelgrass	0.2
Total primary production	37.2

Table 4. Fate of primary production in Cobscook Bay

Consumer	Annual Consumption (kgC y^{-1} X10^6)
Zooplankton grazing	0.05
Benthic filter feeders	10.1
Grazing on macroalgae	0.9
Detritus, filtered	1.5
Total consumption	12.6
Detritus, direct deposit	12.1
Detritus exported	12.5

Table 5. Import-export balance for several major chemical constituents in Cobscook Bay

Date 1995	NO_3 gN d-1	NH_4 gN d-1	PO_4 gP d-1	SiO_3 gS d-1	C gC d-1
May 2, 3, 4	1.0 E7	1.6 E6	-4.3 E5	1.0 E7	-2.7 E6
July 11, 12, 13	4.2 E6	8.9 E6	-1.5 E6	-1.1 E6	9.8 E6
July 21, 22, 23	4.4 E6	1.2 E7	-3.0 E6	1.3 E7	3.2 E6
Oct. 24, 25, 26	-3.0E7	-3.9 E5	-8.2 E6	-5.5 E7	-1.1 E7
Nov. 7, 8, 9	5.0 E6	-4.8 E6	1.1E6	-2.2 E7	-7.8 E6

Figure 1. The energy signature of Cobscook Bay with energy sources listed in order of increasing transformity

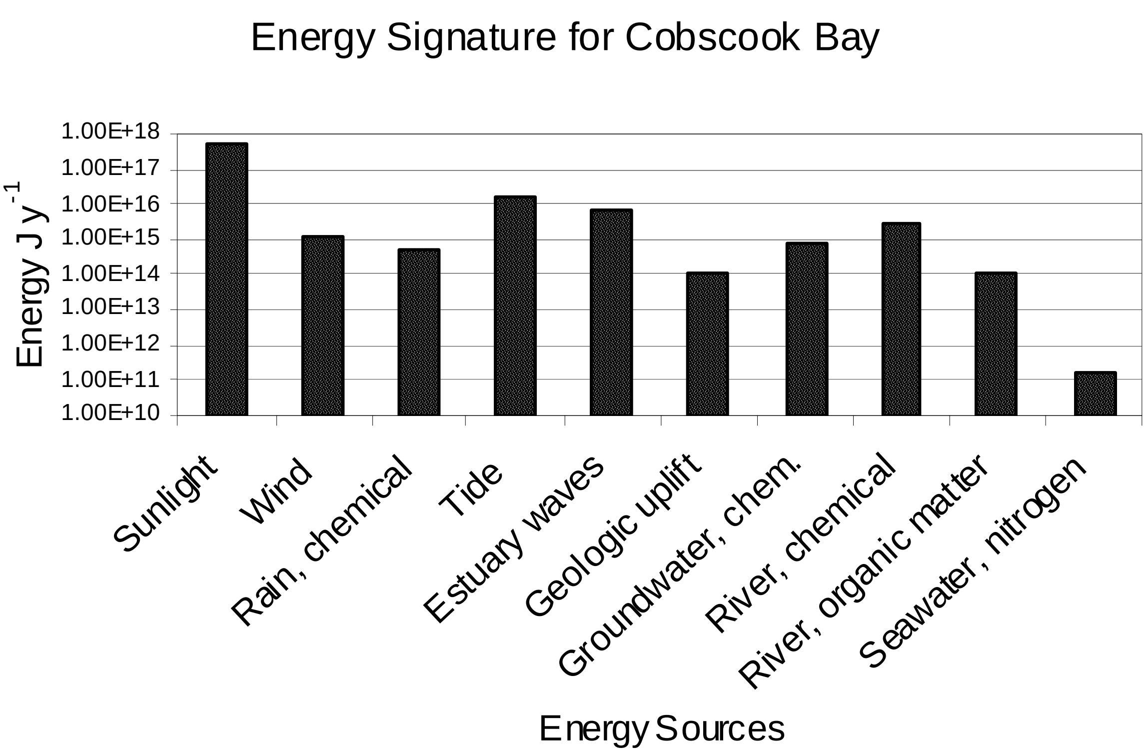


Figure 2. The emergy signature of Cobscook Bay, with energy sources listed in order of increasing transformity. The gray patterned bar shows the emergy in the net flux of NO_3-N into the Bay.

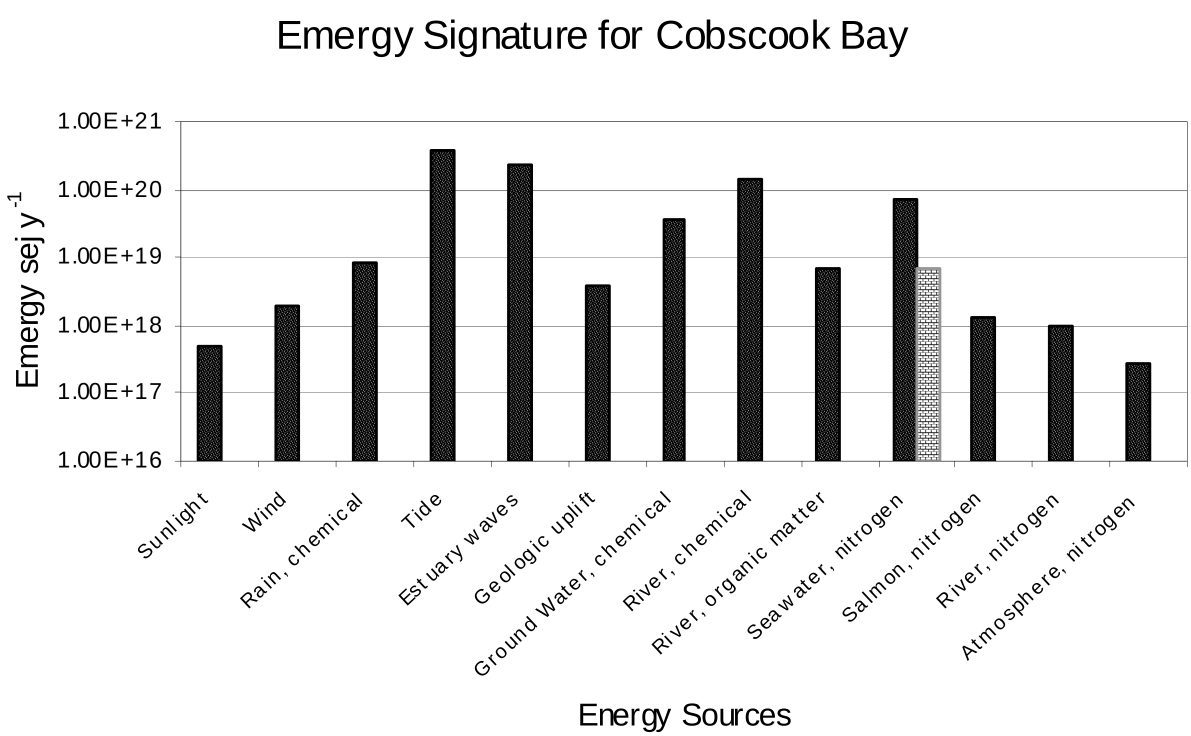
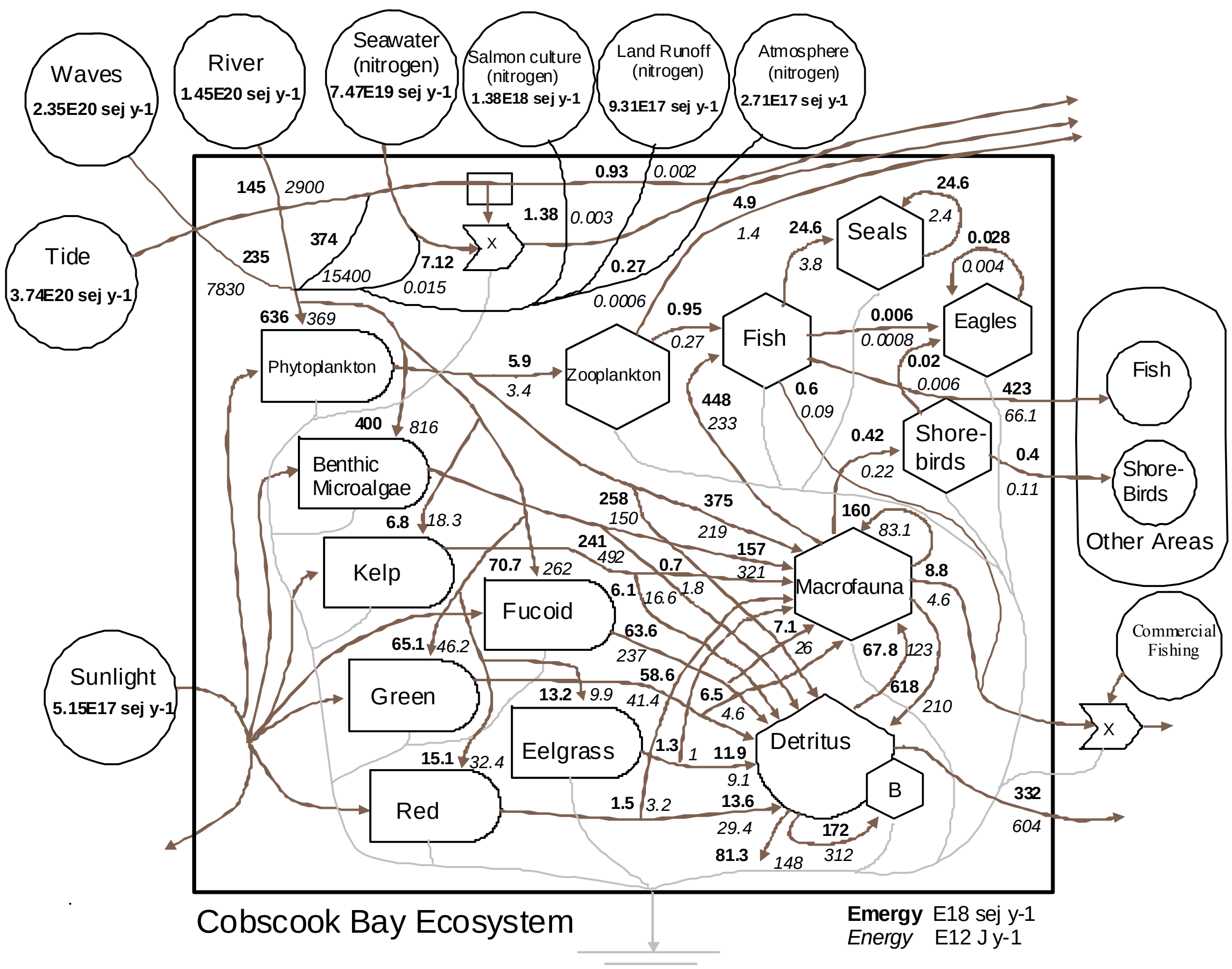


Figure 3. Emergy evaluation of the Cobscook Bay ecosystem network. The emergy received by the ecosystem is shown on the energy sources arrayed around the edge of the box, representing the ecosystem, in order of increasing transformity. Flows within the system are labeled with two numbers: (1) the emergy in sej y^{-1} required for that pathway (bold), and (2) the energy flow along the pathway in J y^{-1} (italics). Dividing (1) by (2) gives the transformity of the pathway. See Campbell (2004b) for definition of the pathways.

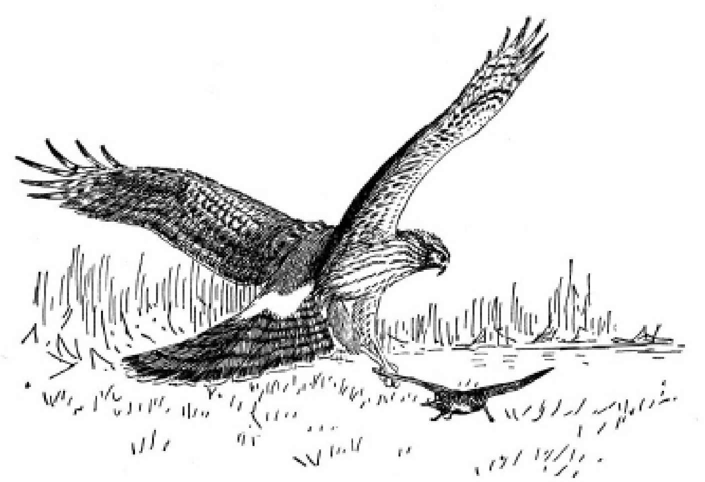


Poster Session

Chairs: Alison Evans, Coastal Planners, Centre Burlington, Nova Scotia

and

Jocelyne Hellou, Fisheries and Oceans Canada, Dartmouth, Nova Scotia



A. ECOSYSTEM TOOLS, TECHNIQUES AND ORGANIZATIONS

BENTHIC BIODIVERSITY IN THE BAY OF FUNDY—CAN REGIONAL CHARACTERIZATION BY HYDROGRAPHIC FACTORS INDICATE LEVELS OF BENTHIC BIODIVERSITY?

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The results presented in this study are part of a larger Bay of Fundy bodiversity project that focuses on subtidal, hard-bottom, invertebrate communities in the outer Bay of Fundy. The overall aim is to develop a framework for management and protection of these coastal habitats, based on analysis of community type, species diversity, and the processes affecting the species assemblages. The knowledge gained by the overall project will assist managers in making timely and appropriate decisions related to coastal management, and in the objective rationalization of significant ecological areas, based on biodiversity, which can then be used as a framework for development of a system of marine protected areas.

Previous studies (Ward et al. 1999) have shown that if the conservation objective is maximization of species representation within small coastal areas, then precise locations should be chosen based on fish and invertebrate assemblages, because the use of these two surrogates increases the probability of including the most taxa. On the other hand, if larger areas are to be managed, then the locations can be chosen based on habitat categories and regional characterization. The ability to locate invertebrate assemblages and areas of enhanced species richness, or "regional biodiversity hotspots", would maximize species representation and protection. This requires the characterization of communities and their habitat, and the defining of appropriate indicators that would point towards high species diversity.

The study uses information from historical transect surveys (MacKay et al. 1978a, b, c; MacKay and Bosien 1979) and long-term oceanographic monitoring information (Fisheries and Oceans Canada) to analyze for spatial variations that may explain large-scale patterns in species richness in the southwest Bay of Fundy.

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A PROTOTYPE INTERACTIVE GIS DELIVERY SYSTEM FOR DISSEMINATING STATISTICALLY DOWN-SCALED CLIMATE CHANGE SCENARIOS, VARIABILITY AND EXTREMES IN ATLANTIC CANADA

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Over the past several years, Environment Canada has been developing expertise in the use of on-line, Internet-based mapping applications for the delivery of environmental data to the impacts and adaptation community. These applications provide both spatial and temporal analysis tools, including geographical information systems (GIS) functionality, access to downloadable stored data, interpreted products, on-the-fly generation/analysis, real time charting, client based data entry forms, statistical analysis, and a range of security features. Data currently housed in Excel or other spreadsheet-based systems can be ported to fully relational databases, resulting in improved data acquisition speed, accessibility, and functionality. The system includes several on-line query options through the use of drop-down menus and is designed to aid both expert and non-expert users in assessing the impact of climate change scenarios on their site-specific region of interest.

The heart of the interactive system is the Autodesk Mapguide software, which allows for flexible, user-friendly, spatial querying. The system is built on a series of four nested scale National and Regional base maps (1:20 million, 1:7.5 million, 1:2 million and 1:1 million). As users zoom into local areas of interest the base map scale will change automatically to display a reasonable level of detail. Available themes for the base maps include drainage features (coastlines, rivers, lakes), boundaries, roads, transmission lines, major population centers, and national parks. These layers can be turned on or off and can provide users with the ability to navigate to a particular area of interest using recognizable landmarks. Displayed data can be printed at any time.

The climate change component of Mapguide will be populated with both historical (1961–1990) and projected (2011–2040, 2041–2070, 2071–2100) data for the basic meteorological parameters Tmax, Tmin, and Pcpn, from 14 sites in Atlantic Canada. This suite of data has been generated by down-scaling, using a <u>S</u>tatistical <u>D</u>own-<u>s</u>caling <u>M</u>odel (SDSM) and output from the <u>C</u>anadian <u>G</u>lobal <u>C</u>oupled <u>M</u>odel (CGCM1) running the GHG+A1* experiment. All data can be accessed and displayed through several mechanisms: down-scaled data (including 20 ensembles of projected results) can be downloaded in FTP Zip format; interpreted products, such as climate variability graphs, analyzed extreme climate indices (generated using STARDEX software), and Extreme Value Analyses using Gumbel

* “GHG+A1” is a typical designation describing the type of “experiment” parameters that were used during a specific climate model run. Most climate models are “forced” with a percentage of greenhouse gases (GHG), typically an increase of 1% a year for 100 years, to give projections of their impacts out to 2100. Some models also add sulphate aerosols (A) as a controlling parameter, since aersols have the effect of “cooling” the atmosphere. A designation of GHG+A1 on a particular set of climate model output refers to the fact that the results of the model run were done using greenhouse gases and aerosols as controlling parameters. The 1 (one) refers to the fact that there may be more than one GHG+A experiment and this one happens to be number one.

statistics can be displayed or downloaded as tables, histograms, or maps contoured over eastern Canada. Contour maps of modular data were generated using the Spline-Tension (W=0.1) contouring algorithm within the GIS analytical software, and can be overlaid with any other thematic layer.

Current plans are to increase the number of down-scaled sites from 14 to 26, and to use two more world-class GCM driving models, namely the CGCM2, and the Hadley Centre's Third Generation Coupled Ocean-Atmosphere GCM (HADCM3), in order to create a range of future climates scenarios readily available through this GIS interface.

A TECHNIQUE FOR AN AUTOMATED MAPPING OF SALT MARSH EXTENT FROM AERIAL PHOTOGRAPHY— CAPE JOURMAIN, NEW BRUNSWICK

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Conventional practice for classifying aerial photography has been to delineate polygon boundaries, either manually through on-screen digitizing or tracing them with a marker. The benefit of manual classification is accuracy, the drawback being that it is time consuming. In contrast, an automated classification with image processing software is a much faster classification method, yet traditionally it is not necessarily best for air-photo interpretation for two main reasons; one is that air-photos compared to satellite imagery (for which most automated classifiers are designed), most often do not contain the same degree of spectral resolution—particularly in this project as all photos were true-colour. The second reason is on account of shadow. An analyst can examine an image and with his or her eye they can group the shadow from trees together with the tree class. However, spectrally, shadow is very different from the tree, and as a result the software may see the two as being distinct. Despite these two shortcomings it was thought that an automated classification would still work, as salt marsh tends to have somewhat unique spectral properties, and of course grows next to water, i.e. the ground is flat and the effect of shadow negligible. A third reason to try the automated classification has to do with the software used, eCognition v.4.0. eCognition encompasses a feature known as segmentation whereby regions with similar spectral properties are first grouped, then it is the analyst's responsibility to find the features that will segregate these groupings into similar landcover classes. It was hoped that once the boundaries are segmented ('drawn'), then classification would proceed efficiently.

A preliminary classification resulted in some overlap between salt marsh vegetation and upland field/meadow; apparently the two types of grasses did not vary enough. To aid in their separation, a highly accurate LIDAR digital elevation model (DEM) for Cape Jourmain was provided by Tim Webster of the Centre of Geographical Sciences (COGS). The DEM allowed for a rule to be added stating that only areas less than 0.75 m above mean sea level could even be considered for the salt marsh class. The 0.75 m cut-off was determined through visual inspection of the photographs and DEM.

The technique for mapping saltmarsh extent can be easily applied to other areas in the region, both along the Gulf of St. Lawrence and the Bay of Fundy requiring only minor adjustments in the software's parameters. The methodology can also be replicated at different temporal scales and could be used to detect change over time relatively quickly.

NEW TOOLS AND APPROACHES IN DATA INTEGRATION FOR MARINE PROTECTED AREAS PLANNING

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This poster reviews the technical challenges of data integration and visualization that were encountered as part of a case study involving the proposed Musquash marine protected area. The technical challenges are particularly important considering the spatial data scale, format, precision and accuracy issues intertwined with the jurisdiction and administrative uncertainty found in Canadian marine space. Also shown is how CARIS Spatial Fusion™ was used to integrate and retrieve marine-based information that was later used to highlight decision-making options.

AN INTERACTIVE SPECIES INFORMATION SYSTEM FOR THE BAY OF FUNDY

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The Atlantic Reference Centre (ARC) completed the database development of a species information system (SIS) for the Bay of Fundy with funding from the New Brunswick Environmental Trust Fund (ETF). The system includes marine algae, all invertebrate phyla from sponges to hemichordates, fishes, shorebirds, and marine mammals. For each species, information (where possible) is provided on the scientific name with author and year of description; synonyms and common names, citing publications aiding identification and providing ecological information; habitat description; and the importance as an environmental indicator or for commercial, conservation, educational, scientific or social reasons. The final phase of development, also funded by NB ETF, consists of the website implementation of the SIS, through hosting by the Centre for Marine Biodiversity. Additional information, such as a taxonomic list and links to complementary information, are included during this phase. The project seeks to provide comprehensive and easily accessible species information that is useful to scientists, managers of the environment and resources, as well as the public-at-large.

SUBLITTORAL ECOLOGY AND HABITAT CONSERVATION IN THE OUTER BAY OF FUNDY—PURPOSE AND OBJECTIVES OF THE BOFEP WORKING GROUP

Rabindra Singh and Members of the Working Group

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The BoFEP Working Group on Sublittoral Ecology and Habitat Conservation has an overall aim to provide a means of disseminating information on sublittoral ecology and habitat conservation in the Outer Bay of Fundy (WG Brochure 2004). The Working Group will help define benthic habitats that are of high ecological and conservation value, using a systematic method for the synthesis of relevant data and information. Such a process will, at the same time, help to identify priority areas and geographic gaps in data and knowledge that can be addressed by members of the group, or under other initiatives. This work links to on-going initiatives such as Applied Coastal Ecosystem Studies (ACES, an interdisciplinary project at the St. Andrews Biological Station), the Gulf of Maine Census of Marine Life, the Centre for Marine Biodiversity (CMB) and their proposed Discovery Corridor, and the Marine Invertebrate Diversity Initiative (MIDI). The products will be useful to researchers and the public, and can be used by federal and provincial managers to aid in development of coastal and ocean policies, and management initiatives in the Southwest New Brunswick area. The Working Group's target audience includes the other BoFEP working groups and the public, with the aim of building awareness and involving communities. Membership is open to all interested individuals and organizations.

ACTIVITIES OF THE BOFEP MINAS BASIN WORKING GROUP

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The Minas Basin is a highly productive and dynamic ecosystem, blessed with many natural resources that can be used sustainably for the benefit of its surrounding communities. Some species, habitats, and ecological processes are now threatened by current and anticipated activities in the Basin and its watershed. To sustain or rejuvenate this ecosystem requires co-operation among scientists, researchers, resource users, residents of communities, the private sector, and governments at all levels. The Minas Basin Working Group (MBWG) of the Bay of Fundy Ecosystem Partnership (BoFEP) was established to facilitate co-operative efforts and partnerships to protect and sustain environmental quality in the region, and to promote the sustainable use of natural resources. The MBWG has been very active over the past two years. There have been four Minas Basin Community Forums, a Global Programme of Action Coalition for the Gulf of Maine (GPAC) sponsored Minas Basin Workshop to assess the state of the basin and its watershed, the development of two publications inventorying issues and activities in the watershed, considerable networking with community groups, and stimulation/initiation of other specific projects, e.g., groundwater resources, coastal planning, assessment of causeways, marine environmental quality indicators on the mudflats. The group has approximately 20 members and meets monthly. Through discussion and networking, the group is producing new project opportunities dealing with the overall health and integrated management of the Basin and its resources.

PROPOSED FUNDY BIOSPHERE INITIATIVE

Peter Etheridge

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The Bay of Fundy and the watersheds that drain into the Bay are rich in a diversity that ranges from the mudflats and marshes, that provide the base resources that support marine life in the Bay itself, to the mosaic of coniferous and deciduous forests that cover the rugged cliffs and deep ravines that cut through the terrain. Generations of people have found security, been supported, and been inspired by this ecosystem that compares with the natural wonders found elsewhere in the world that are recognized by the international network of United Nations Educational, Science and Cultural Organization (UNESCO) biosphere sites. However, rapid changes in technology and the increasing demands that we are making on our natural resources are creating new challenges that require new ways of thinking about the relationship of humans to the landscapes that support them. Biosphere designation is one means that enables local communities, scientists and policy makers to address this challenge.

The UNESCO Biosphere Site Program is based on the understanding that human communities live and function within larger ecosystems, and that the health and integrity of both communities and ecosystems depend on enhancing that relationship. Creating a UNESCO biosphere site is a means of bringing about that increased awareness and respect for the integrity of the social, economic and environmental components that make up sustainable landscapes.

In early 2000, a planning committee was formed in the name of the Bay of Fundy Biosphere Initiative (BoFBI). Planning group members visited established biosphere sites in Quebec, held community meetings, and circulated brochures. The time that it takes to acquire designation as a biosphere depends greatly on the support generated and the financial and in-kind resources developed. The planning group continues to build the organization, acquire operational funds, engage communities, and pursue foundational projects. The poster and hand out materials will present information on:

- The proposed area
- Functions of a biosphere site
- Landscape components
- Why a biosphere network?
- Who benefits from a biosphere site?
- Potential conservation benefits
- Potential economic benefits
- Some specific ideas for the upper Bay of Fundy biosphere region
- Who supports the upper Bay of Fundy Biosphere Initiative?
- How can people and communities get involved with the Biosphere Initiative?

B. SALT MARSHES AND TIDAL RESTRICTIONS

CHANGE IN SALT MARSH HABITAT OVER THE LAST 25 YEARS NEAR KINGSPORT, NOVA SCOTIA

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The purpose of this one semester project was to examine the spatial patterns of change in salt marsh habitat near Kingsport, Nova Scotia, over the last 25 years. Salt marsh habitat was quantified from 1977 to 2002, using ArcView 8.3™ and Spatial Analyst extension. Aerial photographs from 1977, 1982, 1992 and 2002 were scanned and rectified, using 1:10,000 digital planimetric maps of the surrounding region. Areas of marsh visible on the photographs were digitized, using on-screen digitizing procedures. Unfortunately, the 1982 and 1992 photographs were not taken at low tide and although waters appear to be at bank-full conditions along the creeks, area estimations would underestimate the amount of total habitat, since *Spartina alterniflora* located below the water line would not be included. These data were thus only used for visualization purposes, and not included in overall calculations of erosion and accretion over the 25-year period. Areas of erosion and accretion are identified, based on an overlay analysis between 1977 and 2002. Between these periods, there was approximately 260,060 m^2 decrease in marsh habitat and a 314,052 m^2 decrease in marsh area. There are some issues regarding the precision of these estimates, due to the difficulty of differentiating the 'back marsh' vegetation from transition upland type, since the area was not formally surveyed in the field, but it was ground-truthed visually. There does appear to be an approximate balance in erosion and progradation of salt marsh habitat in the Kingsport area. Future work will need to formally ground-truth the area and identify control points within the marsh itself, such as old dykes. Although limited in nature, due to the restriction of a one-semester course, this research project demonstrates the use of geographical information systems (GIS) to quantitatively assess changes in salt marsh habitat in the Minas Basin and greater Bay of Fundy.

CHANGE IN DYKELAND PRACTICES IN AGRICULTURAL SALT MARSHES IN COBEQUID BAY, BAY OF FUNDY

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Abstract

This poster presents preliminary results of a research program designed to examine the change in dykeland practices in agricultural salt marsh of Cobequid Bay in the Bay of Fundy, and to document the observed changes of the marshes in response to these modifications. The area of study in Cobequid Bay contains twelve marsh bodies, each with dykes and aboiteaux maintained by the province. The region includes over 2,000 hectares of protected marsh with as many as 30 aboiteaux structures. This research incorporated both interviews with Nova Scotia agricultural personnel as well as preliminary geographical information systems (GIS) analysis and field observations. Each marsh in Cobequid Bay managed by the Nova Scotia Department of Agriculture and Fisheries was assessed in terms of degree of modification, and an initial assessment of change in intertidal habitat as being either erosion, accretion or conversion to agricultural land. These data are presented in a matrix format using the Marsh Project Number, which is the marsh body identification number used by governmental departments to simplify marsh recognition. Overall, the dykeland around Cobequid Bay has experienced many reconstruction projects and the responses of the marshes have been varied. New structures (dyke, aboiteaux, shore protection) have been constructed on almost all marshes (11/12). In addition, existing structures on marshland in this area have all been modified since the 1950s or abandoned. During the federal reconstruction process, smaller holds of marshland were joined into larger more economical marsh bodies, and many older dykes and aboiteaux became obsolete and were abandoned. Intertidal environments have been directly modified (dredging or construction of new channel) on 7 of the 12 marshes. The overall response of the seaward edge of marsh habitat has varied: four present evidence of erosion, seven deposition or expansion. Of these seven, enough new marsh habitat was created along the seaward margin to convert this to new agricultural land. The work presented here represents the preliminary documentation of dykeland modification and categorization of these activities. Increasing the use of modern data analysis techniques, such as GIS and computer modeling, would aid in the accuracy and interpretation of marsh responses to dyke structures.

Introduction

The history of Nova Scotia is tied to agriculture. Settlers around the Bay of Fundy have constructed dykes and aboiteaux for over 350 years, in order to farm the fertile tidal marshes of the Bay of Fundy. The Acadians built dykes because it was easier to dyke in saltwater marshes than to clear trees off higher land; the marsh soil was also more productive. Marshland in the province was privately dyked until 1948, when the federal government set up the *Maritime Marshland Rehabilitation Act* to rebuild the dykes in the Maritimes. The government of Nova Scotia took over the maintenance of the dykes gradually between 1967 and 1970, when the federal government satisfied its mandate to rebuild the dykes. Today, 17,400 hectares of land in Nova Scotia are protected by dyke and aboiteaux, and continual maintenance has been a necessary, labour intensive, and expensive undertaking.

The purpose of this poster is to examine the historical land use and dyking practices of agricultural salt marsh of Cobequid Bay in the Bay of Fundy, and document the observed changes of the marshes in response to dyke structures.

Historical Dyke Activities

French settlers first constructed the maritime dykelands in the 1700s. The new settlers found it easier to build dykes than to clear the upland of trees, and the dyked tidal marshes provided a better quality of soil than the uplands. Salt marshes are transitional areas between land and water, occurring along the intertidal shore of estuaries (Ross 2002). The tidal flooding that inundates these coastal grasslands twice daily deposits silt-sized particles that form soils ideal for farming.

Traditionally, dykes were built with wood posts, firmly packed mud, and grass sod cut from the marsh. A dyke is an earthen structure that prevents tidal flooding of the land it protects. During low tide, the land behind the dyke is drained through an aboiteau sluice. An aboiteau is a culvert under the dyke that has a gate on the tidal side of a dyke. This structure allows fresh water to flow out during times of low tide and prevents salt water from flooding the land during high tides. When water on the landside is higher than water on the tidal side, the gate opens and water will drain out. When water is higher on the tidal side, the gate closes and prevents salt water from flowing to the landside (Figure 1a and 1b). The height of the tide determines the height to which dykes have to be constructed. Elevations of dykes are maintained so that their height is one to two feet above predicted maximum tide elevations (NSDAF 2001). Most dykes measure between one and 2.5 m in height. Historically, aboiteaux were constructed mainly of wood, either hollowed-out logs or boards. Written and oral sources indicate that it took a team of between five to ten Acadians one day to build a section of dyke measuring approximately five m long, 1.8 m high and 3.6 m wide at the base (Ross 2002). During the 1950s, the federal government rebuilt the dyke system in Nova Scotia using modern construction techniques and heavy machinery.

Marsh Legislation and Modern Construction Techniques

Five years after the Acadian deportation in 1755, the government of Nova Scotia passed the first act relating to dykeland. The act provided for each group of landowners to annually assign commissioners, who would decide what work was required for the following year, and to arrange for labour and raise the funds needed to keep the dykes in good condition. Until the 1940s, the dyke system in Nova Scotia was maintained in this manner.

By 1943, the federal and provincial governments of Nova Scotia and New Brunswick came to recognize the value of the dykelands and formed the Maritime Dykeland Rehabilitation Committee. For the first time, the condition of the Maritime dykelands was to be treated as a single ongoing project (NSDAM 1987). In 1948, the federal government created the *Maritime Marshland Rehabilitation Act*.

Under the act, the federal government would build, replace and repair dykes where it was believed to be economically sound. At the time, the three Maritime Provinces co-operated with landowners to promote land-use programs and to improve internal drainage of dykelands. Over the next 20 years, the Maritime Marshland Rehabilitation Administration (MMRA) began applying modern engineering techniques to the traditional problems of dykeland construction and maintenance. Based in Amherst, Nova Scotia, the MMRA ensured the protection of 18,000 hectares of tidal farmland in Nova Scotia and 115,000 hectares in New Brunswick, building over 370 kms of dyke in the process (NSDAM 1987).

The federal government turned over the responsibility of maintenance for the dykes to the province in 1967. Since then, small holds have been assembled into larger, more efficient units through a drainage technique known as landforming. Landforming basically involves shaping the surface of the soil so that excess rainfall will run off into grassed waterways and ditches. This allows the soil to dry much faster, making it possible to grow a greater variety of crops on the dyked marsh soil. The Nova Scotia Department of Agriculture and Fisheries, Resource Stewardship Division, Land Protection Section is currently responsible for tidal dyke maintenance. At the present time, the landowners are responsible for maintenance of internal dyke roads, and also the acquisition of land required for the reconstruction of dykes and aboiteaux.

Study Area and Methodology

The area of study in Cobequid Bay (Figure 2) contains twelve marsh bodies each with dykes and aboiteaux maintained by the province. The region includes over 2,000 hectares of protected marsh with as many as 30 aboiteaux structures. This research incorporated both interviews with NS Department of Agriculture and Fisheries personnel, as well as preliminary GIS analysis and field observations. Each marsh in Cobequid Bay managed by the NS Department of Agriculture and Fisheries was assessed in terms of degree of modification and an initial assessment change in intertidal habitat as either erosion, accretion, or conversion to agricultural land. The data are presented in a matrix format using the Marsh Project Number, which is the marsh body identification number used by governmental departments to simplify marsh recognition.

Each type of change to a marsh is listed in the column header, and each header is divided into categories describing the change. New structures indicates construction of dykes, aboiteaux, and addition of shore protection where none had existed previously. Construction of new dykes took place to reclaim marshland and aboiteaux were constructed in new locations due to the evolution of drainage patterns. Shore protection usually involved adding rock facing or concrete barriers to protect shorelines from erosion and tidal inundation (Figure 3).

Changes to existing dykes, aboiteaux, culverts, and shore protection are indicated under “Modification of Existing Structures”. Modification of dykes includes rebuilding all of or sections of existing dykes, or significantly altering the height by building on top of an existing dyke. Aboiteaux modifications include culvert replacement, addition of downstream sidewalls, and installation of flared upstream entrances. “Modification of Intertidal Environment” consists of dredging new or existing channels for intertidal drainage. Dredging a new channel involves redirecting the upland drainage system, while dredging an existing channel serves to improve existing drainage channels by removing the accumulation of sediment blocking an aboiteau structure. During the federal reconstruction process, smaller holds of marshland were joined into larger more economical marsh bodies, and many older dykes and aboiteaux became obsolete. Where these structures were deserted is found in the "Abandoned" column. "Observations of Marsh Responses to Dyke Structures" lists observations of erosion (Figure 4), deposition/expansion, and conversion of marshland directly related to dyke structures. A marsh body increases or decreases in area in response to dyke structures, due to the effect on tidal cycles and currents. A marsh body has eroded when mass wasting due to tidal action decreases the total marsh area. Conversion takes place when the land use of the marsh changes, for example salt marsh transformed into agricultural field is a land use conversion.

Results

Overall the dykeland around the Cobequid Bay has experienced many reconstruction projects and the responses of the marshes have been varied. Table 1 summarizes the elements included in each project and the subsequent marsh response.

These practices, however, may not have taken place over the entire length of marsh. Therefore, one marsh body may have new dykes constructed over part of its length, whereas another section dyke along the same marsh body may be abandoned.

New structures (dyke, aboiteaux, shore protection) have been constructed on almost all marshes (11/12). In addition, existing structures on marshland in this area have all been modified since the 1950s or abandoned. The highly variable deposition and accretion patterns, as well as anthropogenic influence over the years, have altered the size and drainage patterns within the marshes. Therefore, new structures were constructed in response to changing conditions. During the federal reconstruction process, smaller holds of marshland were joined into larger more economical marsh bodies, and many older dykes and aboiteaux became obsolete and were abandoned. Intertidal environments have been directly modified (dredging or construction of new channel) on 7 of the 12 marshes. Although dredging can be a regular maintenance practice on some of the more actively accreting marshes, only the major construction projects are shown here. The overall response of the seaward edge of marsh habitat has varied: four present evidence of erosion, seven deposition or expansion. Of these seven, enough new marsh habitat was created along the seaward margin to convert this to new agricultural land.

Discussion and Conclusion

The reconstruction of the dykelands using modern construction techniques (Figure 5) joined together smaller holds of agricultural lands into more efficient and easily maintained larger units. In most cases, the new federally-built dykes were constructed over, or used the same orientation, as the existing structures. Due to heavy accumulation of sediments and decay of construction materials, the aboiteaux drainage system was reorganized to be more efficient and contain fewer structures. Most wooden culverts of older aboiteaux culverts have been replaced or relined with high-density polyethylene pipe (Figures 6). The design of aboiteaux has been also been modernized to reduce blockage and increase flow capacity. Structures around the downstream end of an aboiteau, called sidewalls, reduce the chance of a gate being blocked, and a flared entrance on the upstream end increases the flow capacity of the culvert. In some marsh bodies, the reconstruction effort involved both construction of new dyke along with the restoration of existing dyke. An example of this took place on NS12, where a new section of dyke was built in front of an abandoned section between two areas of reconstructed dyke. The total amount of agricultural land was expanded and the amount of aboiteaux needed to drain the upland was reduced to a single culvert.

Dredging drainage channels can be a routine maintenance practice on some dykelands, especially where accretion is particularly high. When the upstream flow is too low to remove the accumulation of silt on the tidal side of a dyke, dredging is necessary for proper drainage of the agricultural fields. Therefore, the modifications to the intertidal environment listed in the chart only accounts for dredging in major reconstruction projects. For instance, in NS15, a new river channel was dredged to redirect the upstream flow to a central aboiteau. Dykes have been abandoned where land has been reclaimed or when drainage patterns have changed and the land behind the dyke is no longer threatened by tidal inundation.

Marsh responses to dyke structures vary from marsh to marsh. In some cases, especially with the larger marsh bodies, responses to dyke structures include both erosion and deposition/expansion. These observations are due to the size and location of marshlands in the Bay. Some dyked marshes are located in areas of the Bay that are actively eroding and accreting in different regions along the same stretch of shoreline. The process of erosion and deposition is not constant for a particular area, and a marsh that is actively eroding for years may suddenly start accreting and building on existing marsh. The amount of sedimentation on Fundy's shores is highly sensitive to shifts in currents, and the categorization of a marsh as expanding or eroding is usually short-lived. The continual maintenance and observation of the dykelands is a labour intensive and expensive undertaking. Future research will investigate the role of natural forcing functions, such as changes in wind/wave climate, ice, channel migration, and sediment availability.

Future Directions

A more comprehensive examination of the marshes in the Bay of Fundy is needed to provide a complete picture of the processes that shape marsh response to dyke structures. The area studied is small compared to the extent of agricultural salt marsh of the Bay. Since erosion and deposition change in time for certain areas of marsh, it would be beneficial to document observed changes in sedimentation and currents in different regions around the Bay. Modern data analysis tools, such as GIS databases and computer modelling, can be used to track and predict future changes and responses to dyke construction or proposed marshland projects. The NS Department of Agriculture and Fisheries has compiled a GIS database of Nova Scotia's dykelands that contains maps of current marsh body expanses. If this database were updated using survey techniques, and land use data were collected periodically, marsh changes could be monitored more easily and accurately. With the increasing use of GIS technology and computer modelling, the picture of Nova Scotia's changing dykelands will be more comprehensive and changes can be studied and/or predicted.

Acknowledgments

This project would not have been possible without the co-operation of NSDAF Resource Stewardship Division personnel, including Hank Kolstee, Darryl Hingley, and Ken Carrol. Thanks to Kelly Mazerolle and Greg Baker for field assistance and map creation. The summer research project was funded by a NSERC discovery grant to Danika van Proosdij and the Nova Scotia Government Summer Experience Program.

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Table 1. Matrix of marsh response to dyking practices

Marsh Number	New Structures			Modification of Existing Structures			Modification of Intertidal Environment		Abandoned		Observations of Marsh Responses to Dyke Structures		
	Dyke	Aboiteaux	Shore Protection	Rebuilding Over Existing Dyke	Culvert	Shore Protection	Dredged Existing Channel	Dredged New Channel	Dyke	Aboiteaux	Erosion	Deposition/ Expansion	Conversion
NS11				■	■	■		■		■			
NS12	■	■		■		■		■	■	■		■	■
NS15					■			■	■	■			■
NS23	■		■	■	■				■	■	■	■	
NS39	■			■	■		■		■		■		
NS40	■		■		■	■			■	■		■	■
NS64	■	■		■	■		■		■	■		■	■
NS66	■			■	■				■	■		■	■
NS67				■	■	■			■	■	■	■	
NS81	■	■		■	■	■	■		■	■		■	■
NS86			■	■	■	■			■				
NS90	■			■	■					■	■		

Figure 1. Aboiteau at a) low tide and b) high tide

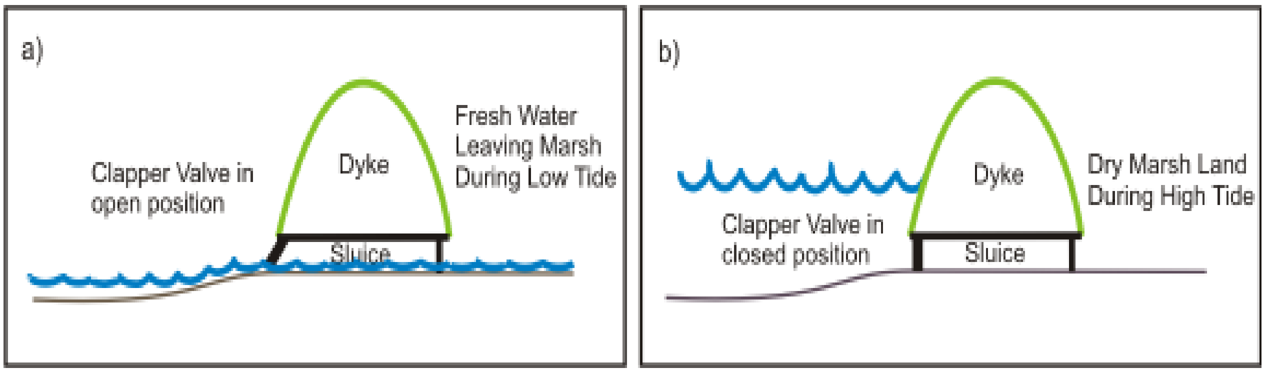

Figure 2. Study area Marsh Indicator Map over 1994 aerial photograph (Marshland data provided by NSDAF, map created by G. Baker, 2004)

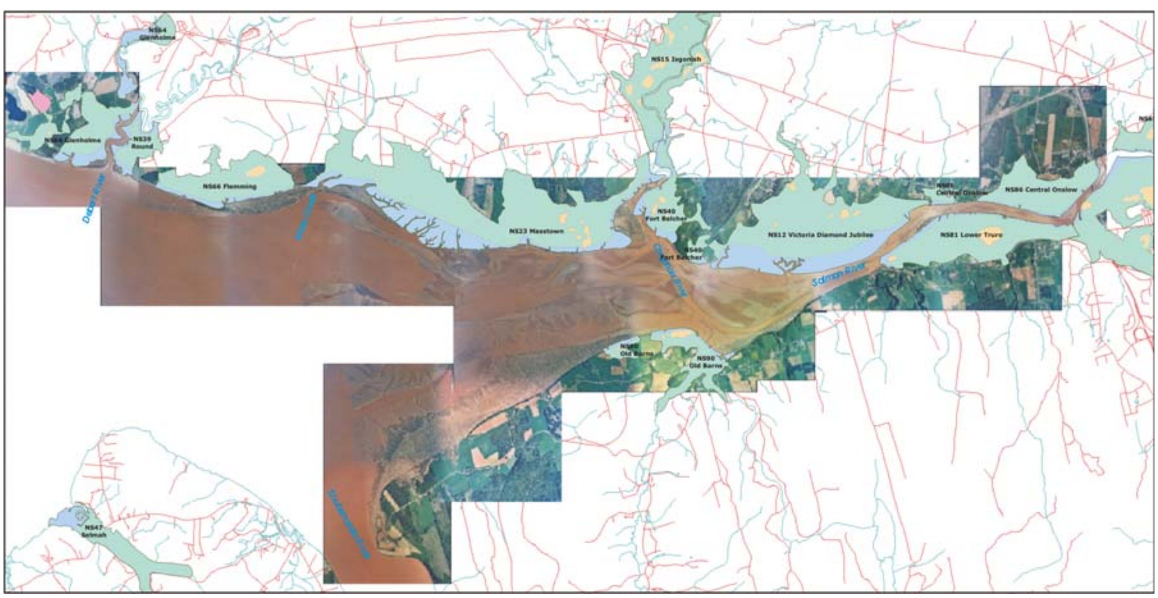

Figure 3. Example of shore protection along Cobequid Bay (Photo by D. van Proosdij, June 2004)

Figure 4. Bank slumping and erosion at Old Barns (Photo by D. van Proosdij, June 2004)

Figure 5. Construction of modern dyke (Source: H. Kolstee, NSDAF, 2004)

Figure 6. Culvert being replaced with high-density polyethylene pipe (Source: H. Kolstee, NSDAF, 2004)

VARIATIONS IN SEDIMENT DEPOSITION AND SUSPENDED PARTICULATE MATTER ON THREE MACROTIDAL SALT MARSHES IN THE MINAS BASIN

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The purpose of this research was to compare sediment deposition and suspended sediment concentrations between three low marsh environments in the Minas Basin. Three marshes (Windsor, Ransom Creek and Oak Point) were chosen, based on accessibility, variable topographic gradient, and the presence of a significant amount of *Spartina alterniflora*. Accessibility was an important variable since all three sites had to be sampled within a single tide. Suspended particulate matter (SPM) and sediment deposition were measured over 15 tides during the summer of 2003, using rising-stage bottles and surface mounted sediment traps. Three stations were established along one transect perpendicular to the marsh/mudflat interface at each marsh. Topographic surveys were conducted at each site using a Leica TPS700 total station tied into a high precision geodetic survey monument. Elevations were expressed relative to mean sea level as expressed by the EMG96 Geoid model. Significant differences in SPM were recorded between Oak Point and both Ransom and Windsor. Similar amounts of SPM were recorded at Ransom and Windsor. Oak Point exhibited the lowest amounts of sediment deposition and SPM. Highest amounts of deposition were recorded on the Windsor salt marsh. Further analysis is ongoing. These data will contribute to ongoing salt marsh sediment dynamics research underway in the Minas Basin.

USE OF GEOGRAPHICAL INFORMATION SYSTEMS TO ASSIST IN THE PRIORITIZATION OF RESTRICTED AND PARTIALLY RESTRICTED SALT MARSH SITES FOR RESTORATION

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The purpose of this one semester project was to use geographical information systems (GIS) to assist the Conservation Council of New Brunswick to incorporate their 'tidal barrier audits' into a digital database. The overall aim was to assist in the prioritization of potential salt marsh sites within the Bay of Fundy for restoration. All barriers from the study were categorized and georeferenced on a digital map of New Brunswick. More detailed analysis was conducted within Albert and Westmorland counties, which are located in southeastern New Brunswick, using 1:10,000 planimetric digital map sheets and global positioning system (GPS) locations of all the tidal barriers. Within the study area, there are 15 bridges, 28 culverts, four aboiteaux, three railway bridges, and one each of causeway/dam, covered bridge, culvert/aboiteaux, causeway/aboiteaux, causeway/bridge, and water control structure. The main purpose of this section of the study was to rank tidal barriers identified as restricted and partially restricted, using criteria identified in the tidal barrier audit and spatial variables such as accessibility, land use, density and salmon habitat. Area of marsh was not able to be determined for this study due to lack of availability of the aerial photographs in time for the project. All queries and analyses were conducted using ArcView 8.3™, and data were transformed to New Brunswick CSRS 98 Stereographic NAD 83 for compatibility. Sites were identified which could be assessed for non-spatial parameters such as landowner co-operation and local politics. The main strength of using GIS is its ability to conduct spatial queries quickly and easily. However, some factors that would be used in the final site selection are unquantifiable.

CONTROLS ON THE DISTRIBUTION OF VEGETATION CHARACTERISTICS IN A TIDALLY RESTRICTED MACROTIDAL SALT MARSH

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Salt marshes on the Bay of Fundy are ecologically significant ecosystems. The Bay of Fundy has lost 80 percent of its salt marshes, mostly due to tidal barriers such as causeways or inadequately sized culverts and historical dykes. The purpose of this project was to determine the relative significance of the controls on the distribution of vegetation characteristics in a partially restricted salt marsh system. This project will serve as an important baseline study to assist in effective restoration and management of a partially restricted ecosystem. The study was conducted on a section of the Cheverie Creek Marsh, on the Minas Basin of the Bay of Fundy. This marsh system is partially restricted due to historical dyking and a culvert that is inadequately sized for the large tides that enter the Minas Basin. Using a stratified random sampling design, 92 stations were sampled along eight transects to examine the hypothesized controls on vegetation characteristics. The controls considered were elevation, organic matter, frequency, and duration of flooding, and distance from the creek. The three vegetation characteristics measured were species richness, density, and average height. The elevations were obtained using a global positioning system (GPS), and modeled in ArcView 3.28™ using Spatial Analyst Extension. The substrate and vegetation characteristics, which were collected with cores and quadrats, respectively, were interpolated using "Inverse Distance Weighted", with a grid size of one meter. It was found that the two dominant plant species on the marsh were *Spartina alterniflora* and *Spartina patens*. Species richness was very low over the marsh surface, as much of the area was monospecific. The average height of the vegetation was greatest at the creek banks and at the upland borders. The average density was lowest at the creek and increased towards the upland edge. Organic matter increased towards the upland edge, and bulk density increased towards the creek. The mean grain size fluctuated over the marsh surface and the soil texture was mostly silt and sand. Linear multiple regressions were used to test the significance of the controls on the vegetation characteristics. Elevation was the only significant control and it affected species richness.

** Second Place Student Poster Award winner

BASELINE DATA COLLECTION AT COGMAGUN ESTUARY, A FRESH WATER IMPOUNDMENT REVERTING TO SALT MARSH HABITAT

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Salt marshes are highly productive habitats that contribute to the Bay of Fundy's marine food web and serve as feeding and refuge habitat for wildlife. Over 80 percent of salt marshes in the Bay of Fundy have been lost or degraded through human activities, such as dyking and coastal development. Salt marsh restoration, a relatively new concept in Atlantic Canada, is a process aimed at returning a damaged salt marsh to a state that is as close as possible to its original natural condition. Such projects are still in their infancy, consequently there is little data concerning the restoration process and how restoration activities may affect an existing ecosystem.

The purpose of this project was to collect baseline data at a Ducks Unlimited freshwater impoundment and the surrounding salt marsh. The impoundment, which is near the mouth of the Cogmagun River, Center Burlington, Nova Scotia, is experiencing tidal breaching. Its dyke structure will no longer be maintained because of high maintenance costs and rising sea levels. Over time, the dyke system will continue to fail and the impoundment will be subject to increased tidal breaching. Natural restoration to a tidal system will be the result.

The field research consisted of the documentation of the abundance of plant and fish species in the impoundment and salt marsh habitats, as well as basic hydrology (salinity, temperature and depth). In observing and documenting changes that occur over time, the natural restoration process can be monitored, and the data will be used as a reference for artificial salt marsh restoration projects.

DIGITAL DATABASE DEVELOPMENT OF ENVIRONMENTAL PARAMETERS RELATING TO TIDAL BARRIERS AND ECOSYSTEM HEALTH IN THE BAY OF FUNDY

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Over the last century, the majority of rivers entering into the Bay of Fundy have been highly modified through the construction of tidal barriers. The construction of these barriers resulted in either partial or complete obstruction to tidal flow in many areas around the Bay. Tidal barriers effectively decrease turbulent energy in the tidal system, causing sediments and other particles to drop from suspension and accumulate as deposits of mud, sand and silt. In other areas, localized erosion is initiated either directly upstream or downstream of a partially restrictive barrier. Ecosystems inhabiting this zone, such as mudflats and salt marshes, are some of the first environments to feel the effects of coastal modification. These changes have cascading impacts on intertidal ecosystems, some negative and others positive. Overall, however, the cumulative impacts of tidal barriers on intertidal ecosystems of the Bay of Fundy are unknown. This is of particular concern because of the increasing interest in removing or modifying tidal barriers in an effort to 'return the tides'. Without a solid baseline of past and present 'states' of these systems, assessing or predicting the success of restoration activities is difficult.

The purpose of this collaborative research project is to develop a comprehensive, digital, spatial database to integrate a series of environmental indicators over time, which can serve as a baseline to assess the cumulative impacts of tidal barriers in the upper Bay of Fundy. The research will focus on the southern bight of the Minas Basin and the surrounding watershed as a case study of the application of such a database.

RETURN THE TIDES—RESULTS OF A THREE-YEAR TIDAL BARRIERS AUDIT IN THE BAY OF FUNDY

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An audit of the tidal barriers on the New Brunswick side of the Bay of Fundy has been completed and the data analyzed. This poster presents the results of the audit. Students were deployed during the summers of 2000–2002, starting from the north of the Bay and working towards the St. Croix Estuary. Many barriers have been found, the most common being culverts that are either too small, damaged or poorly positioned relative to high and low water levels. At each site, the impediment was described, current flow was measured above and below the barrier, and the site was extensively photographed. A full report has been completed and further studies are recommended at specific sites where salt marshes or migratory fish may be at risk, and where the barriers can be removed or reduced at minimal cost.

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C. BIOLOGY, ECOLOGY AND HABITAT PROTECTION/RESTORATION

INTRASPECIFIC GENETIC VARIATION IN THE CENTRIC DIATOM *THALASSIOSIRA NORDENSKIOELDII* CLEVE

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Genetic variation is central to species survival because it can allow the species to respond to changing environmental conditions. Past studies of genetic variation have neglected many groups of ecologically significant micro-organisms, including diatoms. It has been hypothesized that a large reservoir of genetic variation allows the cosmopolitan distribution of many species of phytoplankton. Past studies of this type have required culturing and, therefore, have underestimated the actual levels of variation within diatom species. The present study examined the genetic variation found in naturally occurring populations of a locally common diatom species, *Thalassiosira nordenskioeldii* Cleve. Colonies, as chains of mitotically reproducing cells, were isolated from samples taken during four weeks of a bloom, from three sites in the Bay of Fundy. Cells of each chain were divided into two tubes for parallel analyses; scanning electron microscopy (SEM) for species identification and molecular genetic analysis. Cells for the latter analysis underwent DNA liberation by repeated freezing and thawing. The resulting cellular material was equally divided for PCR amplifications of nuclear fragments (3' end of SSU rRNA for molecular verification of species, and the ITS1 region for estimating genetic variation). SEM revealed that the correct species had been isolated in 89 percent of samples. Sample recovery rates for SEM preparations were 19.8 percent, indicating that more vigilance is required during these steps to prevent colony loss during transfer. Molecular results will be used to provide useful information on the spatial and temporal genetic variability in the local populations of a common and abundant spring diatom.

** First Place Student Poster Award winner

A SPATIALLY HIERARCHICAL SAMPLING DESIGN TO STUDY THE DISTRIBUTION OF THE AMPHIPOD *COROPHIUM VOLUTATOR* ON THE MUDFLATS OF THE UPPER BAY OF FUNDY

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We used a spatially hierarchical sampling design to obtain information on the distribution and scale of patchiness of the amphipod *Corophium volutator* on Daniel's Flat in the upper Bay of Fundy. Core samples were taken at the four corners of 10-cm squares that were located at the corners of 1-m squares. The 1-m squares were located at the corners of three 10-m squares that were placed 100 m apart on a line parallel to shore. Nested ANOVA indicated that *C. volutator* densities varied significantly according to the position of the 10-cm and 1-m squares. Therefore, *C. volutator* distribution appears to include patches of ~10 cm and 1 m in size. However, most of the variation was not explained by the model, suggesting that the distribution also includes patches smaller than 10 cm. This sampling design will be a useful tool for future descriptive and experimental studies, as it allows the quantification of changes in patch size (in addition to changes in density) between different factors.

THE ENVIRONMENTAL DAMAGES FUND: SUPPORTING RESTORATION OF COASTAL ECOSYSTEMS

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The accidental release or discharge of chemicals into the environment, or habitat disturbances from human activities, can have adverse effects on fish, wildlife, and other ecosystem components. When a pollution incident occurs that results in environmental damage, courts may use a number of pieces of federal environmental legislation to obtain compensation from a polluter. The compensatory awards received as a result of oil spills, chemical releases, or habitat disruptions may be directed to the Environmental Damages Fund (EDF). The EDF, established by the federal government in 1995, serves as a special holding account to manage funds received in compensation for environmental damages caused by pollution incidents. Awards can be used by communities, aboriginal groups, or other eligible recipients to restore or remediate environmental damage in affected coastal or watershed areas. The EDF operates on the polluter pays principle. It ensures that compensation received from pollution incidents impacting the Bay of Fundy will be directed to support activities that restore the Bay's watersheds and marine environments. This poster will provide an overview of the EDF framework, and will demonstrate the types of community-based environmental restoration projects that have been supported by the Fund.

USE OF RAYLEIGH WAVES AS REFERENCE FOR DETERMINING SETBACK DISTANCES FOR EXPLOSIONS NEAR SHORELINES

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The use of explosives in engineering works, such as stone quarries, may produce negative effects not only on structures and people, but also on the environment. Usually, only the direct compression waves are considered in assessing the damage to fish and marine mammals in the vicinity of the explosion. Rayleigh waves can be transmitted from solid to liquid and, consequently, affect the marine environment. Rayleigh waves are surface waves, with their travel confined to the upper part of the free earth or water surface. However, they attenuate more slowly than the compression and shear waves (the body waves). Also, the low frequency components arising from explosions are characterized by wavelengths, which may involve the upper 100 m of the sea. The relationship among the several factors that influence the attenuation phenomenon (i.e. distance and depth of explosions, weight of charge, soil conditions, shape of excavation) is analyzed and the results are compared with other laws proposed in the literature. The difference in the geometrical attenuation laws of body waves and Rayleigh waves implies that, at a certain distance from the explosion, the peak particle velocity (or, equivalently, the overpressure) is higher for Rayleigh waves than for body waves. In order to respect the upper limits on peak particle velocity and overpressure imposed by the prevailing guidelines (for example, 13 mm/s and 100 kPa, respectively, in the Fisheries and Ocean Canada guidelines), the required setback distance, from the center of the explosive to fish habitat, will be greater for Rayleigh waves than for body waves.

OPTIONS FOR RESTORATION OF BALTZER'S BOG, A WETLAND WITHIN THE BAY OF FUNDY WATERSHED

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Baltzer's Bog is a 72 hectare wetland complex, encompassing bog, fen, marsh, and shallow water areas. The site has a long and varied history of human use. Since 2000, a peat mining operation has extracted a significant portion of overlying peat moss (moss-grade peat) and underlying peat. The mining and associated activities have resulted in severe degradation of approximately three quarters of the bog. As a result of grievances put forward by the local community and scientific interest in the site, the mining operation has recently been halted. This leaves the question of how to restore the wetland. Several actions would contribute to the successful restoration of Baltzer's Bog. Most crucial is the blocking of the drainage ditches in order to raise the water table. Efforts should also be directed towards removing trees, re-establishing a "hummock and hollow" topography on the site, encouraging wetland vegetation, and establishing a buffer around the bog to prevent siltation and eutrophication. Transects consisting of vertical peat faces together with the peat/substratum boundary, have been exposed at the site, and so paleo-environmental studies should be conducted while the opportunity exists. Baltzer's Bog presents a valuable opportunity for learning about peatlands and their restoration in the Bay of Fundy watershed.

D. CONTAMINANTS

THE OCCURRENCE, BEHAVIOUR AND FATE OF NATURAL AND SYNTHETIC ESTROGENIC COMPOUNDS IN HALIFAX HARBOUR

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In recent years, there has been a great deal of concern in the scientific community about a group of chemicals, found in treated and untreated sewage effluents, known as endocrine disrupting compounds (EDCs). A specific group of EDCs, known as estrogenic compounds, are capable of mimicking the natural endogenous hormone estradiol, and in turn causing specific changes in the sexual development of many aquatic organisms (Arcand-Hoy et al. 1998). A variety of compounds have been identified as being estrogenic compounds, including the natural estrogen hormones, and many anthropogenic compounds, such as certain pharmaceuticals and synthetic industrial compounds.

An important aspect of the research in the field of estrogenic compounds is to examine their behaviour and fate once they are released into the environment in sewage effluents. To date, the majority of research on this topic has occurred in freshwater environments (Lai et al. 2000; Holthaus et al. 2002; Jürgens et al. 2002), while research in the marine environment is limited (Ying and Kookana 2003). The goal of this study is to examine the behaviour and fate of several estrogenic compounds in the marine environment. To accomplish this, an analytical method has been developed to detect several phenolic estrogenic compounds in marine samples. This method was applied to samples collected from Halifax Harbour. These samples were also used to conduct experiments in the laboratory to examine the sorption and biodegradation of these compounds in marine seawater and sediment.

Three phenolic estrogenic compounds were selected as the target compounds for study. The steroid 17â-estradiol is a natural estrogen hormone that is produced in higher concentrations by females, and is found in both treated and untreated sewage effluents. Ethynylestradiol is a synthetic estrogen and is the active ingredient in oral contraceptives. Bisphenol-A is a synthetic industrial compound used in the manufacture of various plastic products.

Halifax Harbour, like many other marine inlets, has been used for the disposal of human and industrial wastes for over 200 years. There are currently 44 sewer outfalls and 10 fluvial drainage systems that release over 180,000 cubic meters of raw untreated sewage per day (Buckley et al. 1995). Due to this large volume of sewage pollution, Halifax Harbour represents an ideal location to study estrogenic compounds in the marine environment. Locations for the sampling of water and sediment from the Harbour were selected based on their proximity to known sewage outlets.

The analytical method for the detection of the target compounds in seawater was based on previously established methods for freshwater analysis. A 4-L seawater sample was collected and filtered to remove suspended particulate matter. The target compounds were extracted from the water sample using an Empore SDB-XC solid phase extraction disk. Analysis was performed using either high performance liquid chromatography (HPLC) with fluorescence detection or gas chromatography-mass spectrometry (GC-MS).

The sorption and biodegradation of the target compounds in different marine sediments were studied using a series of laboratory experiments. Mixtures of seawater and sediment from different locations around Halifax Harbour were spiked with the target compounds. Samples were taken from this mixture at predetermined time intervals over a period of two weeks to determine the concentrations in the water and sediment phases. The effect of different sediment microbial communities on the biodegradation rates of the compounds was examined by comparing sewage contaminated samples collected from Halifax Harbour with those from a clean reference site in Hantsport (Bay of Fundy).

Preliminary HPLC results, from the analysis of seawater samples collected from two locations near sewage outlets in Halifax Harbour, indicate that Bisphenol-A and estradiol were present at concentrations ranging from 20-100 ng/L. These concentrations are higher than expected for estradiol based on previous studies in freshwater environments impacted by sewage pollution, where concentrations ranged in the 0-10 ng/L range (Snyder et al. 1999; Ternes et al. 1999). Future analysis of water samples will be conducted using GC-MS for more advanced identification and lower detection limits for quantification.

The sorption and biodegradation experiments were conducted using seawater and sediment collected during the summer of 2004 from two sites in Halifax Harbour, as well as the Hantsport, NS, reference site. Table 1 summarizes the properties of the water and sediment collected from these sites. The sediment samples collected from Halifax Harbour were high in organic carbon compared to the reference site, and the Halifax Harbour samples also had high total and fecal coliform counts, which indicate sewage contamination.

The preliminary results for the sorption and biodegradation of estradiol in the seawater/sediment mixtures are shown in Figures 1 and 2. The aqueous concentration graph (Figure 1) shows that for all three sites, the concentration of estradiol decreased significantly in the first 48 hours of the experiment, and by the end of two weeks estradiol was not detected in the aqueous phase. The sediment concentration graph (Figure 2) shows that estradiol concentrations were highest at the beginning of the experiment, and after two weeks all the estradiol had been degraded. The higher concentrations of estradiol in the Halifax Harbour sediment indicates that sorption onto these organic rich sediments plays an important role in removing these compounds from the aqueous phase (Lai et al. 2000). The complete biodegradation of estradiol in the water/sediment mixture from all three sites after two weeks is similar to the biodegradation rates reported in previous studies (Jürgens et al. 2002; Ying and Kookana 2003). This indicates that marine micro-organisms present at the reference site, and perhaps the sewage bacteria in the Halifax Harbour samples, are capable of biodegrading estradiol.

Future research for this project will include conducting further sorption/biodegradation experiments using seawater and sediment collected from other locations in Halifax Harbour where the seawater and sediment properties are different, compared to the locations previously studied. Experiments will also be conducted using autoclaved samples, to study the sorption process without influence from biodegradation. To examine the occurrence of the target compounds in Halifax Harbour, water samples from several locations will be collected, extracted and analyzed using a GC-MS procedure for phenolic compounds.

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Table 1. Properties of the sediment (% Total Carbon, % Organic Carbon) and seawater (Total and Fecal Coliforms) used in the sorption and biodegradation experiments

	Sediment Properties		Seawater Properties	
	T.C. (%)	**O.C. (%)**	**Total Coliforms**	**Fecal Coliforms**
Halifax Harbour Site 4	5.53	5.19	92,000 per 100ml	24,000 per 100ml
Halifax Harbour Site 7	7.17	6.76	1.6 million per 100ml	540,000 per 100ml
Hantsport Reference Site	0.88	0.69	N/A	N/A

Figure 1. The change in concentration of estradiol in the aqueous phase over time during the sorption/ biodegradation experiment. The aqueous phase concentration of estradiol decreased significantly in the first 48 hours of the experiment, and by the end of two weeks estradiol was no longer detected.

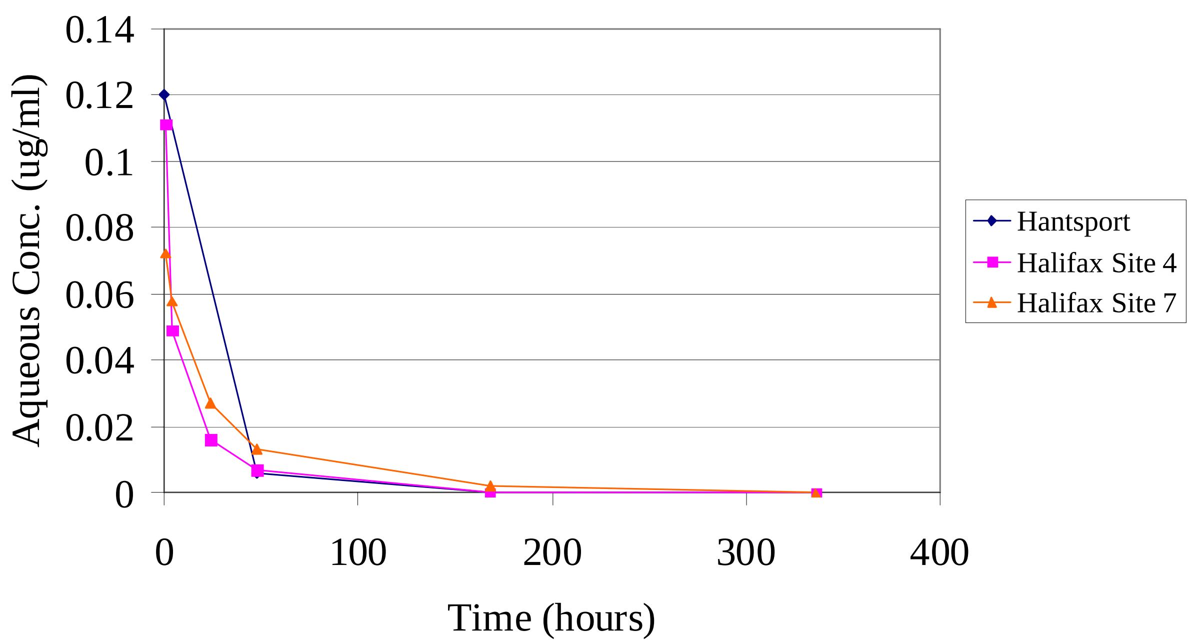
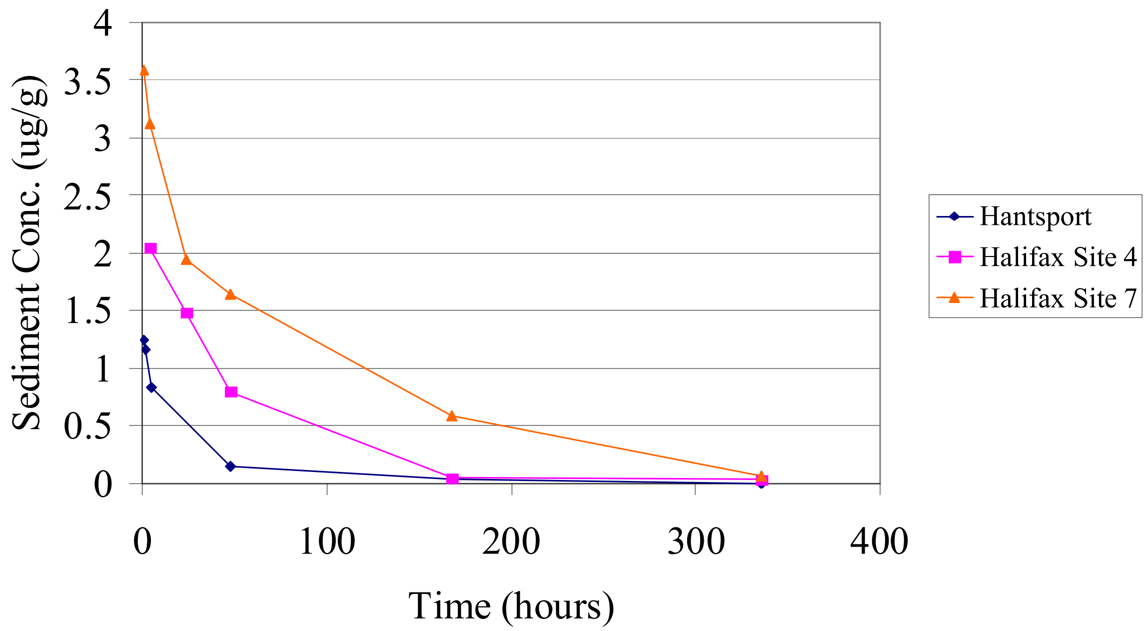


Figure 2. The change in concentration of estradiol in the sediment phase over time during the sorption/biodegradation experiment. The concentration of estradiol in the sediment was initially higher in the samples from Halifax Harbour because of their higher organic carbon content compared to the reference site. After two weeks, estradiol had been completely degraded in the sediment from all three sites.



PESTICIDES IN AN ESTUARY ON PRINCE EDWARD ISLAND, CANADA

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Prince Edward Island (PEI) has a history of fish kills that have been linked to the use of pesticides. In particular, pesticides, such as azinphos-methyl and chlorothalonil, have been linked to fish kills in recent years. Azinphos-methyl, also sold under the name of Guthion, is an insecticide used to control leaf-feeding insects, such as the potato beetle and the corn borer (Kamrin 1997). Chlorothalonil is a widely used fungicide that is used to control fungal diseases, such as late blight and downy mildew (Environment Canada 2004). In many cases, pesticide-laden runoff can be implicated in fish kills shortly after a pesticide application that is followed by a rainfall event. It is noteworthy to mention that while "fish kills" may be the most obvious consequence of such pesticide problems, pesticides kill far more than fish, and the effects of contamination on an ecosystem as a whole should be considered.

However, pesticide use is a mainstay of the agriculture industry and as such has become vital to the province of PEI as a whole. Potatoes alone are the largest agricultural commodity in the province, and typically have an annual farm value nearing 200 million dollars, representing over fifty percent of total farm cash receipts (PEI Department of Agriculture, Fisheries, Aquaculture and Forestry 2004). Overall, primary agriculture and related agri-food processing contributes eleven percent to the provincial Gross Domestic Product (PEI Department of Agriculture, Fisheries, Aquaculture and Forestry 2004). With such importance placed on the industry, in terms of the province's economic health, the merits of the use of pesticides and the needs of farmers should not be overlooked.

This investigation has focussed on the Wilmot River and Dunk River estuary of Summerside Harbour in PEI (Figure 1). The city of Summerside is located approximately fifty kilometers west of Charlottetown, and is of interest due to previously encountered fish kills related to pesticide applications near rivers leading into Summerside Harbour. The estuary itself receives input from the Wilmot River, draining effluents from a number of farms undergoing pesticide remediation experiments, and from the Dunk River, representing more of a reference site, where remediation has not been attempted.

It is known that pesticides can bind to soil and be transported in particulate and soluble phases. As such, pesticides could be transported from the locations where they are applied, swept into nearby rivers, and then end up in estuaries such as the Summerside Harbour. As it is known that pesticides have been involved in several fish kills over the past few years on Prince Edward Island, the degree of pesticide contamination in the estuary is of interest. A list, comprised of eighteen pesticides, ranked by the Air and Toxics Issues Section of Environment Canada–Atlantic Region according to use in Prince

Edward Island, bioconcentration potential, and known toxicity, were analyzed in a number of water and sediment estuarine samples (Table 1).

Surface sediments were collected with an Eckman grab sampler and placed in pre-cleaned glass mason jars with lids lined with solvent rinsed aluminium foil. Samples were placed on ice within two hours of collection and frozen within 24 hours. Water was collected at a 10 cm depth in pre-cleaned one-liter amber glass bottles. Samples were collected from five sites located at approximate distances of 1, 100, 500, 1,000, 2,000 m from the Dunk and Wilmot rivers (Figure 1). The first sample set of sediment and water samples (collected from the total of ten sampling locations) was collected 24 hours after the beginning of a rainfall event on August 8, 2003. Sample collections at the ten sites were repeated on September 11 and October 23, 2003.

The eighteen pesticides were not detected in either the water samples or in the sediment samples (Table 1), with the exception of chlorothalonil (0.6 ug/g at site 4 on the Dunk River in October). To improve detection in the water samples, the samples from five sites along a river (that were sampled at one point in time) were combined, and the volume reduced before gas chromatography-mass spectrometry (GC-MS) analysis. Although detection limits were improved by a factor of 20, pesticides were still not detected. Further analyses of samples are currently underway to determine trace pesticide concentrations (of a subset of more critical pesticides from the pesticide suite) that may be detectable through more complex analytical procedures.

Results will be used to follow up on potential sub-lethal toxic effects of some pesticides on selected marine organisms chosen for their commercial or ecological value.

Acknowledgements

This is a companion investigation to a larger study with Environment Canada and the Province of Prince Edward Island. Credits: B. Bema, L. Chow, A. Cook, J. Culp, A. Denning, K. Doe, L. Edwards, B. Ernst, C. Garron, M. Hewitt, G. Julien, J. Mutch, C. Murphy, S. Murtagh, H. Rees, and K. Webb.

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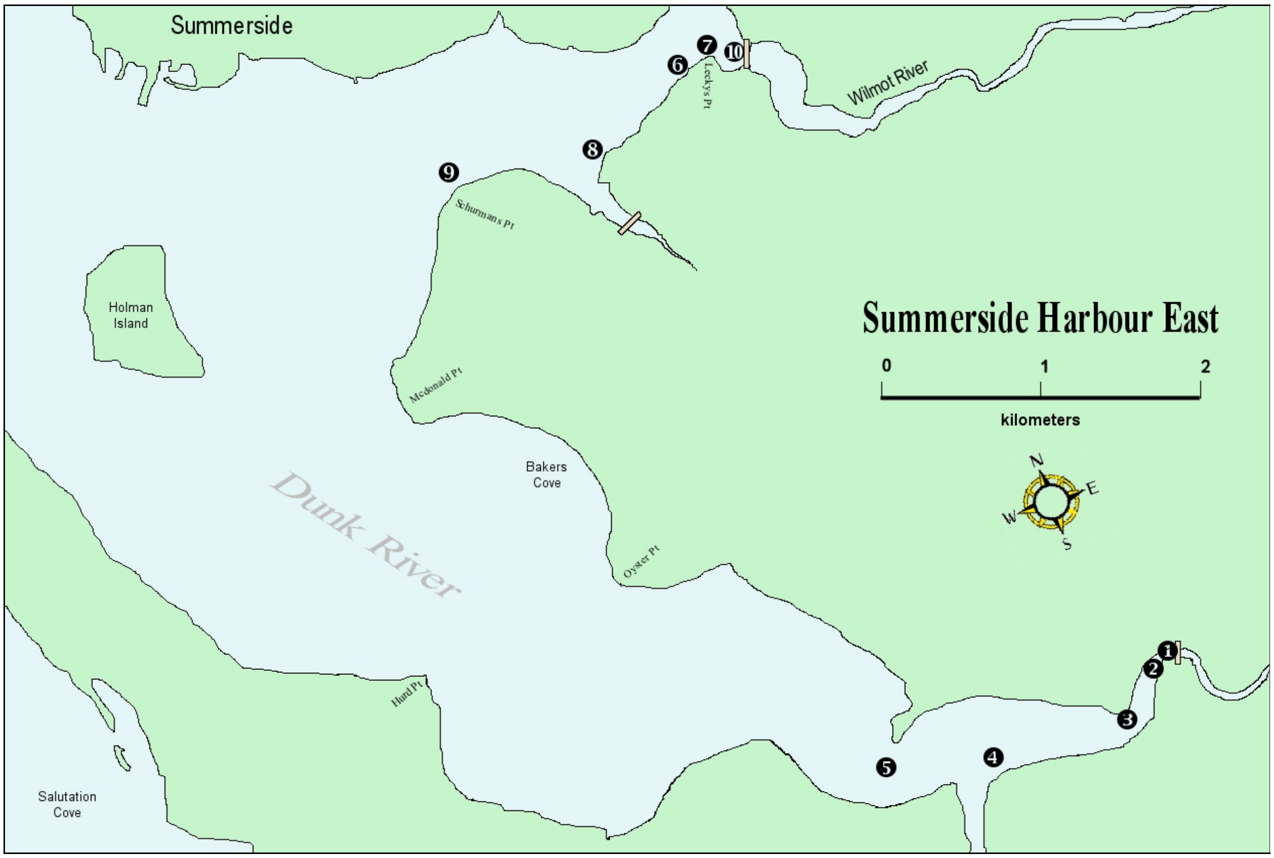
Table 1. Levels of pesticides in water and sediments of the Wilmot River and Dunk River estuary in PEI. Pesticides were chosen according to use in PEI, bioconcentration potential and known toxicity.

Pesticide	**Water (ug/L)**	**Sediment (ug/g)**
Atrazine	<0.008	<0.02
Azinphos-methyl	<0.038	<0.04
Azoxystrobin	<0.039	<0.08
Carbaryl	<0.012	<0.03
Carbofuran	<0.007	<0.03
Chlorothalonil	<0.005	<0.08, 0.6
Cypermethrin	<0.028	<0.07
Dimethoate	<0.021	<0.02
α-endosulfan	<0.007	<0.06
β-endosulfan	<0.008	<0.06
Fonofos	<0.008	<0.04
Heptachlor epoxide	<0.007	<0.06
Hexazinone	<0.043	<0.02
Linuron	<0.016	<0.03
Metalaxyl	<0.028	<0.02
Metobromuron	<0.013	<0.05
Metribuzin	<0.012	<0.06
Permethrin	<0.030	<0.07

Figure 1. Samples were collected from five sites located at approximate distances of 1, 100, 500, 1,000, and 2,000 meters from the outermost bridges of the Dunk River and Wilmot River, PEI.



ECOLOGICAL AND ECOTOXICOLOGICAL STUDIES ON THE INTER-TIDAL AMPHIPOD, *COROPHIUM VOLUTATOR*, IN THE UPPER BAY OF FUNDY, GULF OF MAINE

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The Corophium Working Group (WG) is a research-oriented group of the Bay of Fundy Ecosystem Partnership (BoFEP; see www.bofep.org) focusing on the biology, ecology and ecotoxicology of this Gammaridean amphipod. *Corophium* occurs on mudflats in the upper Bay and is a key food for migrating shorebirds. The WG maintains a bibliography and a collection of key papers and reports on *Corophium* species. Brylinsky is analyzing the literature to identify and verify variables influencing the distribution and abundance of *Corophium*. Hamilton's recent studies, including exclosure studies at Avonport Beach and surveys of several mudflats in the upper Bay, have elucidated some of the primary biotic and abiotic factors that control abundance of *Corophium* and other inter-tidal species, including shorebirds. Research by Barbeau has concentrated on the seasonal population dynamics of *Corophium* at beaches on both sides of the Bay. Kaczmarska focuses on the inter-tidal diatoms and their ecology, as they are a primary food for *Corophium*. Hicklin continues yearly sampling and studies in Shepody Bay to examine the predation pressures induced by migratory shorebirds. Doe is using *Corophium* as a model organism for toxicity studies, currently investigating the effects of Orimulsion® and No. 6 fuel oil. Hellou is interested in the bioavailability, in terms of fate and effects of contaminants, especially polycyclic aromatic compounds (PACs), to *Corophium*. Wells and team have been characterizing the sediments using Microtox® SPT test across the upper Bay. The Working Group is also preparing a review paper on the biology and ecology of *Corophium volutator*.

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NINE-YEAR REVIEW OF GULFWATCH: TRENDS IN TISSUE CONTAMINANT LEVELS IN THE BLUE MUSSEL, *MYTILUS EDULIS*, WITH SPECIAL EMPHASIS ON THE BAY OF FUNDY

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Gulfwatch is an international monitoring program, involving three states and two provinces, that is focused on tissue contaminants in the blue mussel (*Mytilus edulis)*. Data from 1993–2001 have been analyzed to determine spatial and temporal trends, and to provide the basis for program re-design. Tissue levels of nine trace metals, 24 polychlorinated biphenyl (PCB) congeners, 24 polycyclic aromatic hydrocarbons (PAHs), and 16 chlorinated pesticides have been monitored at 38 sites. Annual fall sampling and processing follow standardized methods. Four replicate samples of 40 mussels, 20 each for metals and organic chemicals, are collected from each site. Two laboratories conduct the tissue analyses. Five benchmark sites (one in each jurisdiction) are sampled every year, and other sites are sampled on a 3-year rotation. Two benchmark sites, Hospital Island in New Brunswick and Digby in Nova Scotia, are located in the Bay of Fundy. Of all the benchmark sites, Digby had the greatest number of significant decreasing trends in mussel tissue concentration (chromium, iron, lead and high molecular weight PAHs) between 1993–2001. Hospital Island has significant decreasing trends in mercury and lead tissue levels. Where spatial patterns were observed, they generally indicated that tissue contaminant concentrations tended to be higher in the southern Gulf compared to the northern Gulf, particularly for organics (pp= DDD, pp= DDE, PCBs). Some contaminants showed no spatial pattern, but showed highly elevated levels in some areas (e.g., Yarmouth, Nova Scotia, was ranked second and third highest of all Gulfwatch sites, in terms of silver and low molecular weight PAH concentrations, respectively). Gulfwatch illustrates the role of tissue monitoring in hazard and risk assessment by identifying temporal and spatial trends in ecosystem exposure and exposure variability.

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SEWAGE MANAGEMENT IN THE GULF OF MAINE—IMPLEMENTING RECOMMENDATIONS OF THE 2002 HALIFAX WORKSHOP

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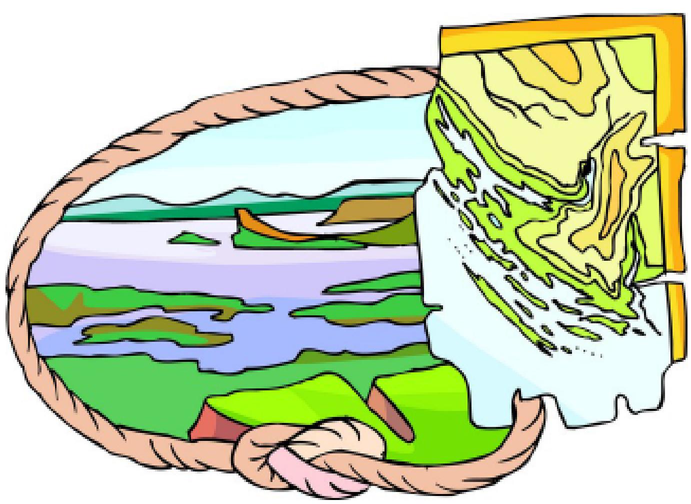
The GOMCME (Gulf of Maine Council on the Marine Environment) held a workshop on sewage management in the Gulf of Maine-Bay of Fundy, at Bedford Institute of Oceanography, Dartmouth, Nova Scotia, in April 2002. The workshop proceedings were published in 2002 (Hinch et al. 2002). A set of recommendations was presented to the GOMCME in June 2002, with an emphasis on 1) raising awareness with respect to wastewater management; 2) establishing the link between sewage discharges and ecosystem and human health; 3) assessing socio-economic impacts of sewage discharge; and 4) producing innovative approaches to address the sewage management issues. Progress on implementing these recommendations in a systematic way is presented. New opportunities for multi-partner initiatives, to combat both point and non-point sewage discharges to coastal waters of the Gulf of Maine, need to be launched, such as through Canada's new sewage strategy and the 4th Gulf of Maine Council on the Marine Environment Action Plan (2006–2011).

Reference

Hinch, P. R., S. Bryan, K. Hughes, and P. G. Wells (Eds). 2002. *Sewage Management in the Gulf of Maine. Workshop Report*. Gulf of Maine Council on the Marine Environment, Augusta, ME, and Concord, NH.

Concurrent Round Tables on Workshop Themes



Following the future-oriented plenary session on the final morning of the workshop, the participants formed three round tables to discuss the future of the Bay of Fundy in relation to:

- The Health of the Bay
- The Management of the Bay and its Resources
- The Coastal Communities of the Bay

The ensuing discussions were thought provoking and animated. However, in the short time available it was only possible to focus on a limited number of facets of each of these broad topics. Nevertheless, a number of very interesting points were explored by each group and presented in the final plenary session. These discussions are summarized as follows:

ROUND TABLE 1 – The Health of the Bay

Coordinators: Jocelyne Hellou (DFO), Peter Wells (EC), Phil Yeats (DFO)
Rapporteur: Phil Yeats (DFO)

Our initial intention was to identify two or three of the most critical concerns pertaining to marine environmental health in the Bay of Fundy as foci for further discussion. However, we found it impossible to select a small number of concerns that we could all agree on, and instead, created a shopping list of issues that were considered important by members of the group. The most critical concerns raised, in no particular order of priority, include the following:

- reduction in biodiversity
- introduction of invasive species
- intertidal harvesting and the resulting habitat disturbance
- presence of a variety of contaminants in water, sediments and biota
- biological effects of low levels of contaminants
- climate change consequences
- water quality concerns, particularly in relation to sewage and heavy metals
- environmental impacts of physical barriers (dams and causeways) on rivers
- environmental impacts of habitat restoration efforts (such as causeway removal or dyke breaching)

Next we considered useful techniques that might be available to assess changes in ecosystem health associated with the above issues. It was noted that the papers and posters presented during this workshop described many innovative techniques. A number of concerns were raised, however. First, there is a need to clearly define biodiversity in the Bay of Fundy context, in order to be able to develop effective programs to monitor this critical indicator of overall ecosystem health. There is also a need to understand the functioning and ecological importance of salt marshes in a broader context, particularly in relation to the overall marine productivity of the Bay. It is important to develop effective ways for measuring and monitoring the short- and long-term impacts of human activities, such as resource harvesting (rockweed, clams, baitworms, etc.), in the intertidal zone. The use of molluscs in environmental assessments should also be carefully considered and expanded.

A number of gaps in our knowledge need to be addressed in order to develop effective ways of assessing and monitoring the state of the Bay. We need to develop a regionally appropriate suite of marine environmental quality criteria, particularly a comprehensive set of guidelines that include both biotic and environmental components. The more important biological, chemical and physical interactions occurring within the Bay's ecosystem need to be much better understood—we need to model how the whole system works. There is also a special need to identify sensitive indicators that will provide an early warning of a general deterioration in ecosystem health. However, it is clear that there is no universal, or cookie-cutter, approach to the many problems confronting the Bay—we need to develop specific approaches for dealing with each of the principal environmental health issues.

There was general agreement that it would be worthwhile to expand the terms of reference of the existing BoFEP Contaminants and Ecosystem Health Working Group, in order to further explore many of the ideas raised by the round table, and to seek creative ways of addressing some of the important issues identified.

ROUND TABLE 2 – The Management of the Bay and its Resources

Coordinators: Tony Charles (St. Mary's University), Mike Butler (ACZISC)
Rapporteur: Lisa Isaacman (Dalhousie University)

In the limited time available, we focused our discussions on a) the acquisition and dissemination of the information required for effective management, and on b) the roles that BoFEP might play with regard to management of the Bay of Fundy.

A. Data Collection, Sharing and Management

Data Sharing. Data can serve multiple purposes, but often it does not because it is not in an organization's mission or mandate to use it, or make it available, for other purposes. Indeed, the mandate of an organization may specifically proscribe sharing of information or data. How are we to co-share information if it is not in the mandate of the organization that collected the data? Who funds the collection of this data? How do you release mapping and other data, in view of some of these ownership issues? There is a clear need for protocols on information sharing and decision making. In addition, co-sharing of information, and its management, is often an issue of leadership.

Communication. How are we to communicate the information to others? How do we disseminate it to different user groups? How do we get information to people in a timely manner (e.g., emergency measures responses)? The data needs to be processed and the information made available to all who require it. The need for data processing is a strong argument in support of information management protocols that could be developed to address the requirements of data processing.

Use of the Information. The user base of data and information broadens over time, as different community and other groups are given access to the data in a useable form. This allows them to increase the sophistication of their deliberations and their questions. However, care is needed in making information broadly available to the general public in order to ensure that it is not misinterpreted or used improperly. There is some concern about the possible misuse of information provided, including illegal misuse.

Demand-Driven Information. The provision of information should be demand-driven, and the demand side (who wants the information?) needs to be clearly defined. There may be many different players on the demand side. This brings us to the question of scale. Knowing who wants the information enables us to develop effective ways of getting the appropriate information to them. We need to do this for different types, scales and levels of user groups.

Scale. Information needs to be provided on a scale that is useful to the recipient—on a 'macro' scale, for large institutions such as the government of Canada and on a 'micro' scale for local or community groups such as the Minas Basin Working Group.

Participation. A great deal of ocean management pertains to living and non-living resource management, which traditionally does not involve the public. It is not sufficient to just hold an information workshop for the public to attend; we must allow for public input into management plans before they are even developed. However, it is not clear how best to get everyone to the table.

Information Systems. There needs to be an integrated approach to incorporating information systems into the management process. Ideally, everybody should have access to a regional database of Fundy information, possibly by means of a consortium agreement, in which all organizations provide some of the funding in return for access to the information. The information system should have one central official portal, but with a distributed system of databases. The important questions are: where will it be located and who will maintain it over the long term?

Digital Library. A digital library makes it possible to scale up and down, but where do we have the capacity for such a digital library? Dalhousie University has the capacity, but not the funding, for such a system. However, if it could secure the funding to initially set it up, it might have some permanence, since once it becomes part of such an institution it usually doesn't "die off" easily. We have yet to scratch the surface of the technological capabilities, the possibilities for information sharing and enhancing the information management design process. The Georgia Basin Project in British Columbia/Washington is one example of how such technologies can improve communication. It is essential to have good information accessible through a central location, but it must be part of a distributed information system.

B. Ideas for BoFEP: Future Role in Managing the Bay and Linkages

Role of BoFEP. To what extent does BoFEP speak for the Bay of Fundy at present? What role should BoFEP play in the management of the Bay, particularly in integrated management? Should it play an active role? Or is its principal role advocacy, information dissemination, and providing advice? How do we communicate amongst ourselves and with our partners on an ongoing basis and not just at periodic meetings? We need to let more people know what BoFEP is doing.

Federal/Provincial Agreements. A good example of such an agreement is the Canada/BC federal/provincial memorandum of understanding (MOU) recently put in place to implement the *Oceans Act*. Details of this agreement will be available in the next Atlantic Coastal Zone Information Steering Committee (ACZISC) e-newsletter update. The Bay of Fundy could in the future be part of a similar East Coast MOU. It would be helpful if BoFEP could be there to make sure that the interests of the whole Bay of Fundy are considered, not just specific provincial interests. Specifically, BoFEP could coordinate management on an ecosystem level, to ensure that the Bay of Fundy is managed as an ecosystem, rather than simply drawing a line along its length and stating that New Brunswick and Nova Scotia are responsible for their respective sides. What should be the role of local areas in a large-scale MOU such as this? Public participation needs to be built into the design process for the agreement; this is a clear message from direct experience with land-use planning

ESSIM. It is important to understand and share with other areas the ESSIM (Eastern Scotian Shelf Integrated Management) Project and its process. A draft management plan will be ready for spring 2005. ESSIM is developing a series of ecological use and human use objectives. The former is moving forward and has about 170 objectives that are becoming very well organized. The framework for human-use objectives is more difficult as there are few appropriate examples in the world, or in the agency (i.e. DFO) itself. BoFEP has linkages to community-based groups, whereas, ESSIM does not. Perhaps the two organizations could develop a working relationship and learn from each other.

ROUND TABLE 3 – The Coastal Communities of the Bay

Coordinators: Janet Larkman (WVDA), Stephen Hawboldt (CARP),
Ted Hoskins (Saltwater Network)
Rapporteur: Carol Welch (Bay of Fundy Discovery Centre Association)

The discussion focused primarily on what is happening in the Bay's coastal communities with respect to their participation in the management of renewable resources, and how best to enhance this participation. The round table was an opportunity to tell some of the more informative community stories from the region, to share some of the successful collaborative experiences, and to learn from and support each other in our ongoing efforts.

For example, in northern Maine, a network of lobster fishermen has been working effectively together for several years. Shocked by the dramatic collapse of the groundfishery, these fishermen wanted to make sure that a similar thing did not happen to their lobster fishery. Initially, the group was rather small and it took time to build the necessary level of trust among those involved. Typically, fishermen are fiercely independent, and sharing information about their resource and their activities does not come naturally. However, they managed to develop a set of mutually acceptable principles that facilitated their working together in a trusting and constructive manner. They managed to get beyond their initial self-interest, and soon came to recognize their many mutual interests and the benefits of working together effectively as a team to address the issues and protect their livelihoods. They created a Marine Resource Centre to support their activities and are increasingly active in trying to influence government policies regarding their fishery.

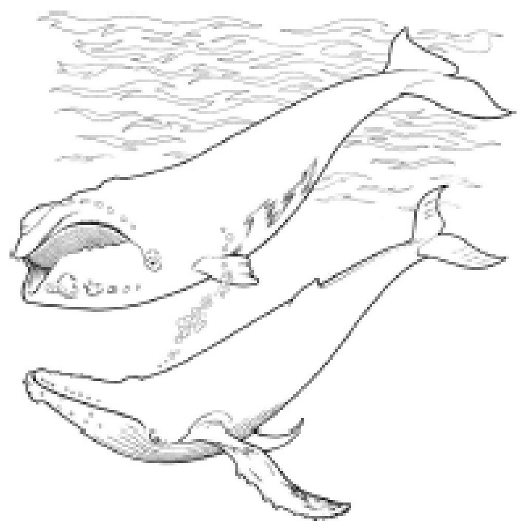
In Atlantic Canada, the Atlantic Coastal Action Program (ACAP), supported by Environment Canada, is probably one of the most successful government-initiated programs pertaining to community social and economic development and aimed at promoting the sustainability of coastal communities. In 1991, the Clean Annapolis River Project (CARP) was designated the first ACAP site in the region. There are now 14 such groups spread throughout the four Atlantic Provinces. An independent audit has recently shown that the ACAP program actually makes money for the government, since far more is collected in payroll taxes than is spent by Environment Canada in supporting the program. ACAP projects have also served as an important practical training ground—and often the first real job in their field—for many new science graduates.

It was noted that there are many organizations throughout the region dealing with different aspects of environmental conservation, the sustainable use of natural resources, and the economic and social well-being of coastal communities. The number of such groups is increasing steadily in response to the proliferating issues, with a resulting rise in competition amongst them for limited volunteers and funds. There is concern about the likelihood of burn-out among inadequately supported volunteers who are involved in just too many issues. It is important to be alert for warning signs of volunteer burn -out. Volunteers need to be helped to reinvigorate themselves, to be given new and interesting challenges, and to be steered towards fulfilling tasks suited to their particular skills and interests. It is also very important to recognize the accomplishments of the volunteers, to reward their efforts, and to celebrate the goals achieved. It was noted that, typically, the more successful organizations have at least one part- or full-time paid staff person to co-ordinate the organization's activities and to provide much-needed support to the volunteers. It was also emphasized that it is critical for each community group to have very clear goals and directions, so that its efforts can be strategically focused. Groups also need to be cautious about raising inappropriate expectations amongst its members and the general public.

It is important to find ways of encouraging and assisting the many different groups to work together to jointly advance their goals and reduce overlap and duplication of effort. It might also prove advantageous if several groups could work together to prepare joint proposals for submission to potential funders, instead of regarding each other as competitors for the limited funds available. Foundations and other funding groups are often inclined to look more favorably on broader, more diverse projects involving several different, but complementary, partners. Innovative, multi-partner projects that engage the public often catch the eye of funders. Furthermore, diverse groups working together are usually much more creative than individual groups working by themselves on their own limited interests. For example, a salmon river association was interested in restocking local streams and restoring fish habitat. They began by involving a local school in the project and setting up a small-scale fish hatchery in the classroom. This encouraged students to learn about salmon biology and ecology and got them interested in restocking local streams with the fish. They involved industry in the project, by working with a cement company to explore the use of waste cement dust to buffer streams acidified by acid rain, thereby turning a waste product into a potentially salable commodity. Working with a local entrepreneur they used scallop shells as another method for improving water quality. Eventually, a university department also became involved in the project. This example demonstrates that a difficult problem confronted may, in fact, be an opportunity if it is looked at in the right way. In addition, such small, community-based efforts can often become seeds for much larger projects. There is no end to what a local community can achieve if the different groups work together and share their creativity.

Although some coordination of community groups may be beneficial, it is probably not necessary, or even desirable, to have a large umbrella organization to coordinate the efforts of the many individual organizations. However, there should be a centralized clearinghouse, serving as a source of relevant, up-to-date information that can be easily accessed by the different groups. This might include a database of potential funding sources, information on government policies and program initiatives, and sources of technical expertise and other support. It was noted that a principal objectives of BoFEP is to facilitate the sharing of scientific and other information amongst its partners, as well as with community groups around the Bay. BoFEP’s working groups, website and the biennial Bay of Fundy science workshops, all play important roles in information sharing, as well as in fostering collaborative conservation and research activities among interested groups.

Minutes of the 2004 BoFEP Annual General Meeting



BAY OF FUNDY ECOSYSTEM PARTNERSHIP (BOFEP)
***** ANNUAL GENERAL MEETING *****

Cornwallis Park, Cornwallis, Nova Scotia
Thursday, September 30th, 2004
5:30 pm to 6:25 pm

***Participants*: Graham Daborn**, Acadia Centre for Estuarine Research (Chairperson); **Amanda Tree,** Acadia Centre for Estuarine Research (Scribe); **Rabindra Singh**, DFO; **Roger Outhouse**, Bay of Fundy Discovery Centre Association; **Marianne Janowicz**, NB Dept. of Environment & Local Government; **Vanessa Paesani**, University of New Brunswick; **Gerhard Pohle**, HMSC; **Andy Didyk**, University of New Brunswick; **Alison Evans**, Coastal Planners; **Brian Craig**, EMAN; **Al Hanson**, Environment Canada; **David Scarratt,** Bay of Fundy Marine Resource Centre; **Maria-Ines Buzeta**, DFO; **Mike Brylinsky**, Acadia Centre for Estuarine Research, Acadia University; **Danika van Proosdij**, Saint Mary's University; **Hank Kolstee**, NS Dept. of Agriculture & Fisheries; **Justin Huston**, NS Dept. of Agriculture & Fisheries; **Marie-Helene Theriault**, University of Moncton; **Francine Rousseau**, Environment Canada, Dartmouth; **Claudette LeBlanc**, ACZISC Secretariat; **Mark TeKamp**, Dalhousie University; **Jon Percy**, Bay of Fundy Ecosystem Partnership; **Karen Beazley**, Dalhousie University; **Andy Sharpe**, CARP; **Colleen Mercer Clarke,** Coastlands Consultants; **Jocelyne Hellou**, DFO; **Bob Pett**, NS Transportation & Public Works; **Mike Butler**, ACZISC; **Barry Jones**, Bay of Fundy Ecosystem Partnership, (Treasurer); **Maxine Westhead**, Dept. of Fisheries and Oceans; **Peter Wells**, Environment Canada and BoFEP (Vice-Chair); **Patricia Hinch**, NS Dept. of Environment & Labour.

***Regrets:* Renee Wissink**, **Art MacKay**, **Tim Vickers**, **Dave Duggan**, **Larry Hildebrand**, **Robert Rangeley**

1. **Welcome and Introductions**
   Graham Daborn called the meeting to order and welcomed all to the BoFEP Annual General Meeting. He introduced himself and Amanda Tree, the BoFEP Coordinator; Jon Percy, the Organizer of the 6th BoF Workshop; and Peter Wells, the Vice-Chair of the organization. Graham Daborn mentioned that the minutes from the previous AGM were located on side table and asked that all please sign in attendance sheets also located on the table.

2. **Additions to/Acceptance of agenda**
   The following addition to the agenda was requested by Graham Daborn;
   - SGSL presentation to be made by Nadine Gauvin as item 8c.
   - BoFEP Past-Chair Position as item 8d added by Barry Jones.

3. **Minutes of April 24th, 2003 AGM**
   The minutes were reviewed and Peter Wells noted that the year should be included with the date of the last AGM and that his name was listed under the regrets, however, he had attended. No other changes were made.
   Motion to accept the minutes as amended (Barry Jones)
   Second (Marianne Janowicz)
   Motion Carried

*** These minutes will be ratified at the 2005 Annual General Meeting.

4. Business arising

Action Item 1 - It is particularly important to move ahead with the mining working group, as this is an increasingly important issue both NS and NB – Graham Daborn mentioned that the mining WG was changed to the Resource Development WG and the Steering Committee had been asked to look for someone to chair the WG but had not found one. He asked if there were any volunteers or recommendations. None were offered.

Action Item 2 - Gordon Fader will be invited to speak at one of the upcoming Steering Committee meetings to discuss mining issues in the Bay of Fundy. – Graham Daborn mentioned that it had not taken place thus far.

Action Item 3 - The Steering Committee was charged with finding an auditor for the present fiscal year. – Barry Jones mentioned that this had been done and would be discussed later in the agenda.

Action Item 4 - The Steering Committee was asked to consider holding a one day mini workshop to consider mining issues in and around the Bay - possibly in conjunction with the MRC. – Graham Daborn stated that this had not been dealt with thus far.

Action Item 5 - The Huntsman Marine Science Centre in St. Andrews, NB will be the location for the 2006 Workshop. Someone from the Centre should begin to make initial plans soon. – Graham Daborn said that this would be discussed later.

5. Financial Report

Barry Jones spoke about the Financial Statement for 2003-04 and noted that there were 2 main elements of funding; BoFEP Inc., the bank account he oversees and Acadia University. Barry Jones stated that we had started off the year with $29,781 with BoFEP, and $10,581 at Acadia University, which gave us a balance of $40,362. Our total cash revenues for the year equaled out to $73,757, and total expenses equaled out to $77,785. We had money at Acadia which was used for the 5th BoF Workshop Proceedings, which brought the total amount of BoFEP funds at Acadia down to zero. Barry Jones mentioned that Environment Canada had required an audit of the 2003-2004 year for BoFEP, so he had gone to an auditor and had received the final copy which was circulated to those interested. Barry Jones mentioned that there was a difference between the auditor's numbers and his numbers due to the BoFEP Coordinator contract with EC which had been paid up to March, 2005; the auditors could not write it off, like he had. He mentioned that the audit had been sent to EC as requested.

Motion to accept the 2003-2004 financial report (Patricia Hinch)

Second (Marianne Janowicz)

Motion Carried.

Barry Jones mentioned that at the last SC meeting, the 2004-2005 budget was set that would cover all of the available funds, leaving us $5000 for our required carryover. The budget as of September 27, 2004 stated the total revenues generated were $67,730 and the expenses to date were $20,000. Graham Daborn stated that there were no copies of the budget available at this time, but it could be sent out later and they could sign off on authority to allow the SC to approve the budget later. Claudette Leblanc mentioned that she had the financial statement that was sent out on September 18th. Barry Jones said that is was the same as that but with 4 additional bills and the addition of up $2,500 that Peter Wells would be picking up for the bibliography project. Claudette Leblanc asked if we could accept the September 18th budget since it had been emailed out to the members. All agreed with this. Barry Jones mentioned the following as a summary of the in and output of the September 18th budget;

Administration	$1,500
Meeting/Travel	$4,000
5th Workshop	$12,000
6th Workshop	$17,696
Communications/Promotions	$5,000
Projects	$13,389 (GoMC project)
Working Groups	$41,500 (based on 7 requests)
Budgetary Carryover	$5,000
Total Expenses	$100,085

Barry Jones mentioned that changes that had taken place since the September 18th budget were as follows;

Audit $1,600 (code 4160 – turned out to be more expensive than originally budgeted $800)

WG – Comm. /Web Site $2,500 (code 4680 – Peter Wells contributed $2,500 for the Projects $5,000 funds, the extra $2500 was distributed amongst smaller things)

Motion to accept the BoFEP 2004-2005 budget with the mentioned changes (Justin Huston)
Second (Patricia Hinch)
Motion Carried.

6. Work Plans and Proposed Budget for 2004-2005

Graham Daborn mentioned that the 2004-2005 workplan had previously been approved and had been submitted to Environment Canada for funding and the budget was previously discussed.

7. Steering Committee/Management Committee report

Graham Daborn reported on the activities during the past year for both the Steering and Management Committees. There had been 7 Management Committee meetings, most of which had been by conference calls. The Steering Committee had met 5 times and quorum was present at all meetings. Both committees work well together and have a good interface between the WGs and BoFEP. Graham Daborn mentioned that they had some problems with obtaining funding to match the funding from Larry Hildebrand, but we had received funding for the Integrated Fisheries Management Project from the EJLB Foundation. He also mentioned the agreement with BoFEP and the GoMCME for $10,000US that had been committed to a GIS project and some BoFEP publications. Peter W. clarified that the $10,000US agreement from the GoMC was for 3 years with the first year committed mainly to the GIS project and that an additional $10,000 from Environment Canada was also given to support the project. The funding from the GoMC for the next two years, $10,000US in each year, had not been assigned and the work that it would be used to support must meet some of the objectives of the GoMC.

8. Other business

a) **Location of 2006 Workshop –** Graham Daborn mentioned that the Huntsman Science Marine Centre had been suggested but had not been finalized. Gerhard Pohle from Huntsman offered his support for this, but mentioned that Huntsman was undergoing some organizational and physical changes that were ongoing and taking up people’s time. He was concerned that they would not be able to accommodate a large number of sessions due to the numbers of people expected to attend the next workshop. Gerhard Pohle suggested the Algonquin as a possible site, but stated that it did cost. Marianne Janowicz encouraged Gerhard Pohle to work it out with Huntsman, and possible alter the set-up of the workshop so that it could be held there. Gerhard Pohle said that there would need to be smaller groups in the sessions. Colleen Mercer Clarke mentioned that the Algonquin had a good rate for workshops if held after the prime season, and they also had reasonable rates at the hotel. Graham Daborn felt that we should leave Huntsman as the primary location and look into others as options if required. Gerhard Pohle said that he would continue with this and would verify the location at Huntsman at the next AGM.

b) **BoFEP - Gulf of Maine Council on the Marine Environment Agreement –** Graham Daborn mentioned that this had already been addressed and that Patricia Hinch and other members who sit on the GOMCME WG had helped to lead this. Graham Daborn added that this was not an entirely popular idea to have a separate agreement with BoFEP for many of the US participants, specifically because BoFEP does not have a large US membership status. Graham Daborn felt that BoFEP should build this up and mentioned that there were a few US scientists attending the workshop, including Peter Larsen.

c) **SGSL Presentation –** Nadine Gauvin from the SGSL thanked all for allowing her to speak at the BoFEP AGM. She mentioned that she had been the SGSL Executive Director of Operations for the past 6 years. The SGSL is similar to BoFEP have the fact that they also have a Steering Committee and Management Committee. She mentioned that the SC would meet quarterly and the MC more often as needed. Nadine Gauvin stated that the Coalition’s mandate involved; helping communication, networking and information sharing; organizing and facilitating meetings, workshops or forums; monitoring the progress of executed strategies and policies; helping communities grow and achieve their sustainability goals; and also to promote sustainability. She mentioned that the Coalition’s partners included; Government agencies, Industry, Community groups, NGO, First Nation, and the public at large. Nadine G. mentioned that they have some WGs like ours and that perhaps we could work together with them in order to cut down on some that overlap. She felt that BoFEP was more science oriented with their research and that SGSL was more associated with community groups, but believed that we could work well together on various projects that are of interest to both groups. Nadine Gauvin suggested having a few members of both SC meet to discuss the possibility of a joint WG, topics for a joint workshop and partnership initiatives. Graham Daborn mentioned that the BoFEP SC had talked about doing this at meetings and had shown interest in progressing with it.

d) **BoFEP Past-Chair Position** – Barry Jones mentioned that it had come to his attention that Graham Daborn may not stay on as the Chair of BoFEP; Graham Daborn said that this was correct. Barry Jones suggested that we propose the creation of the position of Past-Chair for the following year. He mentioned that this could not be done this year due to the time required.

Motion to accept the establishment of the position of Past-Chair to be functional in principle until the next AGM (Barry Jones)

Second (Justin Huston)

Motion Carried. (One contrary vote submitted by Graham Daborn)

9. Nominations and Election of Steering Committee

Michael Butler mentioned that there were 3 people on the nominating committee; Alison Evans, Jamey Smith, and himself. The responsibility of the committee was to come up with potential SC members to a maximum of 24. Michael Butler mentioned that it had been very time consuming task since many people did not respond. Following are those who had agreed to stay on the BoFEP SC;

1) Michael Butler - *alternate Claudette Leblanc*
2) Thierry Chopin
3) Graham Daborn
4) Dave Duggan – *alternates Maria-Ines Buzeta and Maxine Westhead*
5) Al Hanson
6) Steve Hawboldt
7) Francine Rousseau – *will be replacing Larry Hildebrand*
8) Patricia Hinch
9) Marianne Janowicz
10) Barry Jones
11) Jon Percy
12) Robert Rangeley – *alternate not yet assigned*
13) Jamey Smith
14) Amanda Tree
15) Peter Wells
16) Renee Wissink

Michael Butler then listed the following nominations that had been made earlier;

17) Danika van Proosdij
18) Rabindra Singh
19) Sean Smith
20) David Scarratt

He asked the floor for any nominations for the 4 remaining seats and mentioned that they were short on community groups, industry, and First Nation reps. Nominations from the floor were offered and accepted for:

21) Mark TeKamp
22) Hugh Akagi *(Graham Daborn accepted on his behalf)*
23) Colleen Mercer Clarke *(nominated after adjournment; to be ratified by SC)*
24) Gerhard Pohle *(nominated after adjournment; to be confirmed and ratified by SC)*

Motion to accept the 22 nominated members for the BoFEP Steering Committee (Michael Butler)
Second (Barry Jones)
Motion Carried.

Motion to instruct the By-Law committee to work on amendment for next AGM to SC alternatives voting capabilities (Barry Jones)
Second (Dave Scarratt)
Motion Carried.

10. Date and Location of the next AGM

Graham Daborn stated that we needed to determine the location for the next AGM. Justin Huston suggested having the meeting in Sackville, New Brunswick; Peter Wells suggested holding it at Huntsman Marine Science Centre. Gerhard Pohle said that it could be held at Huntsman so long as it was in September. Barry Jones suggested leaving the decision of the date of the AGM up to the chair of BoFEP to be determined at a later date. Graham Daborn asked if this was allowed - Barry Jones stated that it was allowed.
Motion to hold the next Annual General Meeting at the Huntsman Marine Science Centre in St. Andrews, New Brunswick, and to leave by the call of the chair the exact date of the next AGM. (Barry Jones)
Second (Peter Wells)
Motion Carried.

11. Adjournment

Graham Daborn declared the meeting adjourned at 6:25 pm.

ACTION ITEMS

Bay of Fundy Ecosystem Partnership
Annual General Meeting
Champlain Hall, Cornwallis Park, Nova Scotia

September 30th, 2004 5:30–6:25 pm

1. A Chair for the Resource Development Working Group will be found in order to get the WG moving ahead.

2. Gordon Fader will be invited to speak at an upcoming Steering Committee meeting in order to discuss the mining issues in the Bay of Fundy.

3. The Steering Committee will be asked to consider holding a small one day workshop concerning mining issues in and around the Bay of Fundy - possibly in conjunction with the MRC.

4. The Huntsman (HMSC) will be looked into the sponsor for the 7th BoF Workshop. The Algonquin Hotel will be considered as the location.

5. The Steering Committee will consider holding a meeting with the SGSL Coalition in order to discuss the possibility of a joint WG, topics for a joint workshop and partnership initiatives.

6. The position of the BoFEP Past-Chair will be ratified the next AGM.

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