Resource Development and Its Implications in the Bay of Fundy and Gulf of Maine

Proceedings of the 8th BoFEP Bay of Fundy Science Workshop,
Acadia University, Wolfville, Nova Scotia
26–29th May 2009

Editors

A. M. Redden, J. A. Percy, P. G. Wells and S. J. Rolston

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Tribute to George C. Baker

The Proceedings are dedicated to George C. Baker of Kentville, Nova Scotia, to record our respect and appreciation for his contributions to the understanding of the environmental implications of tidal power generation from the Bay of Fundy.

Born in Dartmouth, Nova Scotia in 1918, George Baker graduated with a diploma from the Royal Military College in 1936 and served with the Royal Canadian Corps of Signals. He resigned his commission in 1946 and proceeded to the University of Toronto where he obtained a degree in applied science. Mr. Baker's first post-war job, from 1946 to 1947, was with the Canadian General Electric Company. In 1948, he joined the Kentville (Nova Scotia) Publishing Company, becoming president and serving until 1981. From 1960 until 1981, he was an engineer with the Kentville Electric Commission and, also in 1960, began an even longer association with the Hiltz & Seamone Company Ltd. as an electrical consultant. Between 1968 and 1974, he served as a member and vice-chairman of the Nova Scotia Medical Care Insurance Commission. He was a director of the Tidal Power Corporation from 1971 to 1989 and executive vice-president from 1976. In 1989, Mr. Baker was elected to the Canadian Academy of Engineering, the same year that he was elected a Fellow of the Engineering Institute of Canada. He was also a member of the Association of Professional Engineers of Nova Scotia, the Institute of Electrical and Electronic Engineers, and the Canadian Society for Electrical Engineering (now IEEE Canada). He has received honorary doctoral degrees from the Royal Military College, the Technical University of Nova Scotia, and Acadia University. He was awarded a Centennial Gold Medal by IEEE, and became a Member of the Order of the British Empire (MBE).

It was at George Baker's recommendation that we convened the first broad examination of the environmental implications of Fundy tidal power at Acadia University in 1976. That led to the creation of the Fundy Environmental Studies Committee (1977–1984), which oversaw the first multidisciplinary, multi-institutional study of the whole Bay of Fundy, and substantially increased our knowledge of that rich and diverse ecosystem. Throughout, even though he was optimistic that tidal power could be safely developed in the Bay, George Baker was a strong advocate for objective, science-based investigations of the tidal power issue, including use of the pilot plant at Annapolis Royal to examine issues of fish passage. It is no exaggeration to say that without his leadership and support, the Bay of Fundy science community would know much less about the Bay, and would be far less prepared to address the contemporary challenges of tidal power development.

At its banquet on Thursday, 28th May 2009, George Baker was presented with a BoFEP Special Community Service Award in recognition of his "inspired leadership" on the tidal power issue.

Photo courtesy of the Kentville Advertiser and the Acadia University Archives

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Preface

The 8th BoFEP Bay of Fundy Science Workshop, hosted by the Acadia Centre for Estuarine Research, was held during 26–29 May 2009 at Acadia University, Wolfville, NS. The theme of the Workshop, "Resource Development and its Implications in the Bay of Fundy and Gulf of Maine," reflects the many issues related to the development projects proposed or already underway in the Bay of Fundy – tidal power, quarries, LNG terminals, aquaculture sites, subsea pipelines and subterranean gas storage, to name just a few. This theme became the focus of a Citizens Forum, held just prior to the Workshop, on Tuesday May 26th. Led by Arthur Bull, a network of community members and representatives of a range of organizations convened in Wolfville to consider the implications of present and future industrial developments on the well-being of Fundy's coastal communities.

The Science Workshop was supported by 18 partners and sponsors and attracted 184 participants representing government agencies, industry, NGOs, universities, and the broader community. This year, we saw the participation of numerous high school students, including local co-op students and those who travelled from afar – 11 from Essex Agricultural and Technical High School in Danvers, Massachusetts, and 3 from the L'Sitkuk Environment, Bear River First Nations. A total of 69 papers and 26 posters were presented in 14 scientific sessions. Three plenary talks pertaining to the Workshop themes were also given. Plenary speakers were Gordon Fader (Atlantic Marine Geological Consulting Ltd), Michael Stokesbury (Ocean Tracking Network, Dalhousie University), and Rob Thompson (Parks Canada).

The poster session and a public forum were held in the Atlantic Theatre Festival on the evening of the 27th May. The Public Forum featured an "Update on the Fundy Tidal Energy Demonstration Project" provided by representatives from Minas Basin Pulp and Power, AECOM, and other consultants working on the project. Other workshop sessions included several BoFEP Working Group meetings, a BoFEP "Into the Future" general meeting, an Ecosystem Indicators Partnership (ESIP) Steering Committee meeting, and a well-attended geomatics mini-workshop on COIN Atlantic – Accessing and Managing Information (see Appendix 1 of these Proceedings). Numerous displays were also available for viewing throughout the workshop.

The Workshop Banquet was held at the Old Orchard Inn and was highlighted by an entertaining presentation from Terri McCulloch, manager of the Bay of Fundy Tourism Partnership. A number of awards were presented at the banquet, including a BoFEP Special Community Service Award to George Baker in recognition of his "inspired leadership" on the tidal power issue during previous decades. The BoFEP Environmental Stewardship Award was presented to North Atlantic right whale research scientist, Moira Brown, for outstanding contributions to the environmental health and sustainability of the Bay of Fundy. Jon Percy was presented with a Special Service Award for his outstanding role in disseminating knowledge about the Bay of Fundy. Eight student awards were given for the 1st and 2nd best undergraduate and graduate paper and 1st and 2nd best undergraduate and graduate poster.

These Proceedings contain the abstracts and papers presented at the workshop and address the following main topic areas: tidal power, salt marsh research and restoration, indicators and decision support tools, coastal zone information management, intertidal ecology, fisheries and aquaculture, watersheds, contaminants, and conservation ecology. Overall, the quality of the presentations was excellent and reflects a continued commitment to create and share knowledge and understanding of the Bay of Fundy.

The next BoFEP Workshop is tentatively scheduled to be in New Brunswick (Moncton or Saint John) in October 2011 and will feature the following theme: "Protecting the Watersheds and Estuaries of the Bay of Fundy: Issues, Science and Management." Confirmation will be announced soon and we look forward to seeing you there!

Anna Redden, Jon Percy, Peter Wells and Susan Rolston
Workshop Chair and Editors, September 2009

Acknowledgements

Many people and groups, and generous partners and sponsors, contributed to the success of the 8th BoFEP Bay of Fundy Science Workshop and Citizens Forum. In particular, the authors and presenters of all contributions are greatly thanked for their interest and enthusiastic participation. Warm opening remarks during the welcome reception were provided by Acadia's VP Academic Tom Herman. Several members of the organizing committee worked long and hard before, during and after the meeting and they cannot be appreciated enough. Special mention goes to Jon Percy for extraordinary efforts, Leanna MacDonald, Peter Wells, Graham Daborn, Kathryn Parlee, Arthur Bull, and Susan Rolston, who compiled the paper submissions and patiently edited these proceedings. The following persons provided welcomed assistance just prior to or during the workshop: Jeremy Broome, Claire Coulter, Duane Currie, Ivi Daborn, and Marika Godwin. Also thanked are the many session chairs, judges of student papers and posters and those who contributed informative displays.

Anna Redden
8th BoFEP Bay of Fundy Science Workshop Chair

Workshop Organizers

Chair

Anna Redden, Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS

Committee Members

Gary Bugden ~ Department of Fisheries and Oceans, Bedford Institute of Oceanography, Halifax, NS
Arthur Bull ~ Bay of Fundy Marine Resource Centre, Annapolis Royal, NS
Graham Daborn ~ Acadia University, Wolfville, NS
Leanna McDonald ~ Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS
Kathryn Parlee ~ Environment Canada, Dartmouth, NS
Jon Percy ~ Sea Pen Communications, Granville Ferry, NS
Anna Redden ~ Acadia Centre for Estuarine Research, Acadia University, Wolfville, NS
Peter Wells ~ Dalhousie University, Halifax, NS

Student Awards

Coordinator

Jon Percy

Judges for "Best Papers"
Trevor Avery
Graham Daborn
Jon Percy
Anna Redden
Ashley Sprague

Judges for "Best Posters"
Gerhard Pohle
John Roff

BoFEP Environmental Stewardship Award Committee

Barry Jones, Chair

Partners and Sponsors

Platinum

Gold and Silver

Bronze

Clean Annapolis
River Project

Awards Presented at the Workshop

Third BoFEP Environmental Stewardship Award

Moira W. Brown

The BoFEP Environmental Stewardship Award, presented at each Workshop since 2004, recognizes an individual who has contributed significantly over a long period of time to the environmental health and sustainability of the Bay of Fundy and Gulf of Maine. Dr. M. W. (Moira) Brown, internationally known and recognized for her many years of ecological and conservation research on the North Atlantic right whale, is this year's Award winner. Educated at McGill University (B.Ed., Physical Education 1977; B.Sc., Renewable Resources, 1985) and the University of Guelph (Ph.D., Marine Biology, 1995), she and her team of researchers and students have spent many years in Canadian and U.S. waters of the western North Atlantic studying the biology, population ecology, and conservation of this region's endangered right whale. Her work includes in particular conservation efforts to reduce the impact of ship strikes and fishing activity and gear on the individual whales, as well as promoting government, industry, and private efforts to conserve this magnificent marine animal. She is now based at the New England Aquarium in Boston, and amongst other projects contributes constantly to the research group's North Atlantic Right Whale Photo Identification Catalogue, a catalogue instrumental in tracking the approximately 400 whales (2007) between Florida and Fundy waters. Moira has many publications, including contributions to the superb recent book *The Urban Whale: North Atlantic Right Whales at the Crossroads*. She has many other distinguished achievement awards. With her research team, she exemplifies the expertise, dedication, and passion of a Fundy environmental scientist, at home on the sea with a wind in her face. It is a great honor for BoFEP to present Moira with the BoFEP Award and wishes her many more years of productive field research on the right whale and other conservation issues in the Bay of Fundy and Gulf of Maine.

BoFEP Special Service Award

Jon A. Percy

The BoFEP Special Service Award is a new award from BoFEP, acknowledging the recipient's outstanding service to the organization and its primary objective of sustaining the health of the Bay of Fundy. On behalf of BoFEP and the Workshop Chair, Dr. Anna Redden, it is a great honour for BoFEP to present this award to Dr. Jon A. Percy. Jon is a founding member of BoFEP. He has played an outstanding role over many years disseminating knowledge about the Bay of Fundy through the Fundy Fact Sheets and the website, contributed constantly to the conduct of BoFEP as an organization, and in particular worked tremendously hard on the organization and conduct of this 8th BoFEP Workshop. Jon's knowledge, energy and commitment to all things "Fundy" are an example for all of us to follow. We wish Jon all the very best in the years ahead and thank him, once again, for his many contributions to BoFEP, this workshop, and the entire Bay of Fundy community.

P. G. Wells
Chair, BoFEP

Undergraduate Student Paper Presentation

First - Miriam Coulthard (Mount Allison), The Effect of *Ilyanassa obsoleta* on the Vertical Distribution of *Corophium volutator* in Mudflat Ecosystems of the Bay of Fundy

Second - Beth MacDonald (Mount Allison), Nocturnal Habits of Semipalmated Sandpipers (*Calidris pusilla*) and *Corophium volutator* on Bay of Fundy Mudflats

Graduate Student Paper Presentation

First - Elizabeth Wallace (Acadia/Mount Allison), Effects of Foraging Semipalmated Sandpipers on the Vertical Distribution of *Corophium volutator*

Second - Aaron Frenette (UNB Fredericton), Contemporary Diagnosis of an Intracellular Parasite of Cod: Application for Investigating the Life History of *Loma morhua*

Undergraduate Student Poster

First - Amanda Savoie (UNB Fredericton), Effects of Density of the Amphipod *Corophium volutator* on Sediment Properties

Second - Laura Bursey (UNB, Fredericton), Abundance of Ribbed Mussels (*Geukensia demissa*) in Salt Marshes Located in Contrasting Tidal Regimes: Northumberland Strait vs Upper Bay of Fundy

Graduate Student Poster

First - David Drolet (UNB, Fredericton), Diel and Semi-lunar Cycles in the Swimming Activity of the Amphipod *Corophium volutator* in the Upper Bay of Fundy

Second - Kyle Smith (Dalhousie University), The Characterization and Tracking of Sediment-Laden Ice in Minas Basin, Nova Scotia

About Key Sponsors of BoFEP

The Bay of Fundy Ecosystem Partnership (BoFEP)

The Bay of Fundy Ecosystem Partnership (BoFEP) was formed in 1997 to identify and understand the problems confronting the Bay and to find ways of working together to resolve them. It is a flexible and evolving organization 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 biological diversity.

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

Acadia Centre for Estuarine Research

The Acadia Centre for Estuarine Research (ACER), located at Acadia University in Wolfville, NS, has a 25 year history of conducting research 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. Facility space and additional funds were provided by Acadia University. ACER encourages cooperative, multidisciplinary research programmes that involve scientists and students from regional, national and international institutions. The Centre's most recent projects involve environmental studies related to tidal power development in the Minas Passage, watershed ecology and "health" indicators, salt marsh restoration modeling, and assessing temporal change in the biodiversity of intertidal infauna. ACER has provided Secretariat services to BoFEP since its formation in 1997.

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

Gulf of Maine Council on the Marine Environment (GOMC)

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 GOMC are formally linked through an agreement that promotes shared goals and objectives, and common projects in the Gulf of Maine and Bay of Fundy.

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

Environment Canada

Environment Canada is the federal agency 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 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.

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

Keynote Addresses

THE SEABED OF MINAS PASSAGE AND ITS RELATIONSHIP TO TIDAL POWER DEVELOPMENT

Gordon B. J. Fader

Atlantic Marine Geological Consulting Ltd., Halifax, Nova Scotia (gordon.fader@ns.sympatico.ca**)**

It has been suggested that working in the Minas Passage region of the Bay of Fundy is like functioning in a region that experiences two hurricanes a day. This results from the extreme tides and their associated high current velocities that funnel through the Passage which connects the Bay of Fundy proper in the west to Minas Basin at the head of the Bay. After failure of the 1980s round of tidal power development that envisioned the construction of massive barrages across areas of the inner Bay of Fundy, EPRI, the Electric Power Research Institute of California re-evaluated Atlantic Canada for the development of in-stream tidal power. They concluded that the Minas Passage region contained the "mother load" of global tidal power potential. This conclusion prompted the Nova Scotia provincial government to seek proposals for the development of a tidal power demonstration facility that included testing the commercial potential of three tidal power turbines and associated infrastructure. The provincial response to the strategic environmental assessment (SEA) supported the creation of a demonstration facility for tidal in-stream energy conversion (TISEC) devices, pending environmental approvals. Minas Basin Pulp and Power Company Limited of Hantsport, Nova Scotia, was successful in its bid to develop the overall demonstration facility, including the placement of their chosen turbine technology along with two other device providers.

Over the past year, considerable research has been conducted in Minas Passage using a variety of high-resolution seabed mapping systems and oceanographic instrumentation. Previous research on the Passage was minimal due to the lack of high-resolution technology and the operating limitations imposed by the severe environmental conditions in these waters. Considerable speculation and anecdotal evidence suggested that the survival of bottom-mounted turbines would be at risk from large rocks moving above the seabed and sunken water-logged, neutrally to negatively buoyant trees and/or sediment laden ice blocks that move along the seabed.

Results of the marine surveys have shown that the seabed is a mature scoured depression in which most of the fine-grained sediments have been excavated to the bedrock surface by erosion over many thousands of years. Boulder strewn bedrock crops out on the seabed and consists of red and grey sediments of the Parrsboro Formation in deeper areas and North Mountain Basalt, forming a flat segmented ridge that projects west from Black Rock. In areas where sediments occur, they are thin and gravel covered glaciomarine stiff muds. Till is rare in the region, and in areas outside scoured depressions, glaciomarine sediment is the dominant surficial material. Gravel waves occur closer to shore and appear to be varying their orientation. Slumped sediments have been found on the edge of the shoreline platform and are cut into glaciomarine sediments. Examination of approximately 600 bottom photographs shows no debris such as rope, logs, and wood on the seabed. The bedload sediment transport zone extends only a few decimeters above the seabed and larger boulders and bedrock are encrusted with delicate marine growth that attest to minimal bedload transport and lower current velocities at the benthic boundary layer. The analysis of high-resolution sidescan sonograms and extensive bottom photography show no evidence for seabed impact by moving ice or debris. This presentation will show high-resolution imagery of the seabed of Minas Passage and Minas Channel as the basis for an understanding of sediment distribution and dynamics, stratigraphy, and geological history, essential elements for the siting of in-stream tidal power infrastructure.

For further information, see: G. B. J. Fader, Geological Report for the Proposed In Stream Tidal Power Demonstration Project in Minas Passage, Bay of Fundy, Nova Scotia, Report prepared for Minas Basin Pulp and Paper Co. Ltd., <http://www.gov.ns.ca/nse/ea/minas.passage.tidal.demonstration/Minas_EA_Vol_II_Appendix.03.pdf>.

USING MULTI-SPECIES ELECTRONIC TAGGING AND TRACKING TECHNOLOGY TO BETTER UNDERSTAND ANIMAL BEHAVIOUR AND OCEAN PHYSICS

Michael Stokesbury,[1] Peter Smith,[2] Terry Dick,[3] and Fred Whoriskey[4]

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[2] BIO, Fisheries and Oceans Canada, Dartmouth, Nova Scotia (SmithPC@mar.dfo-mpo.gc.ca)
[3] Department of Biological Sciences, University of Manitoba, Winnipeg, Manitoba (tadick@ms.umanitoba.ca)
[4] Atlantic Salmon Federation, St. Andrews, New Brunswick (asfres@nb.aibn.com)

Large-scale global (Ocean Tracking Network [OTN]) and regional (Tagging of Pacific Pelagics [TOPP], Tag-A-Giant [TAG], and the Pacific Ocean Shelf Tracking [POST]) projects are now allowing researchers to examine migrations of marine animals on a large scale. Pop-off archival satellite tags, satellite linked tags, and acoustic tags deployed on animals now provide researchers with new detailed information on ocean basin-scale migrations and connectivity between populations. The OTN will produce data on animal movement and physical oceanography from all 14 ocean regions. These data will be permanently housed at Dalhousie University and openly accessible to the public. Data from tagged marine animals will be combined with oceanographic measurements from sensors sampling on coordinated schedules allowing researchers to model data on a global scale. Regional projects that tend to be more species specific, such as the TAG program, have now demonstrated how complex the stock structure may be for highly migratory species such as Atlantic bluefin tuna. This information is now being recognized as fundamental to the proper design of fisheries management regimes. The cutting edge of tagging technology is now being beta tested by researchers in the OTN. Large animals such as Atlantic sturgeon and grey seals will soon be tagged with archival tags that store data (including light curves for calculation of geolocation) which are either relayed to satellites or collected by re-capturing tagged animals. Researcher will also recover the data from the acoustic tags that send signals to arrays of passive receivers when a fish is within range. By also tagging with “Business Card” (BC) tags (a miniaturized receiver coupled with a coded pulse transmitter) we obtain time, depth and location stamped data along with records of inter- and intra-specific animal interactions. A computer model has been developed to enable the interpretation of 3-D measurements of parameters related to animal/environment interactions. These variables include feeding and reproductive behaviour of the animals, measurements of local physical oceanography and bathymetric data. This methodology will provide fundamental information for 1) quantifying the impacts of in-stream tidal power infrastructure in the Bay of Fundy, and 2) detecting animal movement, migration and the behaviour of many commercially important and iconic species including Atlantic sturgeon, Atlantic salmon, striped bass, American herring, Atlantic cod and American eels. Such an experiment coupled with the extensive infrastructure provided by the OTN will produce information on local scale behaviours in critical areas, as well as information on large-scale movements and migrations.

PARKS CANADA'S NATIONAL MARINE CONSERVATION AREA PROGRAM: AN OVERVIEW

Rob H. Thompson

Parks Canada, Halifax, Nova Scotia (rob.thompson@pc.gc.ca)

The presentation provides a national perspective on Parks Canada's National Marine Conservation Area (NMCA) program. It highlights the federal context, objectives, legislation, policies and the planning process. It also addresses the current status of various initiatives across the country and ends with a focus on Atlantic Canada. The NMCA program is part of the Federal Marine Protected Areas Strategy under the Oceans Action Plan which serves as the framework to sustainably develop and manage Canada's oceans.

TOURISM AND THE BAY OF FUNDY

Terri McCulloch

Bay of Fundy Tourism Partnership, Parrsboro, Nova Scotia (terri@bayoffundytourism.com)

This talk, given at the banquet, described the various tourism attractions of the Bay of Fundy and the efforts of the Bay of Fundy Tourism Partnership to enhance tourism and visitation in the Bay region. The talk was accompanied by slides of Fundy's natural features and new initiatives such as the Fossil Cliffs Centre at Joggins, Nova Scotia. See <http://www.bayofundytourism.com>.

Session A

TIDAL POWER

Chair: Graham Daborn, Acadia Centre for Estuarine Research, Wolfville, Nova Scotia

INTRODUCTION TO SESSION A: TIDAL POWER

Graham R. Daborn

Acadia Centre for Estuarine Research, Wolfville, Nova Scotia (graham.daborn@acadiau.ca)

Tidal power is an old technology. Mechanical mills driven by tidal movements in estuaries have been widespread in Europe for at least a thousand years (Charlier 1982), used variously for grinding grain or pumping water. In the Bay of Fundy, it is believed that Champlain's 1607 grist mill near Port Royal was driven by tidal movements. Next year (2010), however, we reach the centennial of Turnbull's original proposal for generating electrical energy from the tides in Passamaquoddy Bay. In that last hundred years, there have been four major and numerous minor proposals for large-scale tidal energy development in the Bay of Fundy (Figure 1). Most of these involved creation of one or more barrages, to capture some of the potential energy of the tides, but at least one (the Clarkson proposal of 1915) was for a kinetic energy conversion. Apart from the earliest studies of fisheries in the Outer Bay (1898–1911), tidal power proposals were responsible for surges in research activity in the Bay of Fundy in every decade of the 20th century. It is arguable that most of what we know about the Bay's ecosystem has resulted from these dreams of harnessing its energy (Daborn 2007).

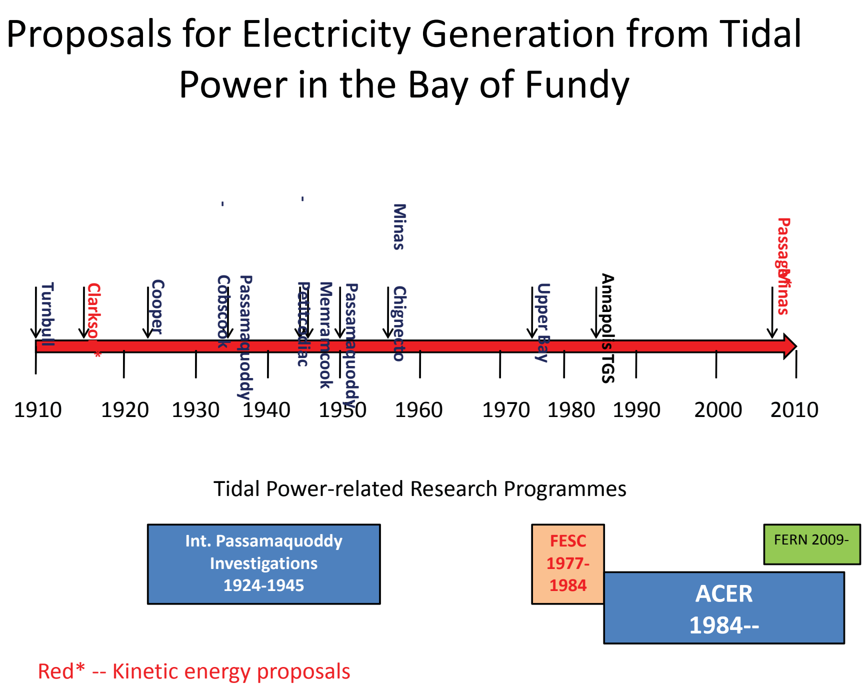

Figure 1. One hundred years of tidal power investigations in the Bay of Fundy

In the 1970s, rising oil prices triggered an extensive examination of the potential for barrage-based tidal power development, this time in the upper Bay of Fundy. Three sites were considered as having high potential: the mouth of Shepody Bay (site A6), the mouth of Cumberland Basin (A8), and the mouth of Cobequid Bay (B9). At the instigation of George Baker (see Dedication, p. iii above), the first comprehensive workshop to identify potential environmental issues was held at Acadia University in November 1976 (Daborn 1977). The conclusion of that workshop was recognition of the paucity of basic knowledge about the upper Bay relative to the outer Bay, and the need for a rapid, collaborative and comprehensive programme of study. Thus was born the Fundy Environmental Studies Committee (FESC), which, under the sponsorship of the Atlantic Provinces Inter-University Council on the Sciences (APICS), oversaw a broad investigation of the Bay of Fundy from 1978 to 1984. Its final report (Gordon and Dadswell 1984), and the numerous other papers and research projects that contributed to it and followed the FESC approach, constitute an outstanding example of what can be achieved when institutions, agencies and individuals collaborate equitably to address a common problem. Although not identified as such, it was the first of the science research networks which have become a popular model in Canada at the present time.

By 1984, interest in Fundy tidal power had ebbed once again as oil prices had declined, and it was decided to terminate FESC. However, there were still many questions remaining about the environmental effects of barrage-based tidal power, and in order to continue the collaborative, multi-institutional approach to these questions, the Acadia Centre for Estuarine Research (ACER) was established at Acadia University in 1985. Over the last 25 years, researchers from regional universities, the Bedford Institute of Oceanography, and the private sector have continued to study the mudflats, salt marshes, fish, sediments, and effects of barrages in the upper Bay of Fundy, as basic research, but also with a view to assessing the long-term and large-scale consequences of potential energy conversion from the Bay. The pilot tidal power plant at Annapolis Royal has been a valuable platform for many of these investigations.

The latest iteration of this century-long story, however, is focused on a range of new technologies that aim to convert kinetic energy of moving tidal waters into electricity. These devices are diverse in design and structure, and present a few familiar questions (e.g., What are the ecosystem-wide effects of energy conversion?), together with a suite of new research challenges. Furthermore, the prime locations for tidal in-stream energy converter (TISEC) devices are in the narrow passages at the entrance to bays or between islands—sites that are still ecologically poorly known. Thus, once again, it appears that new investigations into the oceanography of the Bay of Fundy are needed to lay the foundation for assessment of tidal power potential.

The present initiatives around tidal power development in the Nova Scotia portion of the Bay of Fundy are being coordinated by the Offshore Energy Environmental Research Association (OEER), in collaboration with the Offshore Energy Technical Research Association (OETR). OEER is a consortium of three universities – Acadia, St. Francis Xavier, and Cape Breton – and the Nova Scotia Department of Energy. It is a not-for-profit corporation dedicated to "fostering offshore energy and environmental research and development, including examination of renewable energy resources and their interaction with the marine environment." In 2007, OEER conducted a Strategic Environmental Assessment of Marine Energy from the Bay of Fundy (OEER 2008), supported by preparation of a background document (Jacques Whitford 2008) and an extensive public consultation process. A public consultation process was also carried out in New Brunswick. Because of its intrinsic involvement in the tidal power issue, OEER partnered with BoFEP in support of the Tidal Power Session at this workshop.

The session that follows brought together numerous individuals from government, academia and the private sector currently involved in research on the tidal power issue. Even though the commitment to develop a test facility in Minas Passage for large TISEC devices was made only a couple of years ago, much new information has already been obtained, particularly through the collaborative efforts of the Bedford Institute of Oceanography, the proponents of the tidal power test centre (Minas Basin Pulp and Power Ltd, Nova Scotia Power Inc., Clean Current Systems, and their consultants), academic researchers, and local fishers.

This Tidal Power session was initiated with a Keynote Presentation by Gordon Fader (Atlantic Marine Geological Consulting Ltd.), who described the recent investigations of the bottom substrates in the Minas Passage area. Gordon Fader is Scientist Emeritus at the Bedford Institute of Oceanography, where he was a marine geologist for more than 30 years. His responsibilities for mapping the surficial sediments of eastern Canadian waters, including the Bay of Fundy, have involved him in the development and use of new technologies that have greatly enhanced the ability to survey the ocean floor and to interpret the dynamic processes at work. As a result, Gordon has been involved in numerous high profile projects, including oil and gas development at Hibernia and on the Scotian Shelf, the Swissair 111 investigation, and the search for the Titanic. (He even has a cameo appearance in the movie.) Recently, he has been directly involved in exploring the seabed in Minas Passage and Channel, a portion of the Bay of Fundy that until now was essentially unexplored.

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INSIGHT INTO THE GLACIAL HISTORY OF THE BAY OF FUNDY REVEALED THROUGH SEA FLOOR MAPPING USING MULTIBEAM SONAR

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In 2006, the Geological Survey of Canada, in cooperation with the Canadian Hydrographic Service and the University of New Brunswick, instituted a broad-scale regional mapping program to map the entire sea floor of the Bay of Fundy. To date, 12,466 square kilometres of multibeam sonar coverage have been acquired. The resulting sea floor map contains a wealth of evidence demonstrating the impact of Pleistocene Epoch glaciation on the Bay of Fundy and holds the promise of yielding one of the most comprehensive depictions of a glacial landsystem ever obtained in a marine setting. Glacial ice flowed from the head of the bay in the northeast to the Gulf of Maine in the southwest. In the southwest, a topographically controlled ice stream existed in the bedrock trough between Brier and Grand Manan islands. Streamlined subglacial landforms (drumlins and megaflutes) are prominent on the flanks of the trough. Prominent lobate ridges, convex to the southwest, are ubiquitous in the central portion of the bay. It is not clear if these ridges are subglacial or ice-front in origin; in any case they appear to mark a complex pattern of ice retreat to the northeast. During retreat, icebergs calved from the floating ice front; iceberg keels incised a dense pattern of scours and pits into the sea floor sediment and this pattern is used to infer paleocurrent patterns. Superimposed on the glacial landsystem features are Holocene Epoch sedimentary bedforms that reflect the modern current regime in the Bay of Fundy.

MULTIBEAM BATHYMETRY AND LIDAR SURVEYS OF THE BAY OF FUNDY, CANADA – PROGRESS TO NOVEMBER 2008

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The Bay of Fundy on the east coast of Canada has the largest recorded tides in the world, with a maximum range of about 17 metres. Tidal current velocities that exceed 4.5 m s^{-1} are currently being studied to determine the potential for in-stream tidal electrical power generation. In 2006, the Geological Survey of Canada, in conjunction with the Canadian Hydrographic Service and several universities, commenced a program to map the seabed of the Bay of Fundy. About 12,500 km^2 of multibeam bathymetry have been collected in the bay. Sub-bottom profiler data were collected simultaneously to provide information on the character and thickness of the sediments on the sea floor. Large intertidal areas were surveyed using airborne Light Detection and Ranging (LiDAR), providing an opportunity to generate a continuous map of the marine, intertidal and terrestrial areas. Information from geophysical surveys, seafloor samples, photographs, and video transects is being integrated to produce surficial geology and benthic habitat maps.

Some key findings of the project are:

- Large glacial landforms may provide suitable habitats for fish and shellfish
- Strong tidal currents are reworking sediments
- Migration of large sand waves is observed in repetitive multibeam bathymetry surveys
- Deep tidal-scour channels are present in several areas
- The distribution and morphology of extensive horse mussel reefs have been mapped

INTEGRATING MULTIBEAM BATHYMETRY AND LIDAR SURVEYS OF THE BAY OF FUNDY, USING ISLE HAUTE AS AN EXAMPLE

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Terrestrial LiDAR was acquired during low tide for many of the coastal areas of the Bay of Fundy, with the intention of integrating the multibeam bathymetry in order to construct a seamless digital elevation model. The LiDAR elevation data are referenced to the WGS84 mapping system and the heights transformed to the Canadian Geodetic Vertical Datum of 1928 (CGVD28). The bathymetric data are often referenced to a local chart datum based on an elevation lower than the lowest tide. In order to construct the seamless DEM, the differences in the two vertical datum must be reconciled. In order to test this methodology, terrestrial LiDAR data collected by the Applied Geomatics Research Group and multibeam bathymetric data collected by the Geological Survey of Canada, in conjunction with the Canadian Hydrographic Service, around Isle Haute in the Bay of Fundy have been used. The CGVD28 vertical datum was used as the common vertical reference and the bathymetric data were transformed to this datum. The two elevation models (bathymetry and land) were then merged to form a single, seamless model, where the zero value approximates mean sea level and negative values denote the bathymetry and positive values denote the land elevations. Even with the large tidal range in the Bay of Fundy, a gap exists between the multibeam coverage and the LiDAR coverage. The near shore bathymetry data are difficult to collect with marine vessels because of navigation safety issues and the cost of multibeam surveys in shallow water due to the narrow survey swath. Bathymetric LiDAR technology may be suitable to fill in this "white ribbon" on the map; however this technology is not readily available in the region. This proof of concept project has demonstrated the need to reconcile differences in vertical datums between data sets in order to perform subsequent analysis. For example, the land water boundary is a transient feature that is constantly changing. Geological evidence from other parts of the Bay indicate sea level was once much lower during the last glaciation, then rose to a high stand 10s of meters above the current shoreline 12–15 ka after the ice melted and prior to the crust rebounding. Today the crust is subsiding in this region at a rate estimated to be between 15–20 cm per century, and global sea level is rising and predicted to accelerate under the projected climate conditions. A seamless DEM allows us to simulate past and future sea level changes and better understand the morphology and history of the processes that have shaped the landscape.

A REVIEW OF A RECENT ASSESSMENT OF TIDAL CURRENT ENERGY IN THE MINAS PASSAGE

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Abstract

Karsten et al. (2008) examined the tidal power available for electricity generation from in-stream turbines placed in the Minas Passage of the Bay of Fundy. Here we present a summary of their results. Using their model of the flow through the Minas Passage and the tidal amplitude in the Minas Basin, a formula for the power that can be extracted from the flow by in-stream turbines is presented. The formula agrees remarkably well with two-dimensional, finite element, numerical simulations of the Bay of Fundy-Gulf of Maine system. The simulations suggest that a maximum of 7 GW of power can be extracted by turbines in the Minas Passage, considerably higher than previous estimates.

The theory and simulations also show that the extraction of the maximum power will reduce the flow rate through the Minas Passage and the tides in the Minas Basin by almost 40%. However, a significant portion of the maximum power can be extracted with little change in tidal amplitude since the initial power generation primarily causes an increase in the phase lag of the basin tides, not a change in amplitude. The numerical simulations show that any power extraction in the Minas Passage results in changes in tidal amplitudes throughout the Bay of Fundy and Gulf of Maine. While extracting the maximum power produces significant changes, 2.5 GW of power can be extracted with a maximum 5% change in the tidal amplitude at any location.

Introduction

The large tides in the Bay of Fundy and in particular the Minas Basin are a large source of energy. This has encouraged the discussion of tidal power in the region for nearly one hundred years. In this article, we review the results presented in Karsten, McMillan, Lickley and Haynes (2008) (hereafter KMLH), which assessed the power potential of the tidal currents in the Minas Passage (interested readers are also directed to McMillan and Lickley 2008).

With the development of in-stream tidal turbines, the prospect of tidal power in the Bay of Fundy is being revisited. As discussed in a variety of articles (see, for example, Triton 2006; Blunden and Bahaj 2007; Hagerman et al. 2006; Bryden et al. 2007; Blanchfield et al. 2008), tidal turbines, which act much like wind turbines, are thought to offer many advantages over other forms of power generation. The high density of water and the predictability of the tides suggest that tidal turbines should be able to produce a large amount of reliable power, while the flexibility of individual turbines should make turbines more economically and ecologically attractive than tidal barrages. However, these advantages have yet to be established in practice as most operating turbine projects are small in scale (Sutherland et al. 2007).

Harnessing in-stream tidal power requires placing turbines in regions of high tidal flow. The strongest flow in the Bay of Fundy occurs through the Minas Passage, the relatively deep, thin channel that connects the Minas Basin to the Bay of Fundy (see Figure 4). As such, this region has become the focus of tidal power in Nova Scotia and will be the site of three test turbines to be deployed in 2009 and 2010. This article assesses the resource potential of the Minas Passage, summarizing the results found in KMLH.

The Potential Extractable Power

Recent surveys of potential tidal power sites have estimated the theoretical mean power of a flow through a channel using a formula based on the kinetic energy flux in the undisturbed state (Triton 2006; Hagerman et al. 2006):

$$P_{KE} = \frac{1}{2}\rho A_c \overline{u^3}, \tag{1}$$

where ρ is the density of water, A_c is the cross-sectional area of the channel and *u* is the depth-averaged speed of the flow. The over bar indicates that the cube of the speed is averaged over a tidal cycle so that (1) represents the average power in the tidal current. In Triton (2006), this formula was used to give a power estimate of 1.9 GW for the Minas Passage, while Hagerman et al. (2006) estimated that only a small portion of this, 166 MW, could be reasonably converted to electricity.

Several aspects of this kinetic energy flux estimate require comment. First, an important aspect of the estimate is that the speed is cubed, so the power estimate increases rapidly with small increases in flow speed. Thus, formula (1) suggests that the best region for power is the narrowest portion of a channel with the highest flow speed. Second, the estimate contains no information about what forces the flow. This is extremely important for tidal flows. Extracting power and thus slowing the flow through the channel can increase the tidal head, the difference in tidal elevation across the channel. Thus, extracting power actually increases the forcing that drives the flow (see discussion of Figure 2). Formulas that do not take this into account may underestimate the potential power. Finally, formula (1) does not calculate the extractable power but the existing power in the flow.

Recently, Garrett and Cummins (2005) examined the potential of in-stream power generation from tidal flow in a channel. They reached two important conclusions: first, "the average power produced need not be much less than in a conventional scheme with a dam," and, second, "there is no simple relationship ... between the maximum average power and the average kinetic energy flux in the undisturbed state" (Garrett and Cummins 2005). Garrett and Cummins (2005) and Blanchfield et al. (2008) derived an alternative formula for the maximum, time-averaged, extractable power given by:

$$P_{max} = \frac{1}{4}\rho g a Q_0, \tag{2}$$

where *a* is the amplitude of the forcing tides across the channel, *g* is the acceleration due to gravity, Q_0 is the maximum volumetric flow rate through the channel in the undisturbed state. (The constant of ¼ in formula (2) is determined by the geometry of the passage/basin and can vary over the small range between 0.19 and 0.25, see KMLH for details.) For the Minas Passage, with *a* = 4.7m, $Q_0 = 7.5\times10^5$ m^2/s the formula predicts a maximum extractable power of P_{max} = 8.9 GW, considerably more than predicted by (1). In contrast to (1), formula (2) includes the tidal forcing through *a* and depends linearly on the current speed through the flow rate, Q_0. As well, since the power depends on the volumetric flow rate, the formula does not differentiate between thin channels with strong flow and wide channels with weaker flow.

In KMLH, the theory of Garrett and Cummins (2005)—and the further expansion of the theory in Blanchfield et al. (2008)—are applied to the Minas Passage and Minas Basin. The theory presented in KMLH models the flow through Minas Passage with two differential equations, one for the momentum balance in the passage and one for the conservation of mass connecting the flow through the passage to the tides in the basin. The model includes the drag on the flow in the Minas Passage. The drag is a combination of both natural drag due to bottom friction and nonlinear aspects of the flow, and the drag associated with adding turbines. KMLH give a complete description of how a solution can be found to this pair of equations. The solution gives the amplitude of the flow through Minas Passage and the tides in Minas Basin as functions of the parameters that describe the passage and the turbine drag. From these solutions a formula (equation (17) in KMLH) for the power associated with turbines is presented (It should be noted that equation (17) is missing a factor of β in the numerator).

Here we simply present equation (17) in KMLH written with the parameter values found for the Minas Passage, giving:

$$P_{ext}(\kappa) = \frac{11.5\kappa}{\left(1+\sqrt{1+0.2(1+\kappa)^2}\right)^{\frac{3}{2}}}. \qquad (3)$$

This gives the extractable power, P_{ext}, in GW as a function of κ, the ratio of the turbine drag to the natural drag in the system and is plotted as the blue curve in Figure 1. The formula shows that the power initially increases from zero as turbines are added but that when the turbine drag is large, the flow through the channel is so reduced that the power extracted is reduced and eventually becomes zero for large κ. In between these two limits there is the maximum extractable power of 7.8 GW at κ=7.7, that is when the drag associated with turbines is 7.7 times the natural drag in the channel. KMLH also show that this maximum corresponds to formula (2) with the constant of 0.22.

In order to validate the theory, KMLH simulate the Bay of Fundy-Gulf of Maine tides using a two-dimensional version of the Finite Volume Coastal Ocean Model (FVCOM) (see Chen et al. (2006) for the details of FVCOM). The original model grid was constructed by David Greenberg from the Bedford Institute of Oceanography and extends far beyond the Bay of Fundy and Gulf of Maine system so that it can respond freely to the tidal forcing. The results presented here were found with a model resolution with 16 times the number of elements in the original grid. The model was forced by specifying the M_2 phase and amplitude at the open boundary. The simulation results were compared to observed tides and to other models to ensure the modeled tides were realistic (see KMLH for details). As in Sutherland et al. (2007), the drag associated with the turbines is represented by increasing the bottom friction over the entire Minas Passage. Such a scenario is a rough model of a turbine farm or a series of turbine fences across the Minas Passage. A series of simulations were run, with increasing turbine drag, and the power associated with the turbine drag calculated.

In Figure 1, the turbine power from the theory and simulations is plotted versus κ. For small κ, the two agree remarkably well. But as κ increases, the power in the simulations is somewhat lower than the theory predicts. The power initially increases rapidly to a maximum and then tails off slowly, as the theory predicts. The maximum power in the simulations of 7.0 GW occurs at κ=6.5, in reasonable agreement with the theory. The discrepancy between the theory and simulations most likely results from the theoretical assumption that tides to the west of the Minas Passage are not changed by the turbines, while Figure 4 shows that in the simulations this is not the case.

The Impact of Power Extraction on the Amplitude of the Tides

Any change in the flow through the Minas Passage will have a direct impact on the tides in the Minas Basin and indirect effects throughout the Bay of Fundy and Gulf of Maine. The theoretical formula for the power presented in KMLH can be rearranged to give the power as a function of the relative change in the amplitude of the tides in the Minas Basin as follows:

$$P_{ext}(\Delta\eta) = \frac{1}{2}(1-\Delta\eta)\left(\sqrt{1-0.95(1-\Delta\eta)^2} - 0.21(1-\Delta\eta)^2\right) \qquad (4)$$

where Δη is the relative change in the amplitude of the Minas Basin tides and P_{ext} is the extractable power in GW. In Figure 2 this formula is plotted along with the corresponding change in Minas Basin tides as calculated from the numerical simulations. As one would expect from the previous graphs, the theory and simulations agree for small Δη but differ at larger values as the simulation turbine power is lower. If the maximum power is extracted, the Minas Basin tides are reduced by 36% for the theory and 38% in the simulations. However, the curves rise rapidly so that 2.5 GW can be extracted in the simulations with only a 5% reduction in the basin tides! Since the simulations agree well with the theory for small $\Delta\eta$, it is useful to linearly expand (4) about $\Delta\eta=0$, giving

$$P_{ext}(\Delta\eta) \approx 0.77\Delta\eta. \qquad (5)$$

Remarkably, equation (5) tells us that for low levels of power extraction, 0.77 GW of power can be extracted from the flow for each percentage reduction in the Minas Basin tides!

Before proceeding to the impact of power extraction on the tides throughout the Bay of Fundy and Gulf of Maine, it is worth giving a brief explanation of why it is possible to extract so much power with so little change in the Minas Basin tides. In KMLH, it is shown that when power is extracted from the flow through the Minas Passage, the primary change in the tides is an increase in the phase lag of the Minas Basin tides. This is illustrated in Figure 3 where the tides to the west and east of the Minas Passage are compared for simulations with and without turbines. The phase lag is increased when turbines are added because the turbine drag slows the flow through the Minas Passage and thus delays the tides from reaching the Minas Basin. As shown in Figure 3, the increase in the phase lag increases the tidal head across the Minas Passage. The increased tidal head produces a stronger hydrostatic pressure force across the passage, somewhat offsetting the increased drag. Thus, the tidal currents in the Minas Passage and the tides in the Minas Basin are not reduced as much as one might naively predict.

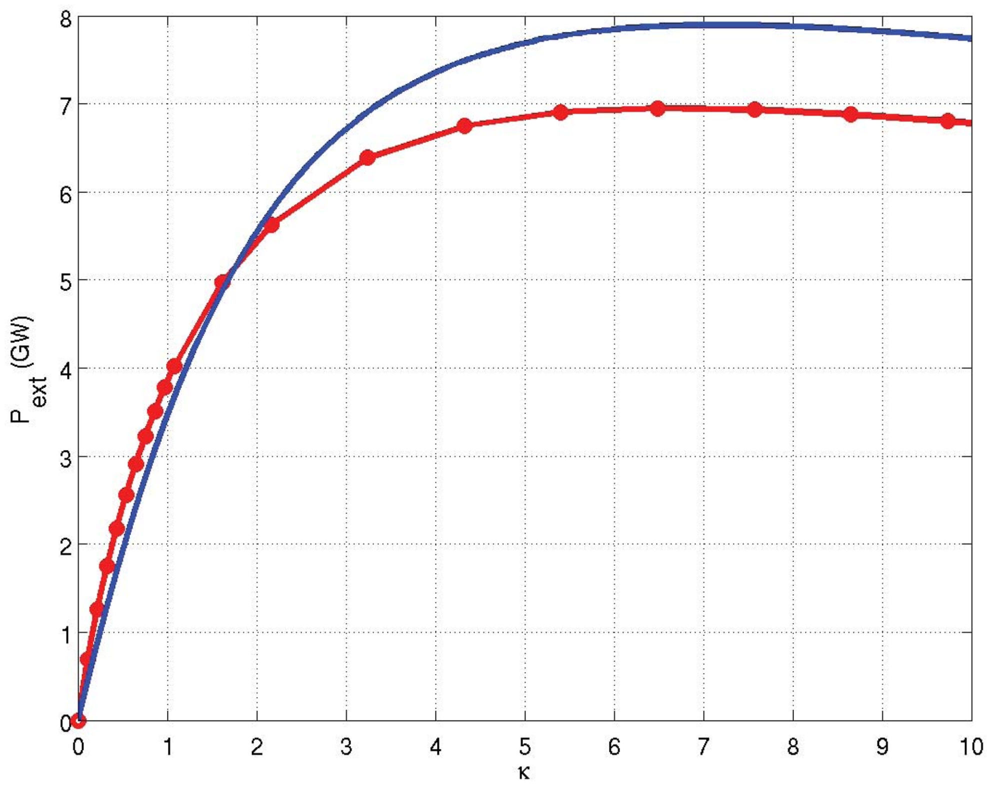

Figure 1. The power extracted by turbines versus the turbine drag parameter, κ, as given by the theory in equation (3) (blue line) and the numerical simulations (red line with dots)

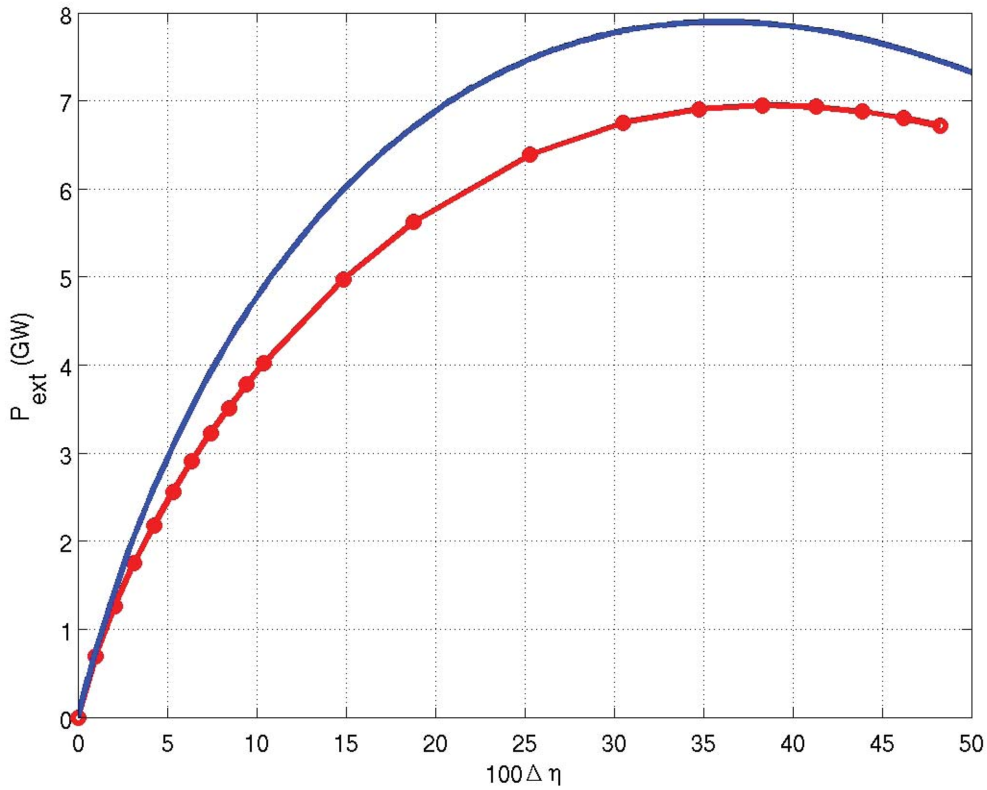

Figure 2: The power extracted by the turbines versus the change in the amplitude of the tides in the Minas Basin as given by equation (4) (blue line) and the numerical simulations (red line with dots)

It is obvious that extracting power in the Minas Passage causes changes to the phase and amplitude of the tides in the Minas Basin. However, KMLH showed that the extraction of power also causes changes throughout the Bay of Fundy and the Gulf of Maine. They plotted the changes through the region if the maximum power is extracted. Here we concentrate on the case where only 2.5 GW of power is extracted. In Figure 4 the change in tidal amplitude that occurs is plotted for the upper Bay of Fundy (upper plot) and throughout the Gulf of Maine (lower plot). As discussed above, the tides in the Minas Basin are reduced almost uniformly by 30 cm or about 5% of the original 6 m tides. The reduction in tides decreases rapidly west of the Minas Basin: the tides are reduced by 15 cm in the Minas Passage and by 10 cm in the rest of Minas Channel. Over the rest of the upper Bay of Fundy, including Chignecto Bay, the tidal amplitudes are reduced by less than 8 cm. Conversely, tidal amplitudes are increased throughout the Gulf of Maine. The tides increase by between 1 to 3 cm for most of the gulf, with larger values to the west and a maximum in the Boston/Cape Cod area. There is little change in the tides near the mouth of the Bay of Fundy and little change outside the Gulf, for example, along the South Shore of Nova Scotia and in the deep ocean.

KMLH examine the changes in the tides that result when power is extracted from the Minas Passage in more detail. In particular they show that the largest relative change is always a local change in the Minas Basin and that the increase in tides in the Gulf of Maine is related to the Bay of Fundy–Gulf of Maine system moving closer to resonance with the forcing tidal period.

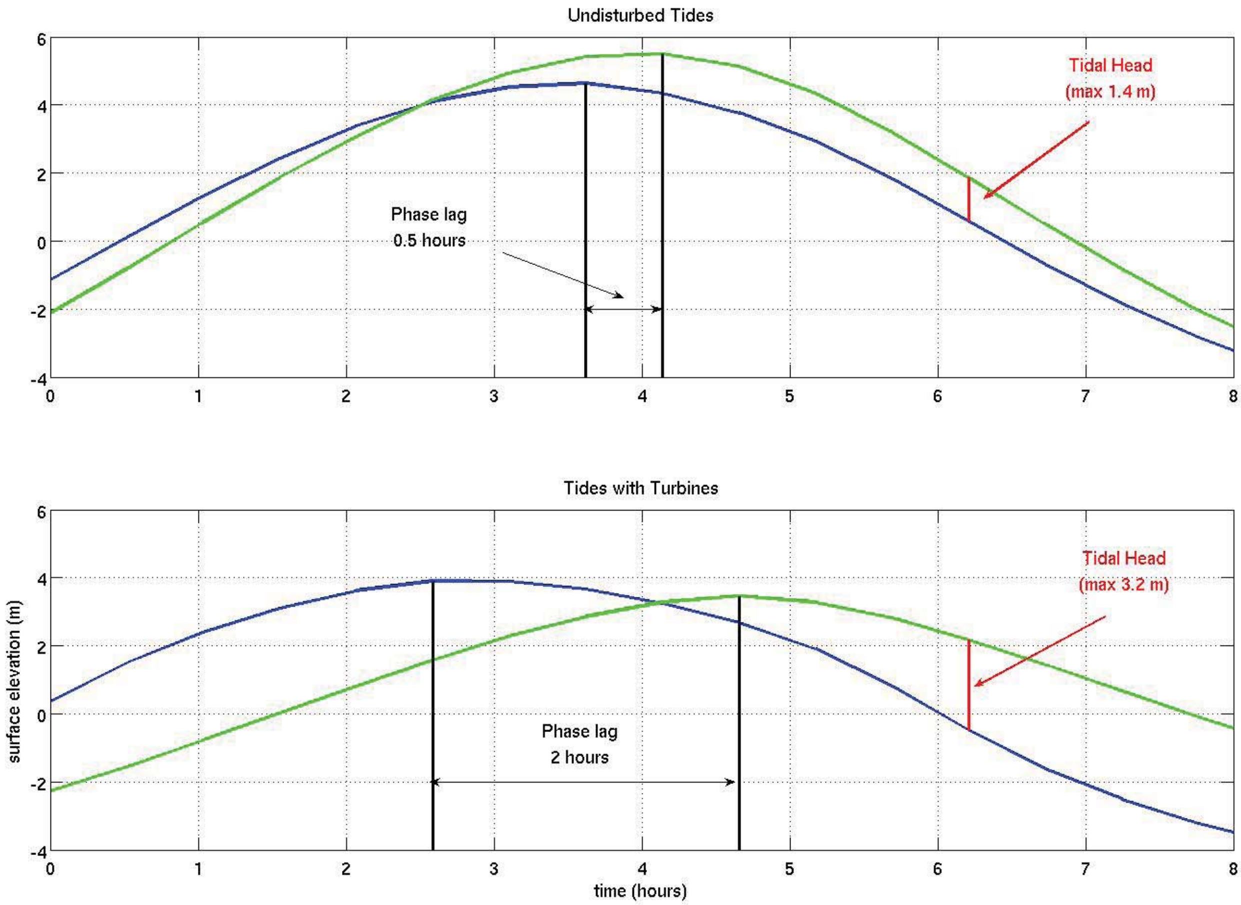

Figure 3: The upper figure plots the tides west of the Minas Passage (blue) and east of the Minas Passage (green) versus time in hours. The phase lag of about a half an hour between these tides results in a maximum tidal head across the Minas Passage of 1.4 m The lower figure plots the same curves but when turbine drag has been added to the Minas Passage. The phase lag has increased to 2 hours resulting in a maximum tidal head of 3.2 m.

Summary

Tidal power has recently received renewed attention as the search for renewable, green power sources intensifies. Here, we have recapped the examination of the high tides in the Bay of Fundy and in particular the large tidal flows through the Minas Passage presented in KMLH. A theoretical framework and the results of numerical simulations argue that up to 7 GW of power could be extracted from the Minas Passage. While the effects of extracting the maximum power are significant, a significant amount of power can be extracted with limited effects on both the local and far-field tides. For example, we show here that 2.5 GW of power can be extracted with only a 30 cm decrease in the Minas Basin tides and a 3 cm increase in the tides along the east coast of the United States. If we assume that the water-to-wire efficiency of in-stream turbines is 30% to 50%, this means that 0.75 to 1.25 GW of electricity could be produced from the flow through the Minas Passage with relatively small changes to the tides in the region.

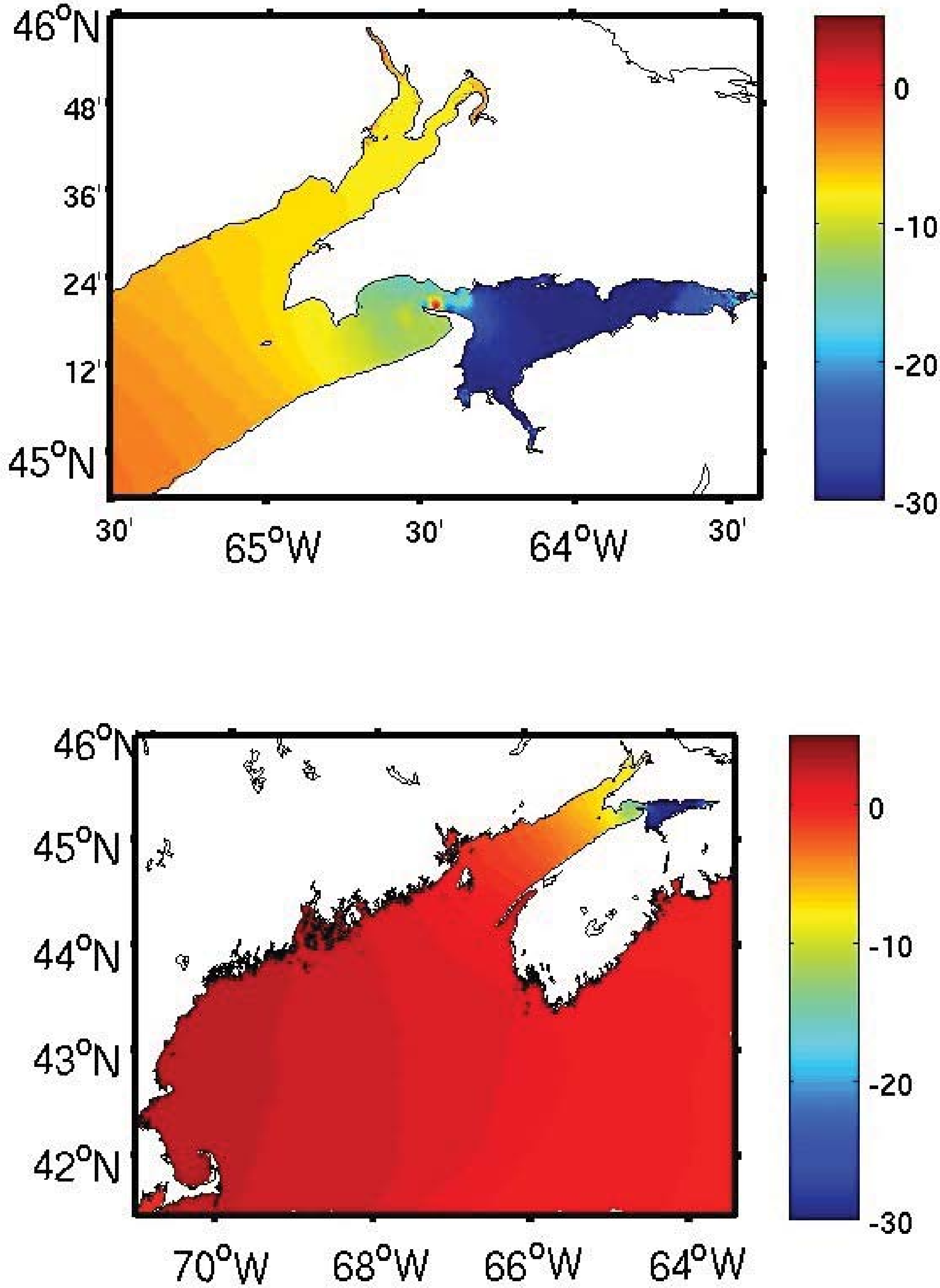

Figure 4: The change in the amplitude of the tides (cm) in the Minas Basin and upper Bay of Fundy (top) and throughout the Gulf of Maine (bottom) as a result of extracting 2.5 GW of power from the Minas Passage

It should be noted that the results of KMLH are the initial results of an ongoing research project. However, more recent simulations of more realistic arrays of turbines in three-dimensional flow do suggest that the conclusions about the maximum extractable power and the impact of extracting power still hold true.

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CURRENTS IN MINAS BASIN, NOVA SCOTIA, CANADA

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Abstract

The Bay of Fundy tides produce tidal heights reaching approximately 12 metres in Minas Basin. These extreme tidal heights are known to generate high currents in Minas Channel. Oceans Ltd used both moored upward-looking and vessel mounted downward-looking acoustic Doppler current profiles (ADCPs) to measure the currents for Minas Basin Pulp and Power Co. to help identify appropriate sites for placing marine current turbines to harness the tidal energy. The currents were found to be aligned with the channel and reached speeds in excess of 5 m/s at some locations. The currents were mainly due to the semidiurnal tidal constituent M2 (semidiurnal lunar constituent) and S2 (semidiurnal solar constituent). Since the magnitude of M2 was approximately several times larger than S2, the currents were high during neap tides as well as during spring tides. The current decreased only slightly with depth. The current measurements demonstrated the potential for a significant amount of power to be generated from Minas Basin.

Introduction

Minas Basin is a semi-enclosed basin located on the southern branch of the upper Bay of Fundy. The waters of Minas Basin exchange with the main part of the Bay of Fundy through Minas Channel, which flows between Cape Split and Cape Sharp, creating extremely strong tidal currents. Tides in Minas Basin are greatly amplified and have a range of the order of 12 metres. The primary cause of the immense tides is resonance in the Bay of Fundy because its dimensions support the oscillation of a standing wave. Strong tidal power as a clean renewable source of energy is attracting attention worldwide. The interest in development of this new energy is being driven by the concern with long-term energy supply and environmental consequences of the release of greenhouse gases from consumption of fossil fuels. The Bay of Fundy with its resonance tides and strong tidal currents makes this area unique for the generation of tidal power.

Current Measurements

The initial task taken on by Oceans Ltd in 2008 was to identify the most appropriate sites with respect to current flow for the placement of turbines in Minas Channel and Minas Passage. Currents were measured in Minas Passage since May, 2008 using ADCPs, in both downward-looking and moored upward-looking modes. Figure 1 gives the positions of mooring for each site. Table 1 provides details on the instruments in Minas Passage. The ADCPs used in Minas Passage were 300 kHz Workhorse broadband systems. The ADCPs were moored at the bottom and collected data from the near bottom to the surface with a sampling interval of 10 minutes and a depth interval of 4 m. An InterOcean current meter S4 meter was fixed to the mooring and measured the bottom currents at a height of 0.5 m above the sea floor at Site 5. The vessel-mounted ADCP collected data through the water column at different locations with a sampling interval of 10 minutes and a bin size of 4 m on May 1, 2008. In this paper water depth refers to the distance from the surface at mid-tide.

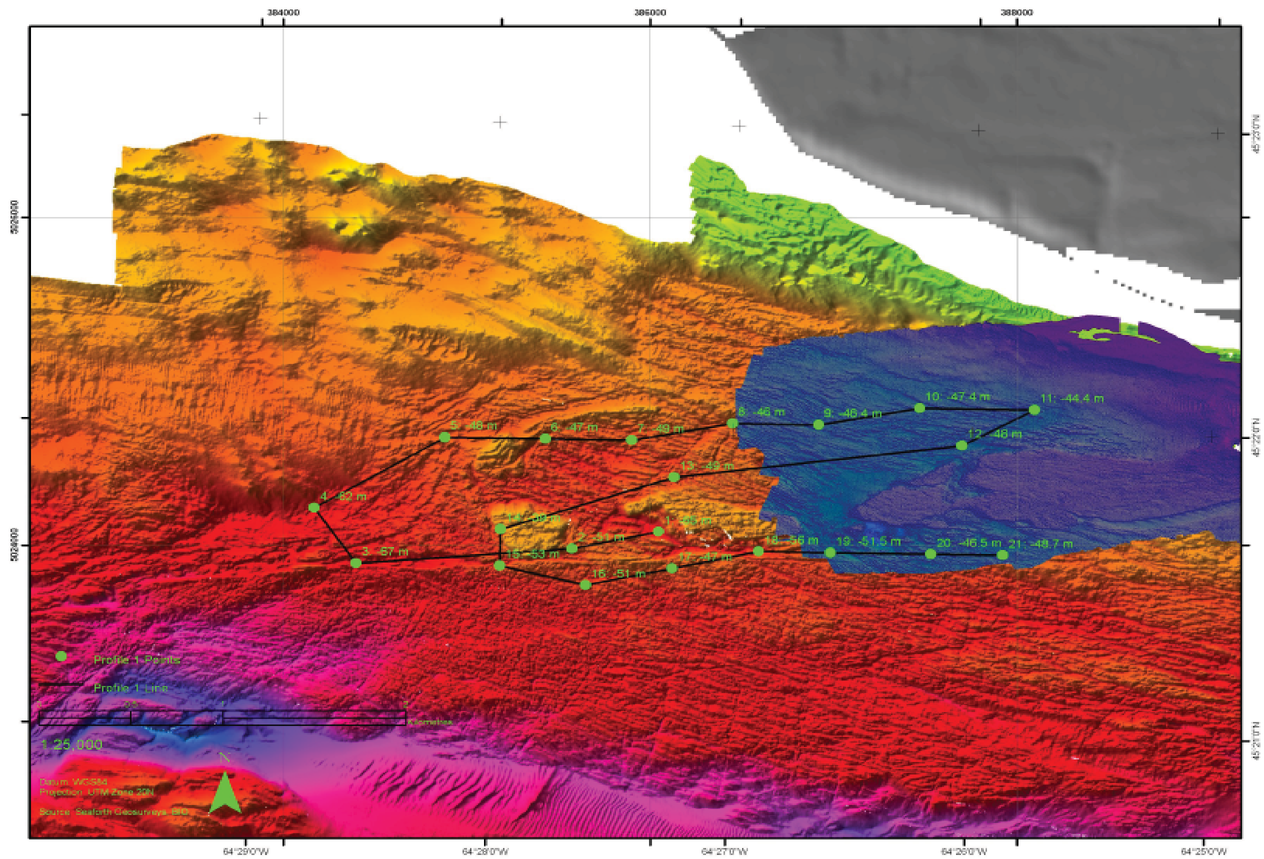


Figure 1. Mooring Positions in Minas Basin

Instruments	Date	Location	Site No.	Meter Depth at mid-tide	Sampling Interval	Bin Size
Vessel-Mounted ADCPs	May 1, 2008	-	-	Surface	10 minutes	4 m
	July 10, 2008	-	-	Surface	10 minutes	1 m
Moored ADCPs	May 2 - June 4, 2008	45° 21´ 53´´N 64° 27´ 32´´W	Site 1	58 m	10 minutes	4 m
	May 4 – May 5, 2008	45° 21´ 22´´N 64° 27´ 50´´W	Site 2	57 m	10 minutes	4 m
	June 5 – July 9, 2008	45° 22´ 15´´N 64° 26´ 53´´W	Site 3	52 m	10 minutes	4 m
	August 21 – September 23, 2008	45° 22´ 11´´N 64° 26´ 38´´W	Site 4	51 m	10 minutes	4 m
	February 14 – March 28, 2009	45° 21´ 56´´N 64° 25' 32´´W	Site 5	46 m	10 minutes	4 m
S4	February 12 – March 29, 2009	45° 21´ 56´´N 64° 25' 32´´W	Site 5	48 m	10 minutes	-

Table 1. List of Current Meters, Minas Basin 2008–2009

Analysis

Vessel-mounted ADCP Data

An ADCP was mounted to the survey vessel on May 1, 2008, during falling tide, to carry out a series of bottom track profiles in the locations shown in Figure 2. Figure 3 shows stick plots of the current at depths of 7 m, 19 m, 31 m and 43 m, respectively. The numbers in the plots are the station numbers. Current directions had no significant change with depth during the sampling time. Current speed had a magnitude of 2.5 m/s at the surface, approximately 2 to 2.5 m/s at mid depths and decreased to 1.5 m/s over the bottom. The current directions were toward the northwest from surface to bottom with an average speed of 2 m/s.

Transect plots in Figure 4 show three vertical sections of speed versus depth and direction versus depth, along the ship's track. The position coordinates are labeled at the starting (left) and ending positions (right) of the plots. The 1st (station 5 to 11) and 3rd (station 15 to 21) tracks are parallel and the 2nd track is along the diagonal. The currents were profiled during falling tide and tend to have lower values than rising tide.

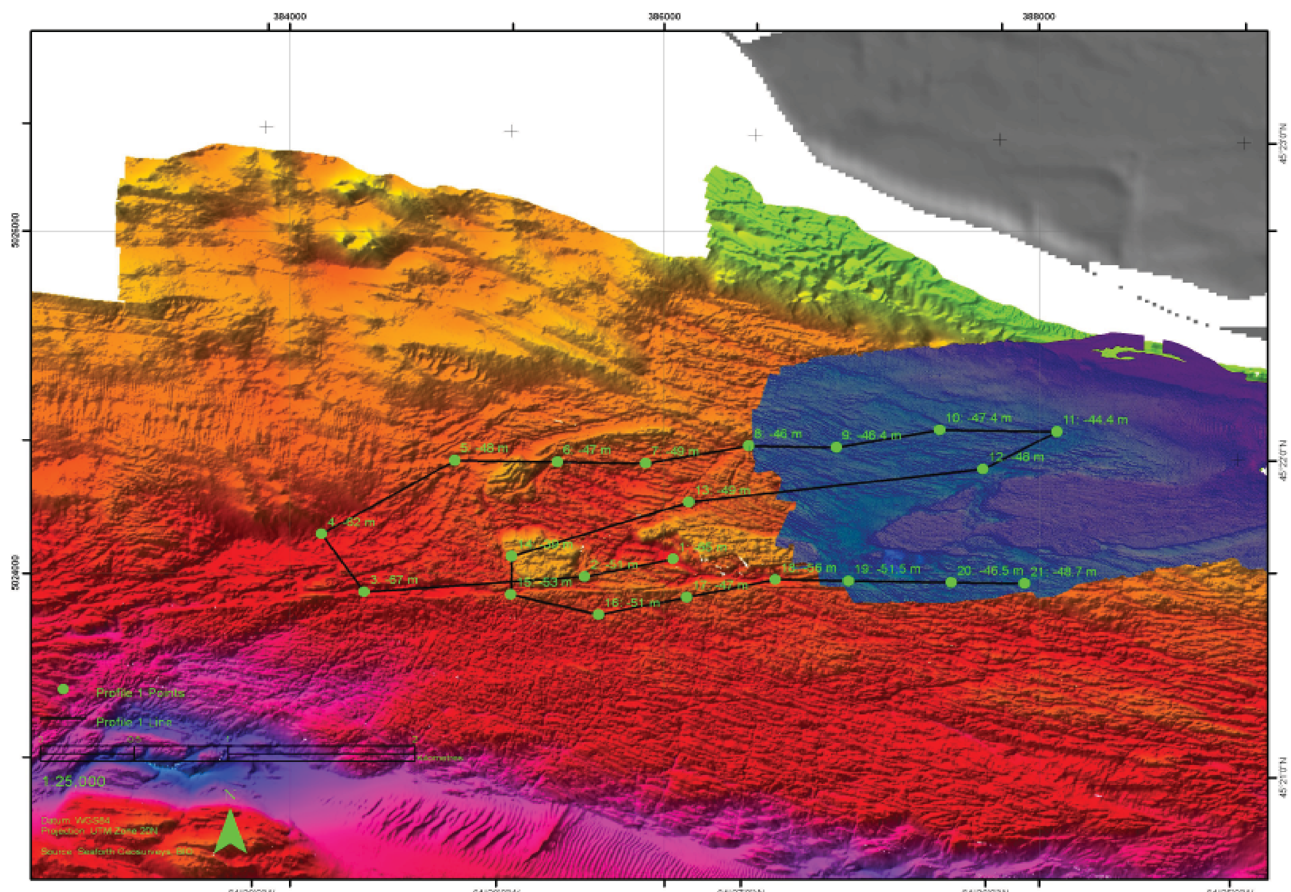


Figure 2. Locations of Profiling Current Data on May 1, 2008

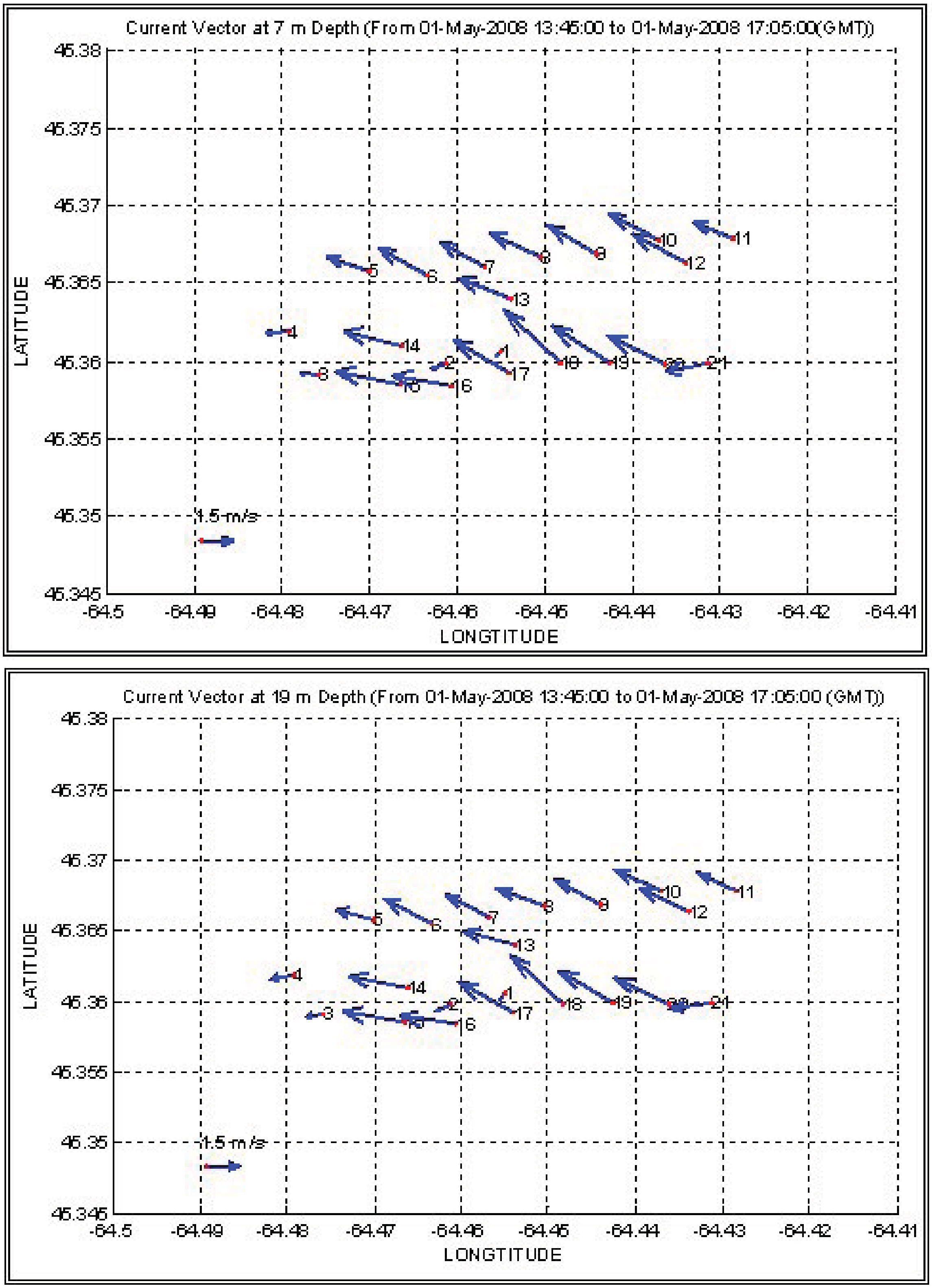
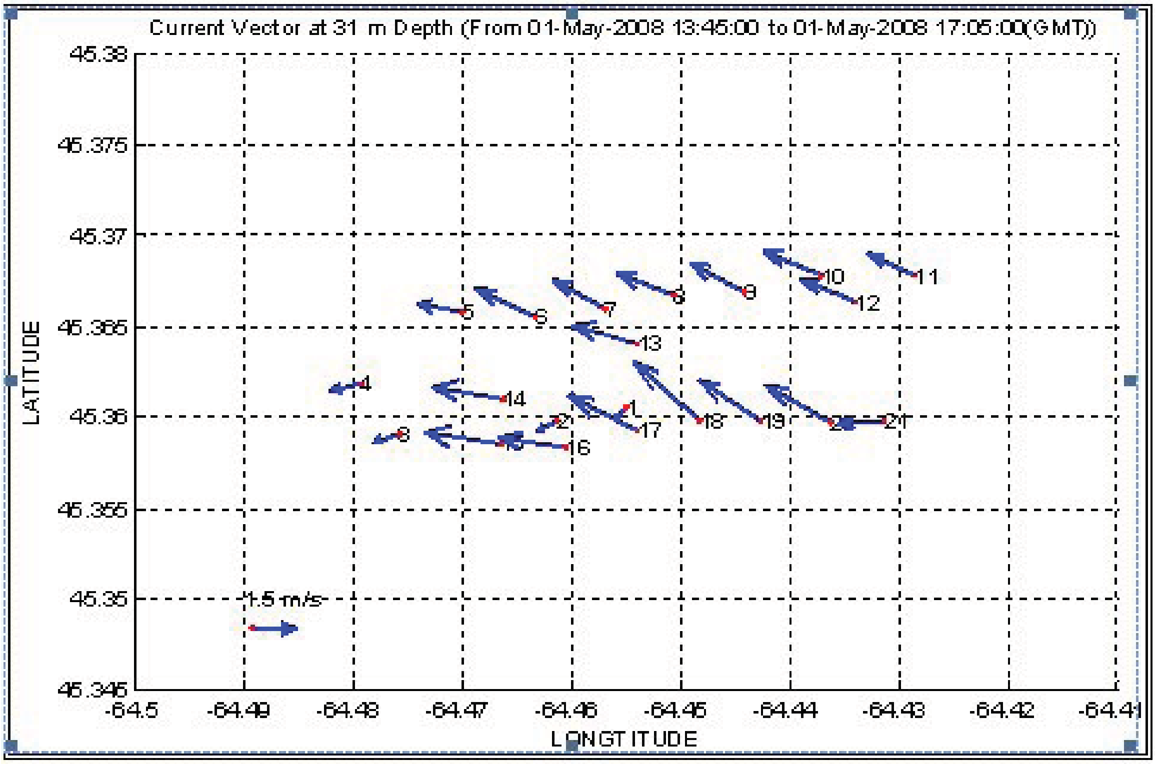


Figure 3. Stick plots of the profiling data on May 1, 2008



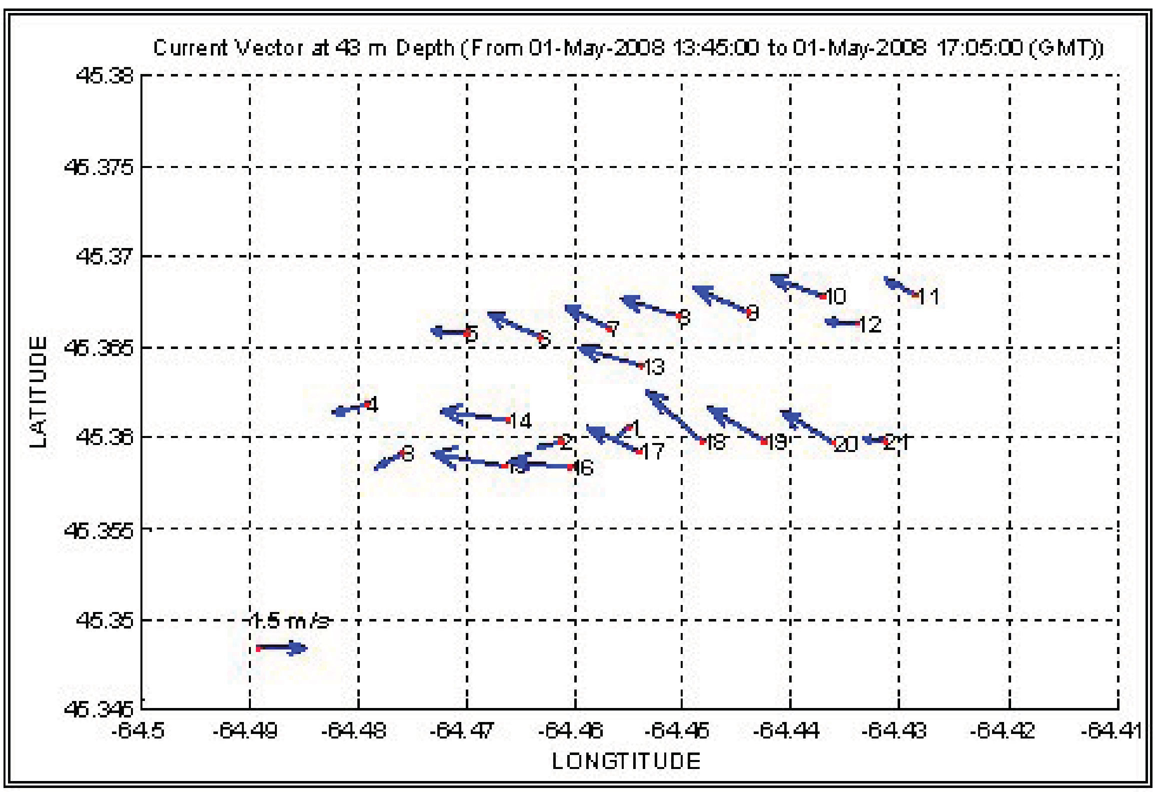
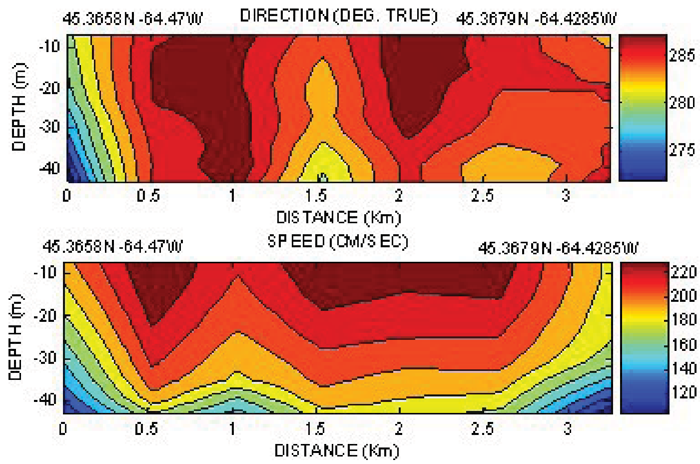
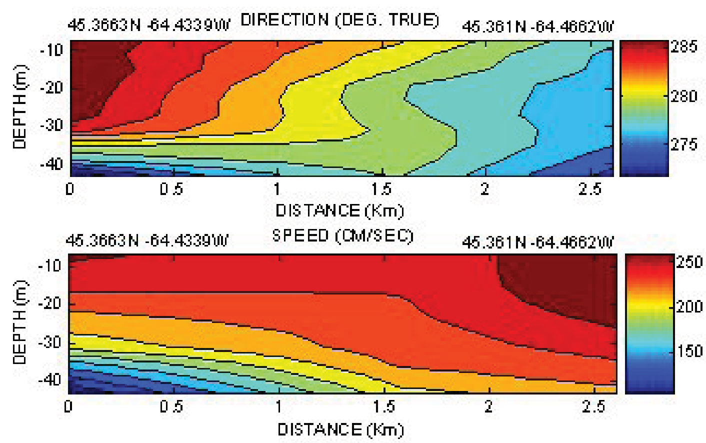


Figure 3. (cont'd) Stick plots of profiling data on May 1, 2008

From Station 5 to Station 11



From Station 12 to Station 14



From Station 15 to Station 21

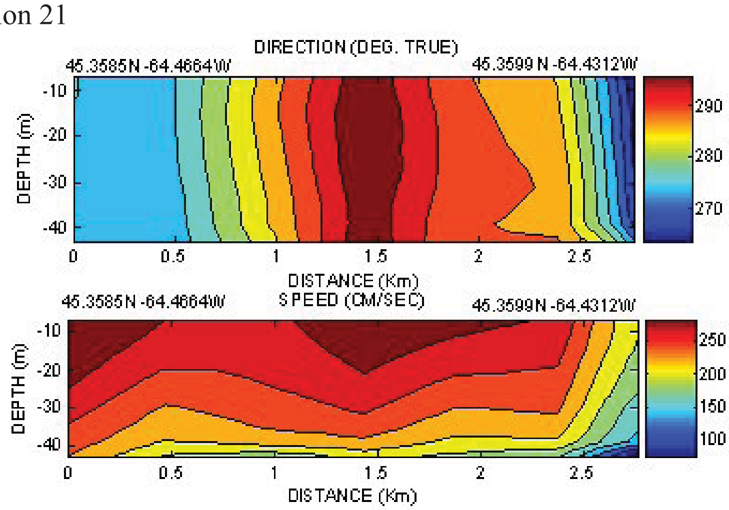


Figure 4. Transect plots of profiling data on May 1, 2008

Moored ADCP Data

Moored ADCPs measure time series of current velocities through the water column. In Minas Basin, ADCP units were moored at five different sites for a month period at each site,

Site 1: May 2 – June 4, 2008
Site 3: June 5 – July 9, 2008
Site 4: August 21 – September 23, 2008
Site 5: February 14 – March 28, 2009.

Current Speed through Water Column

The mean speed, mean velocity, and maximum current speeds with the corresponding directions at specific water depths at each site are presented in Table 2. Currents were extremely high reaching speeds between 4.5 and 5.2 m/s at surface during spring tides. The currents had similar speeds at each site. The strongest currents were measured at site 1 located near the center of the Channel. It had speeds of 0.6 m/s more than the speeds of currents at the other three sites. Current speeds decreased gradually with depth. The difference was approximately 1.3 m/s between surface and bottom at each site. The currents were still extremely high near the bottom with maximum speeds between 3 and 4 m/s. Currents were mainly aligned in the along-channel direction throughout the water column. The slight difference in current directions between the five sites was probably due to the bottom bathymetry.

Site No.	Depth (m)	No. of observations	Mean Speed (cm/s)	Mean Velocity (cm/s)	Dir (°T)	Max speed (cm/s)	Dir (°T)
Site 1	12	4845	249.8	42.4	SE	522.1	108
	24	4845	234.8	41.4	SE	483.9	111
	36	4845	214.2	39.1	SSE	441.8	111
	48	4845	183.1	35.0	SSE	396.8	112
Site 3	14	5029	203.6	63.7	SEE	458.0	116
	22	5029	194.9	60.5	SEE	523.7	240
	38	5029	168.5	49.2	SEE	385.2	115
	46	5029	142.5	38.0	SEE	324.4	115
Site 4	14	4863	204.3	63.9	SEE	441.3	113
	22	4863	195.9	60.9	SEE	429.8	112
	38	4863	169.1	49.0	SEE	374.2	112
	46	4863	139.2	34.8	SEE	302.4	111
Site 5	12	6887	210.8	35.0	SE	464.3	107
	24	6887	188.4	32.6	SE	406.0	107
	32	6887	165.6	29.8	SE	360.4	104
	40	6887	129.8	25.2	SE	287.4	117

Table 2. Mean and maximum current, Minas Basin

The rose plots in Figures 5 to 8 give details of the described pattern of flood and ebb circulation. Asymmetry was noted between flood and ebb current directions. At sites 1 and 3, there was a slight counter-clockwise shift in current direction from the main axis of Minas Passage, and this shift was more obvious below 36 m depth, indicating that it probably resulted from geometric and inertial effects due to bottom topography. There was no asymmetry in current direction at site 4 and 5 since falling tide was in an opposite direction to rising tide.

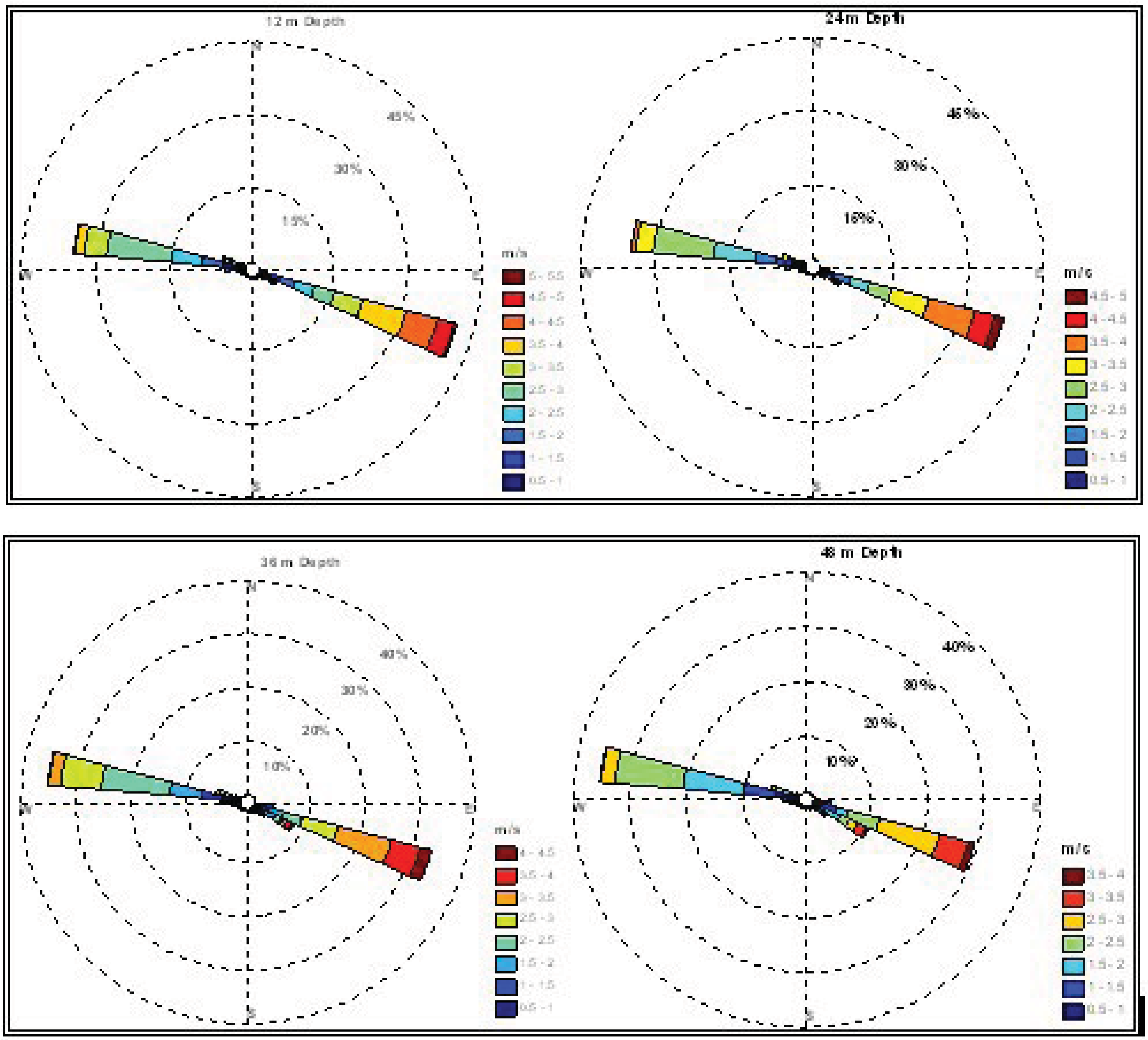


Figure 5. Rose plots at Site 1

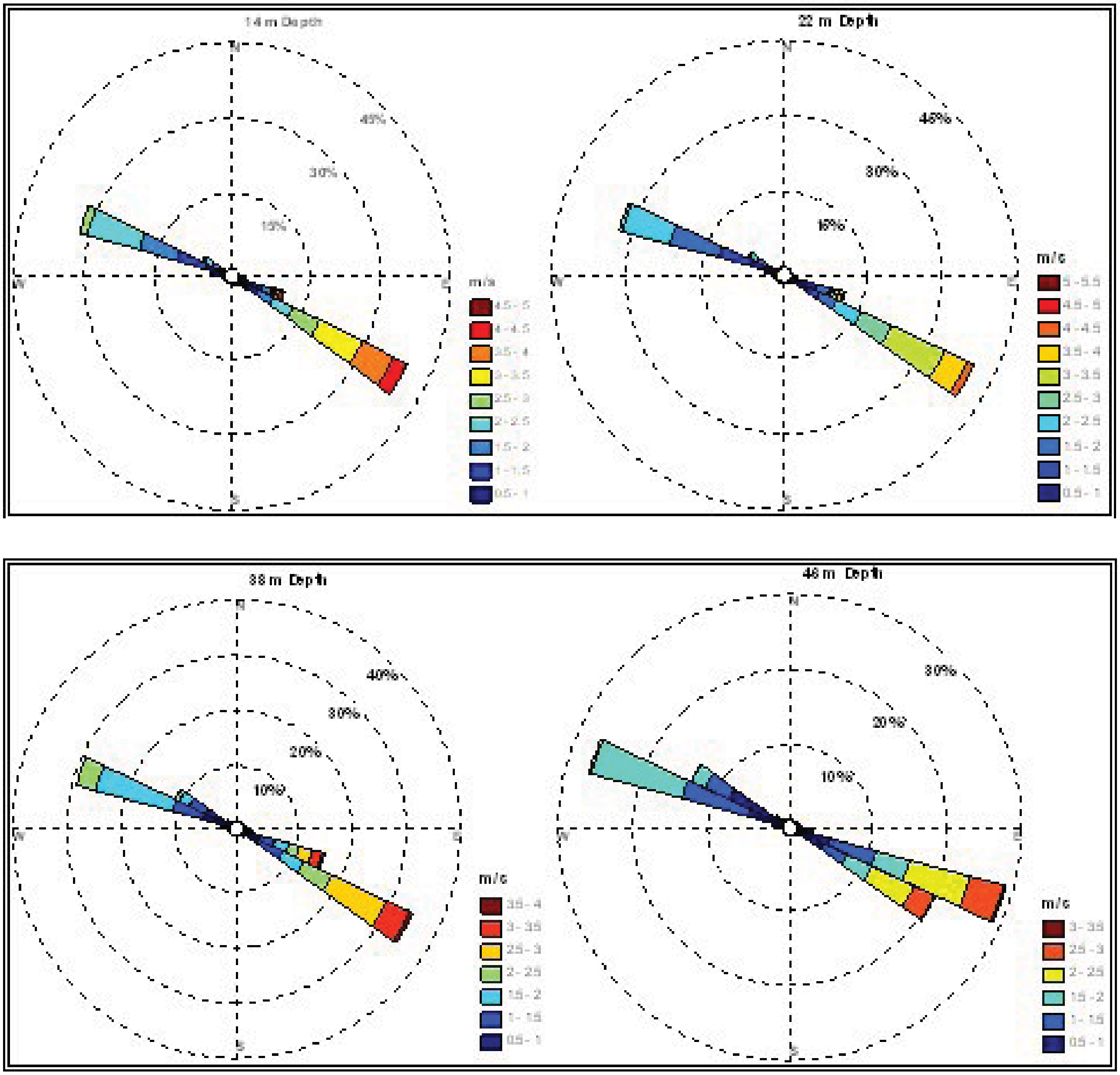


Figure 6. Rose plots at Site 3

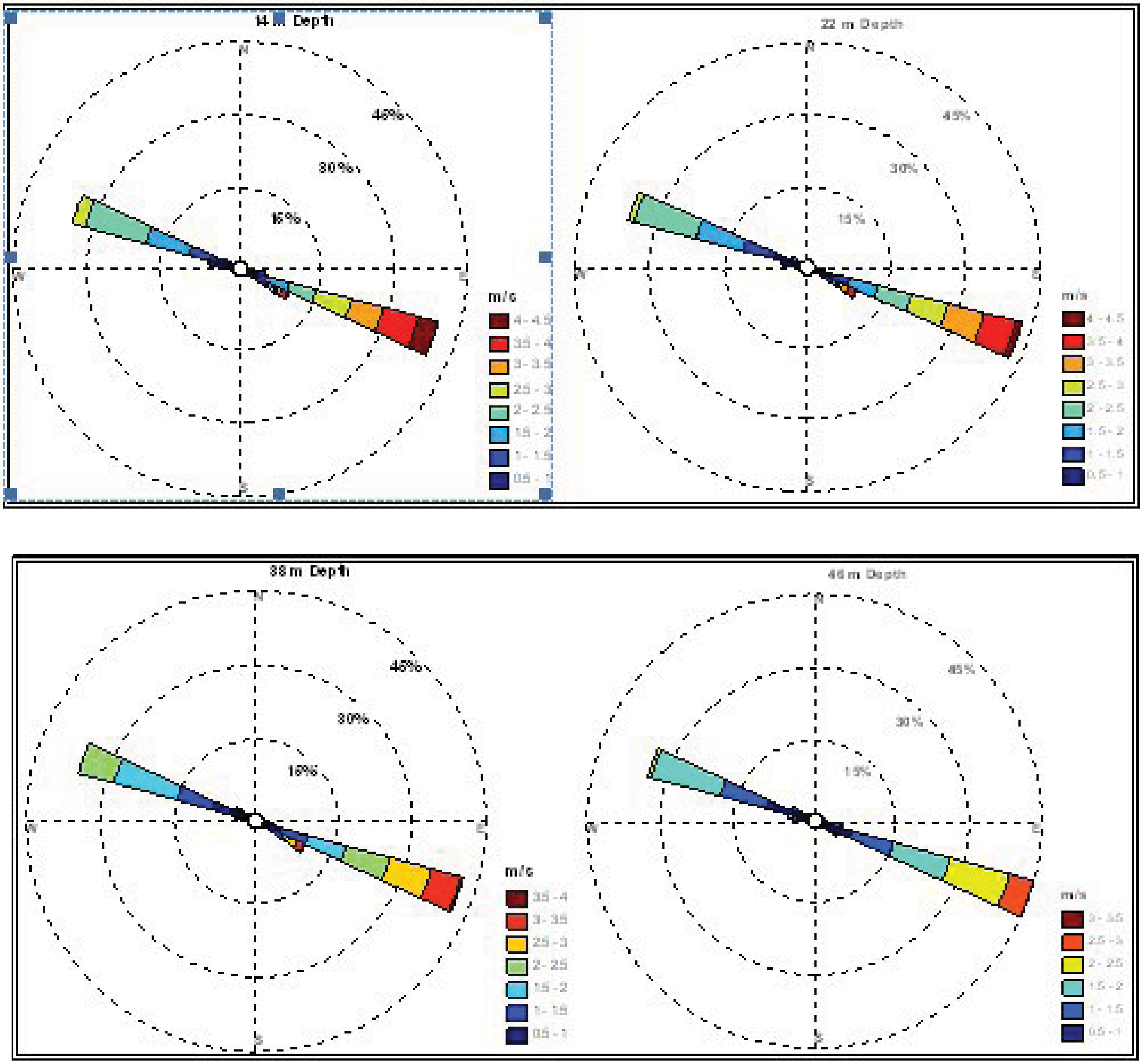


Figure 7. Rose plots at Site 4

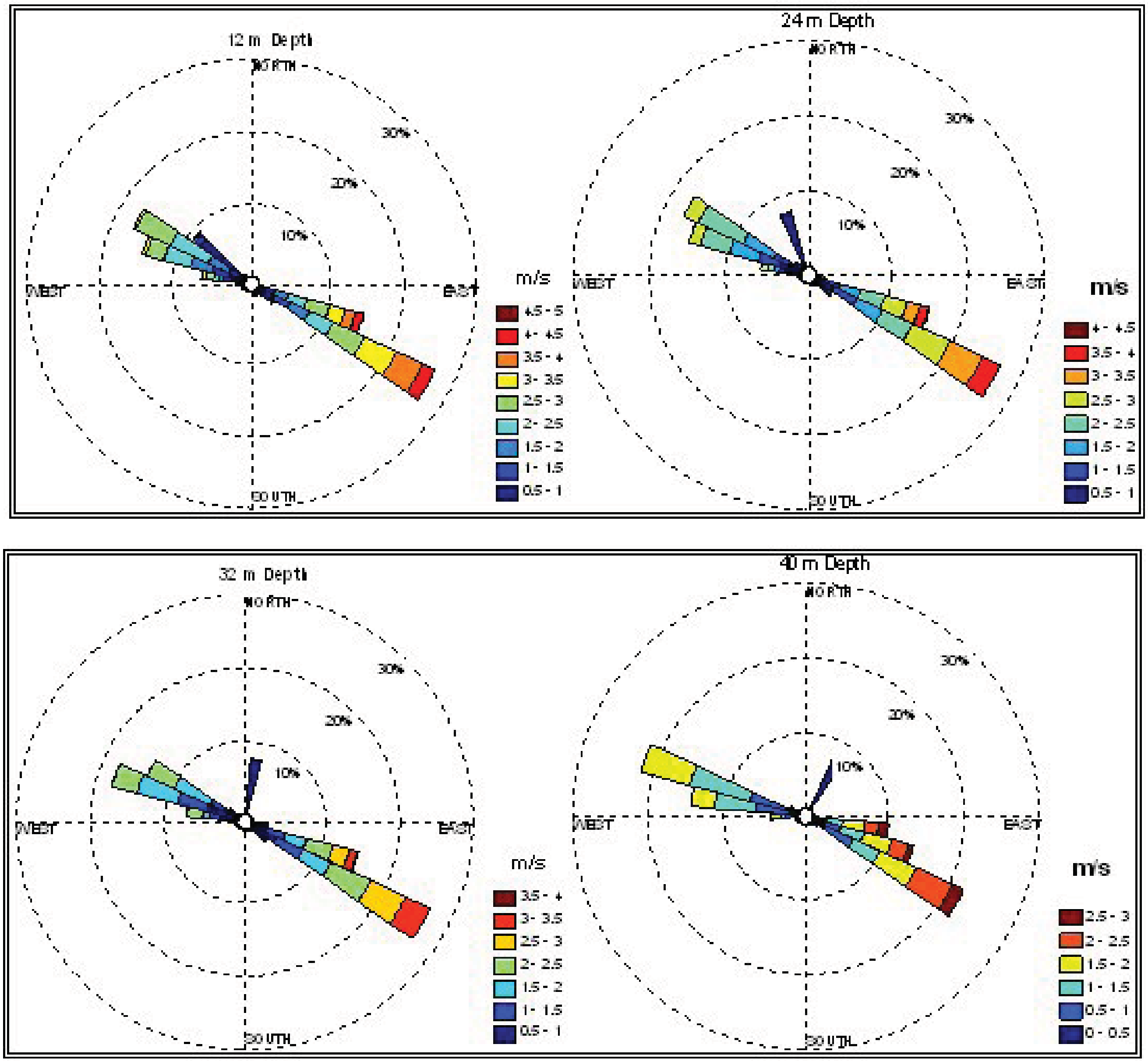
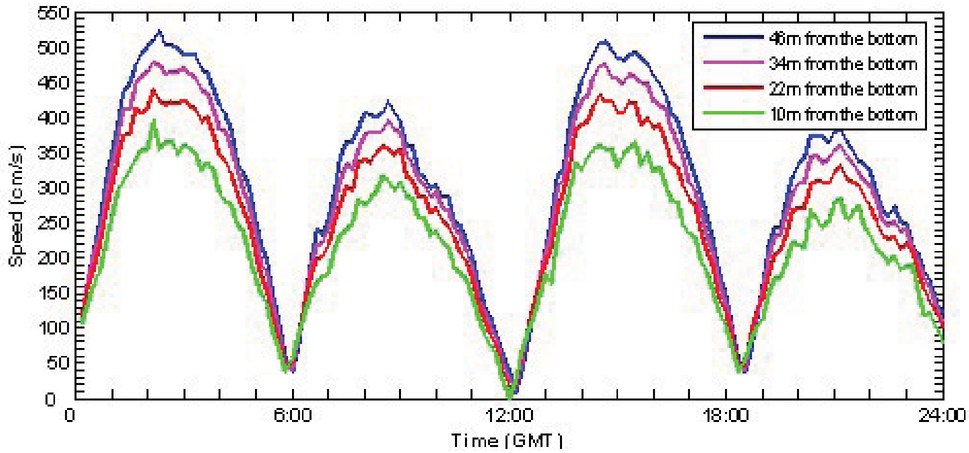


Figure 8. Rose plots at Site 5

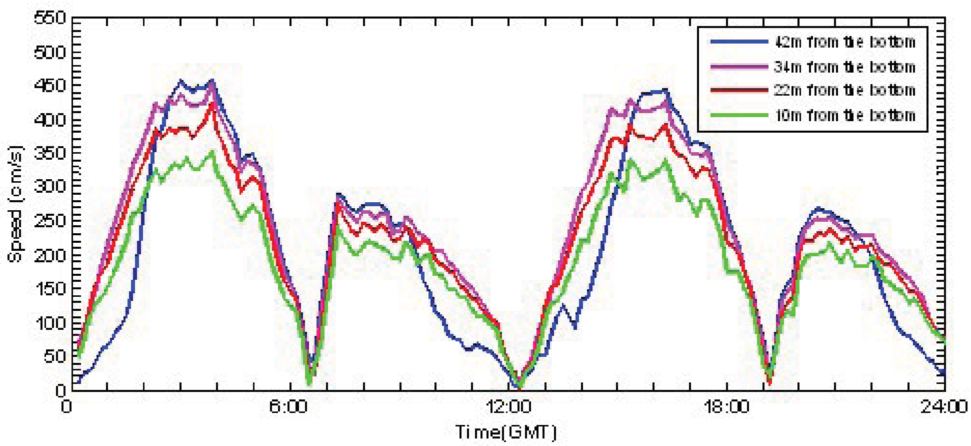
Currents during Spring/Neap Tides

The current in Minas Basin is dominated by the lunar tide with a period of 12.4 hours. Current speeds at four different depths during spring/neap tides at each site are presented in Figures 9 and 10. Current speeds showed some variation with depth for each site. On May 7, 2008, low current was at low tide (11:40) and high tide (5:20 and 17:50). The lowest currents always occur at low and high tide over a very short duration. During neap tides, the magnitudes of speeds decreased by 1 m/s as compared with spring tidal currents. The plots show that the flood (rising tide) and ebb (falling tide) periods in Minas Passage were not equal in duration: flood period was 0.5 hour shorter than ebb at site 1, and 1 hour shorter at sites 3, 4 and 5. As a result of tidal asymmetry, the flood currents in Minas Basin are normally stronger than ebb currents: peak flood current is approximately 1 m/s stronger than the peak ebb current.

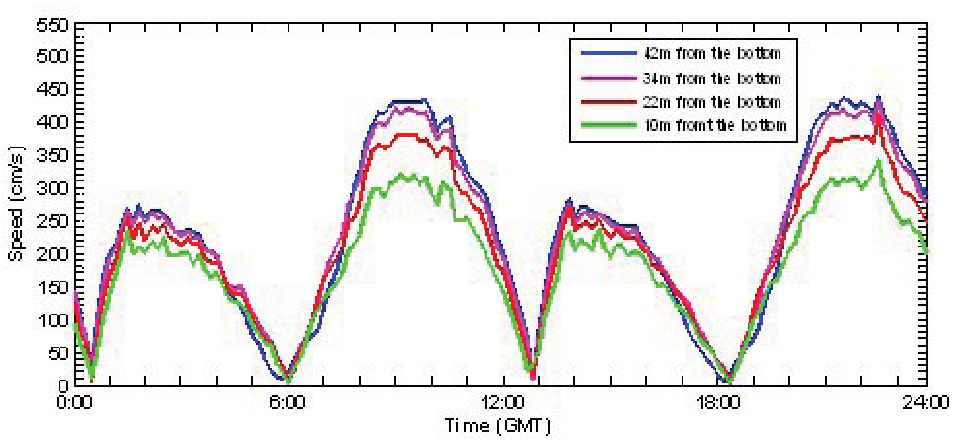
Site 1: May 7, 2008



Site 3: June 6, 2008



Site 4: September 18, 2008



Site 5: March 10, 2009

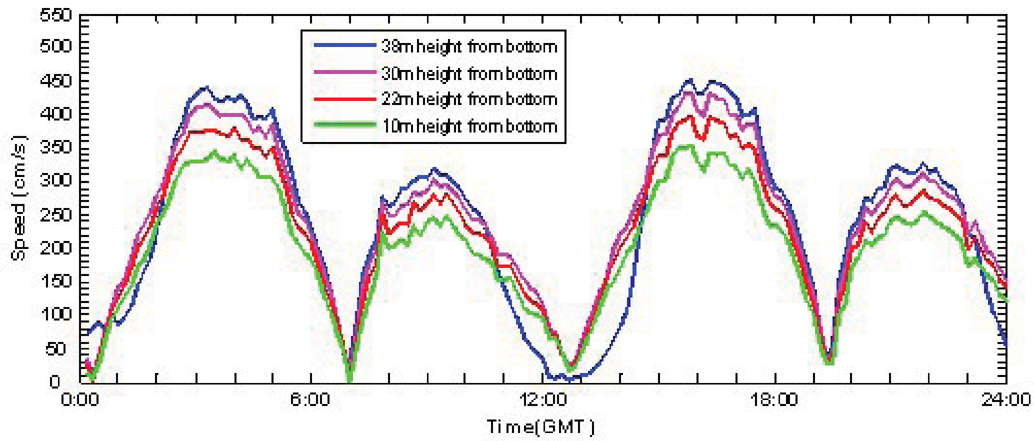
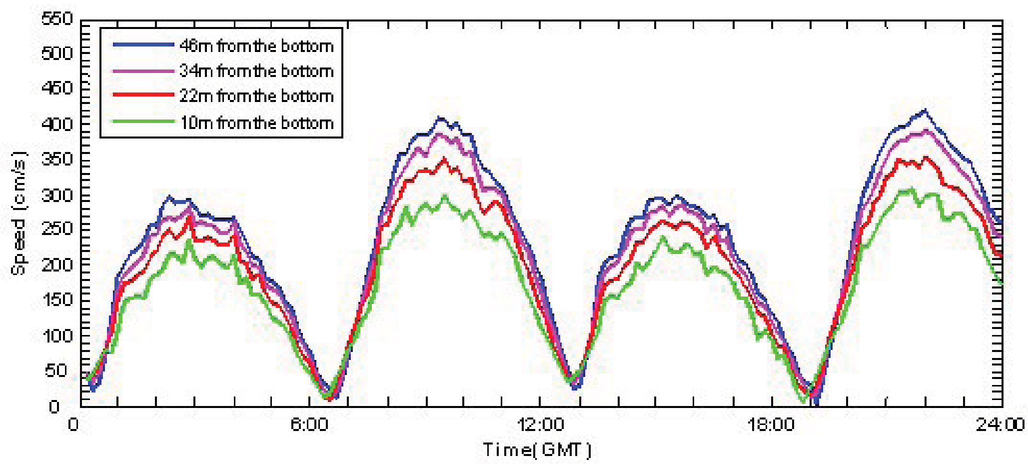
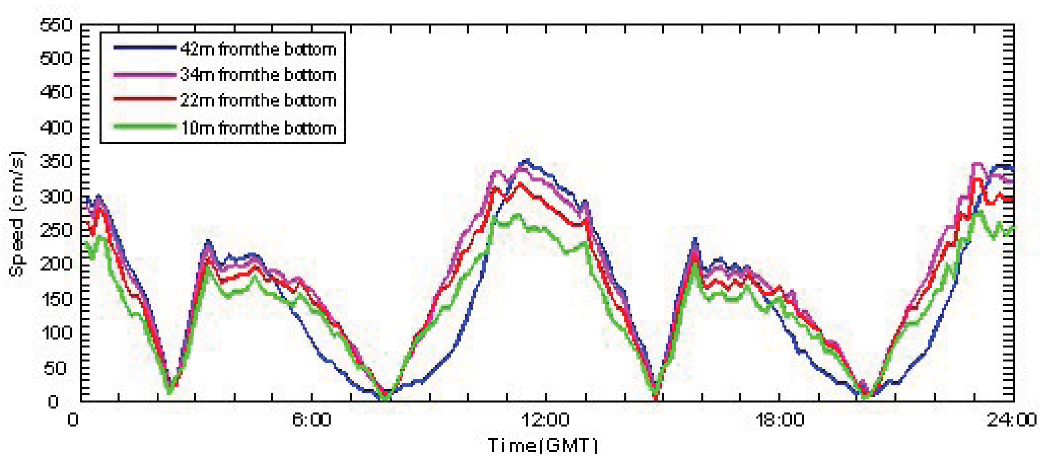


Figure 9. Current speed during spring tides at each site

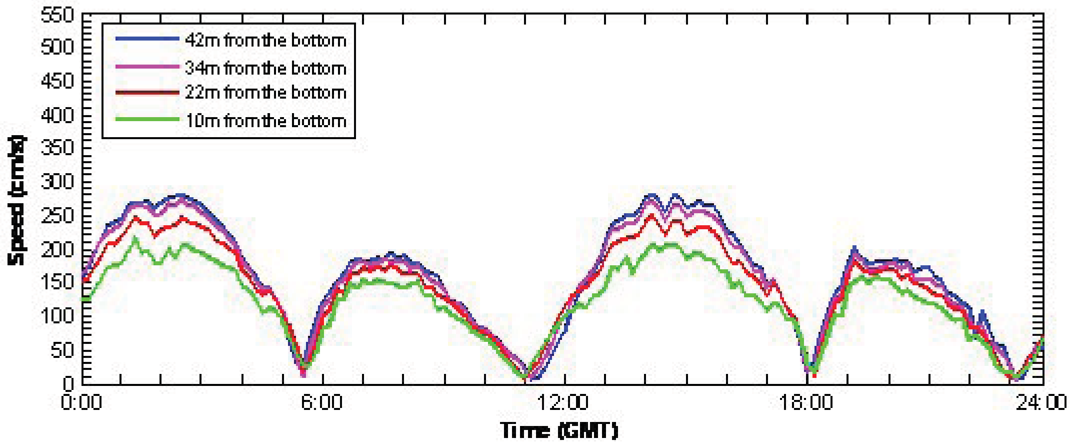
Site 1: May 14, 2008



Site 3: June 15, 2008



Site 4: September 9, 2008



Site 5: March 21, 2009

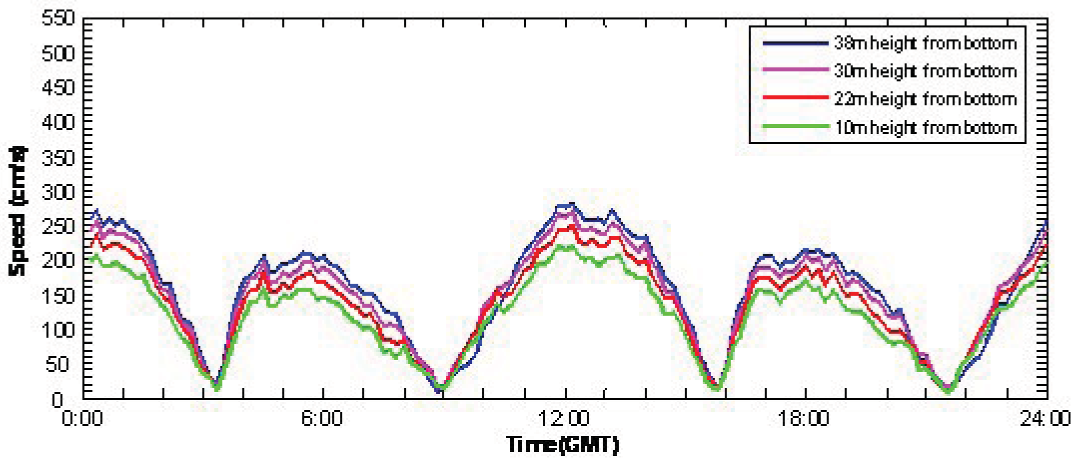


Figure 10. Current speed during neap tides at each site

Semidiurnal Tides

A time series plot of the current speeds and the corresponding tidal heights during spring tide at Site 1 is shown in Figure 11. This figure demonstrates the importance of the semi-diurnal currents at a frequency of two cycles per day from the constituents M2 (semidiurnal lunar) and S2 (semidiurnal solar). During each cycle there are two peaks in currents resulting from rising and falling tide.

A harmonic tidal analysis was performed to calculate the values of the major constituents, M2 and S2 in Minas Basin. In Minas Passage, the current due to M2 and S2 are in the same direction. During spring tides the semidiurnal tidal current is M2 + S2 and during neap tides the semidiurnal tidal current is the difference between M2 and S2. As M2 was several times larger in amplitude than S2 in Minas Basin (see Tables 3 and 4), M2 was the dominant tidal constituent.

The magnitude of M2 decreased with depth with values varying between 3.0 and 3.7 m/s at the surface, to values between 2.0 and 2.7 m/s near bottom. M2 ellipses in Figure 12 indicate that currents flowed into the Basin during rising tide and out during falling tide, and were aligned along the axis of the Passage.

Site 1: May 5 - May 11, 2008

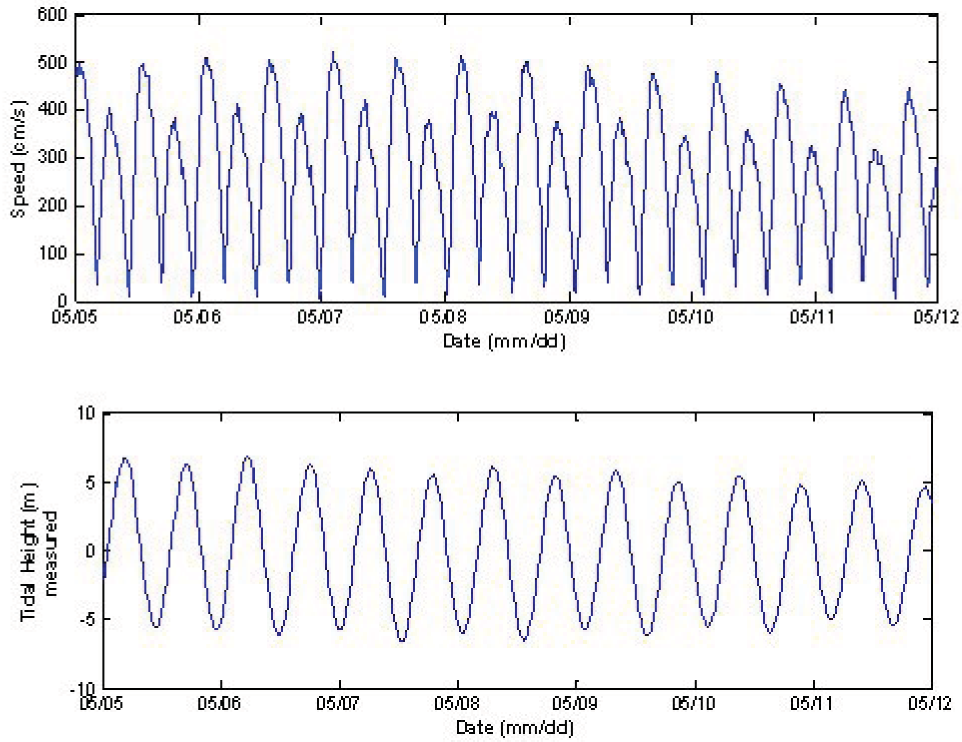


Figure 11. Surface current and tidal height at Site 1

Site Number	Depth (m)	Major Axis (cm/s)	Minor Axis (cm/s)	Inclination (°)	Phase (°)
Site 1	12	373.85	-0.8286	164.93	219.19
	20	357.68	-3.7664	164.25	218.77
	32	329.95	-7.8485	163.33	217.82
	40	306.14	-9.4544	162.46	217.32
	48	271.71	-9.6922	161.42	216.91
Site 3	14	301.11	-2.7494	154.66	211.33
	22	287.57	-2.4893	154.65	211.34
	30	270.89	-2.3513	154.73	211.37
	38	248.39	-1.9836	155.02	211.27
	46	211.11	-1.5281	155.79	211.02
Site 4	14	307.08	-3.5380	158.99	298.16
	22	294.02	-2.4568	158.69	298.12
	30	276.62	-1.9272	158.45	298.02
	38	253.47	-2.1138	158.58	297.90
	46	208.52	-2.1191	160.33	297.28
Site 5	12	285.48	2.407	154.34	358.38
	24	255.23	2.693	154.36	358.19
	32	224.33	2.487	155.45	358.06
	40	175.52	0.404	161.08	357.96

Table 3. M2 tidal constituents

Site Number	Depth (m)	Major Axis (cm/s)	Minor Axis (cm/s)	Inclination (°)	Phase (°)
Site 1	12	47.127	3.8990	162.80	257.64
	20	45.643	4.3195	163.20	259.57
	32	41.255	3.1828	161.79	256.41
	40	38.654	2.8604	161.29	256.48
	48	34.402	2.7543	160.52	256.52
Site 3	14	29.518	-0.6586	156.06	270.86
	22	28.015	-0.8003	155.43	271.37
	30	26.379	-1.0309	154.85	271.73
	38	24.472	-0.6975	154.90	271.17
	46	20.471	-0.8695	155.67	270.39
Site 4	14	58.464	-0.7290	158.83	25.06
	22	55.946	-1.0270	158.65	25.71
	30	52.339	-1.4160	158.37	25.57
	38	47.827	-1.7000	158.32	25.72
	46	39.210	-1.8190	160.05	25.39
Site 5	12	49.68	1.82	162.18	103.64
	24	44.81	1.67	162.28	104.81
	32	38.95	1.50	163.71	105.08
	40	29.96	1.19	169.48	105.26

Table 4. S2 tidal constituents

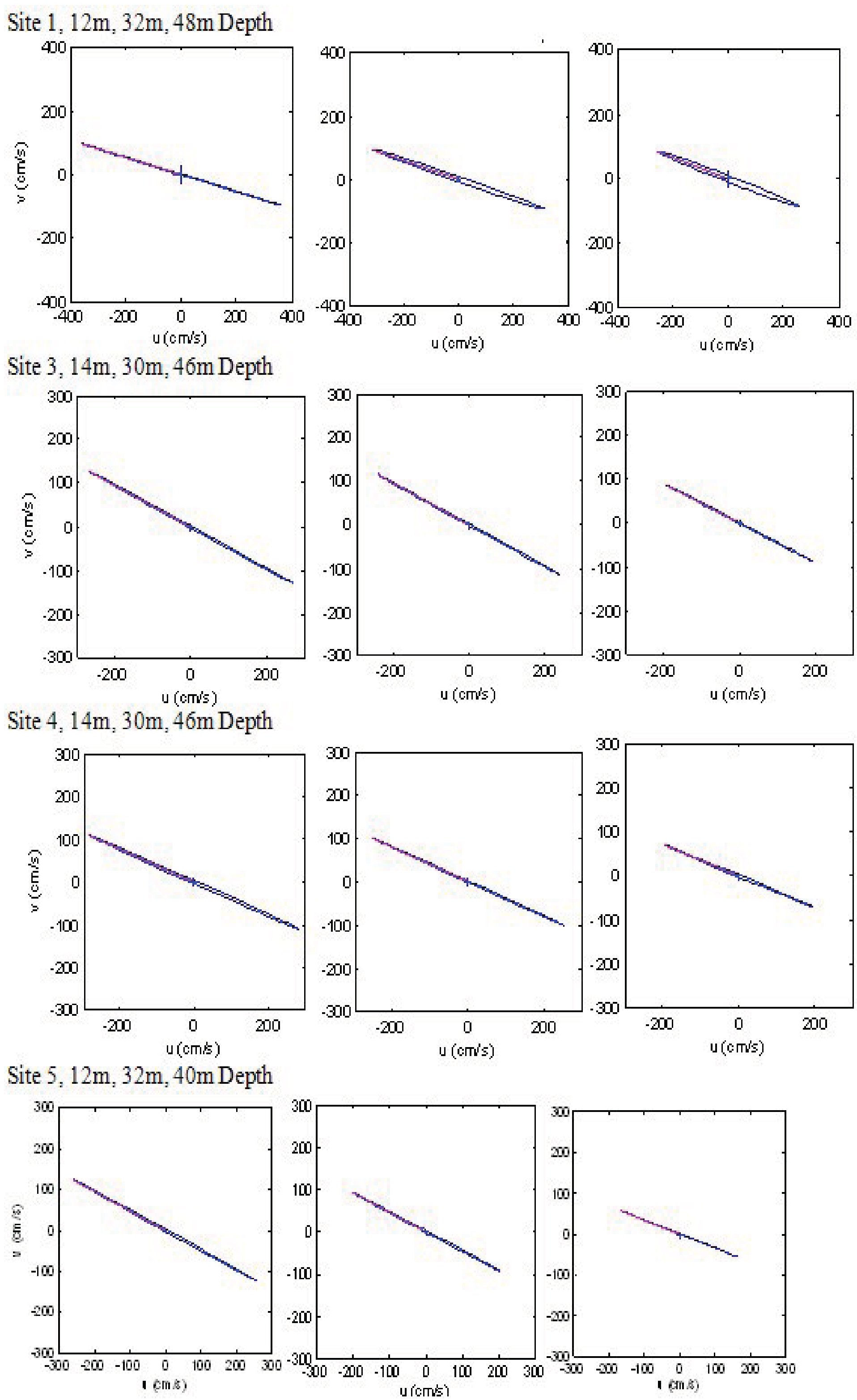


Figure 12. M2 tidal ellipses at each site

Bottom Currents

An InterOean S4 current meter was attached to the bottom stand to measure the currents at a height of 0.5 m above the seabed at Site 5. Figure 14 shows the current speeds during spring and neap tides. The currents were still strong next to the sea floor. During spring tide the maximum current was approximately 150 cm/s and during neap tide the maximum current was approximately 100 cm/s.

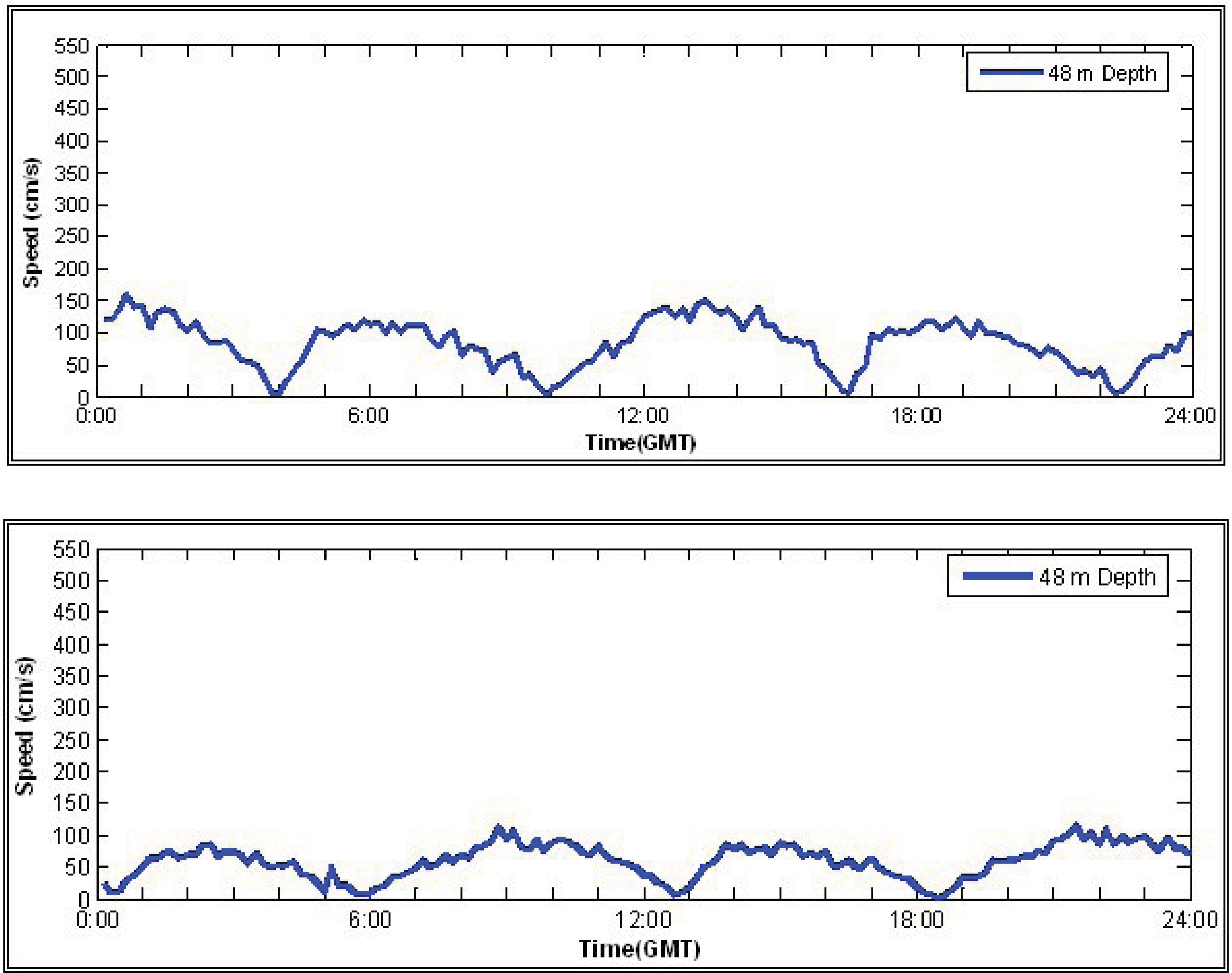


Figure 13. Bottom currents at Site 5

Current Irregularities

Some anomalous phenomena were measured by the ADCP at Site 5 during spring tides on February 13th and 14th, and March 11th (Figure 14), and at Site 3 on June 8th, 2009. The events were characterized by direction changes which lasted for a couple of hours and were present throughout the whole water column. The source of these events has not been identified. It may be due to some oscillation or tidal bore, or simply turbulence from the interaction of the high currents with physical boundaries. The events were observed to occur during rising tide.

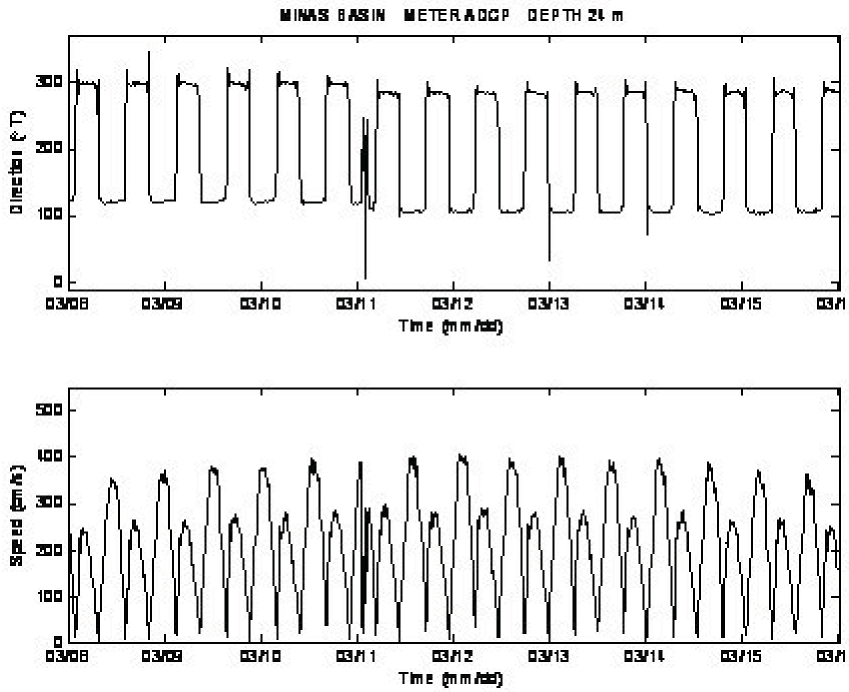


Figure 14. Bottom currents from ADCP at Site 5 between March 8 and March 16, 2009

Figure 15. Surface waters in Minas Basin in March 2009

Figure 15 shows the physical appearance of the surface waters before one of the moorings was retrieved during spring tide in March 2009. There are visual streams of turbulence in otherwise calm water.

Conclusion

The currents in Minas Basin were extremely high at each of the four sites which were sampled for the period of a month. The currents were strong throughout the whole water column, thus having the potential to produce a substantial amount of power from its kinetic energy.

During spring tides, the current speeds varied from near surface to near bottom by 5.2 to 4.0 m/s, 4.6 to 3.2 m/s, 4.4 to 3.0 m/s, and 4.6 to 2.9 m/s at site 1, 3, 4, and 5, respectively. Since the S2 (semidiurnal solar constituent) was 5 to 10 times smaller than M2 (semidiurnal lunar constituent), the tidal currents remains strong during neap tides. Since high and low tide were short in duration (approximately 1 hour), strong currents were flowing either into or out of Minas Basin most of the time. The currents speeds during flood tides were higher than during ebb tides because flood tides were shorter in duration than ebb tides by 0.5 to 1 hour. Even at 0.5 m above bottom, the currents were high reaching speeds of 2.1 m/s during spring tide.

CATASTROPHIC EXPANSION OF TIDAL RANGE IN THE BAY OF FUNDY

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Tidal models for the Bay of Fundy, Canada show that tidal amplification began in the early Holocene, and that by c. 5000 14C yr BP range was almost 80 percent of the present range. Empirical data consisting of 146 sea level index points and other observations appear to contradict model results. Aggregated relative sea level data for Chignecto Bay and Minas Basin show that rapid tidal expansion began a mere c. 3400 14C yr BP. Segregation of the data into two geographically separate sets—Chignecto Bay and Minas Basin—reveals that evidence for rapid late-Holocene tidal expansion is confined to Minas Basin alone. We argue that a sand and gravel spit formerly extended across Minas Basin from Parrsboro to Cape Blomidon, and that the rapid breakdown of this barrier resulted in near-instantaneous tidal expansion. The barrier was subsequently destroyed by growth of the 170 metre deep Minas Passage Scour Trench. We discuss the evidence supporting the barrier's existence, and also some of the implications.

HARD BOTTOM SUBLITTORAL BENTHIC COMMUNITIES IN AREAS PROPOSED FOR IN-STREAM TIDAL POWER DEVELOPMENT, NORTHERN MINAS PASSAGE, BAY OF FUNDY

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Introduction

Nova Scotia's Bay of Fundy has one of the highest tidal regimes in the world and the greatest potential for generating electricity from the tides (Daborn 1977; Hagerman et al. 2006). In 2007 the Province of Nova Scotia undertook to establish a tidal power demonstration research and test facility in the Inner Bay of Fundy, and through a competitive process selected a local company (Minas Basin Pulp and Power Company Limited of Hantsport, Nova Scotia), to design and develop infrastructure on behalf of tidal in-stream device developers. This process culminated in formation of the Fundy Research Centre for Energy (FORCE) in 2009. A site was selected in northern Minas Passage, the narrow strait between the Cape Blomidon-Cape Split peninsula and Cape Sharp west of Parrsboro. The area has the highest tidal currents, suitable seabed geology, appropriate water depth, distance from shipping lanes and fisheries, closeness to shore, access to onshore transportation and power grids, as well as space for potential future development. When the project began, little was known of the subtidal seabed geology and benthic communities of the northern Minas Passage (AMGC 2009; Wildish 1984; Bousfield and Leim 1958), although the site is actively fished for lobster and local fishermen know many of the organisms accidentally captured by commercial fishing gear.

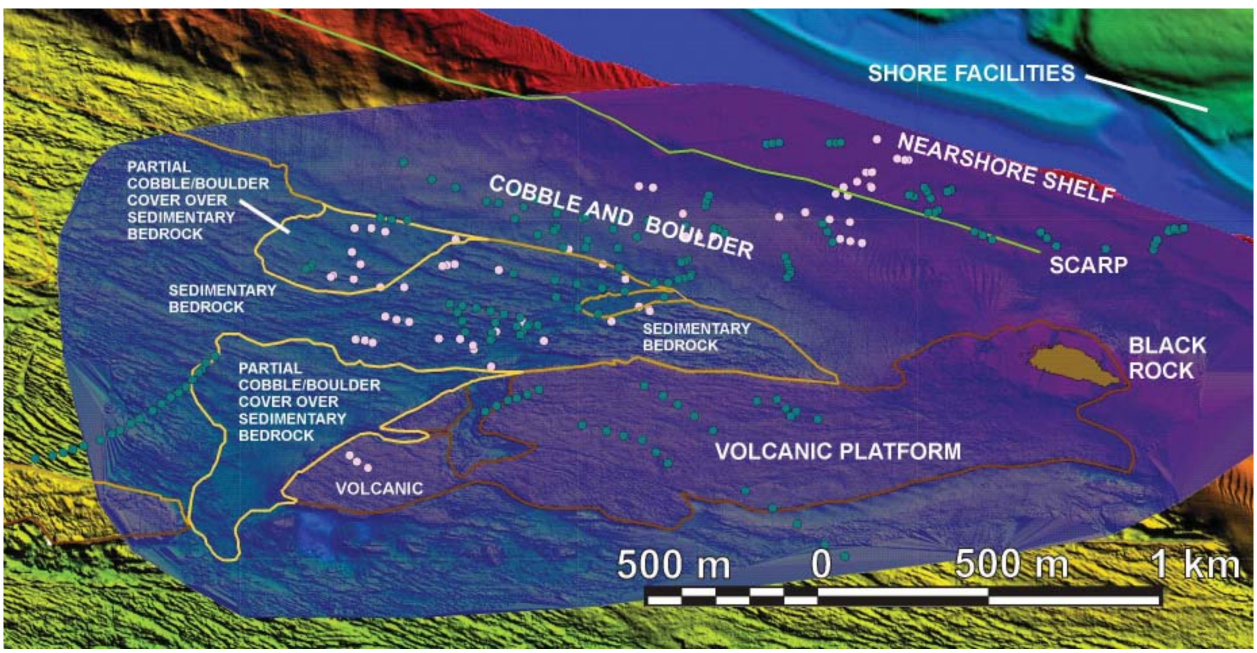

Figure 1. Interpreted geological zones of the study area, redrawn from AMGC (2009MS), and area of coverage of multibeam bathymetry surveys done for the tidal demonstration project (shown in purple). Video and photo locations are indicated by pink and green dots for August and September 2008, respectively.

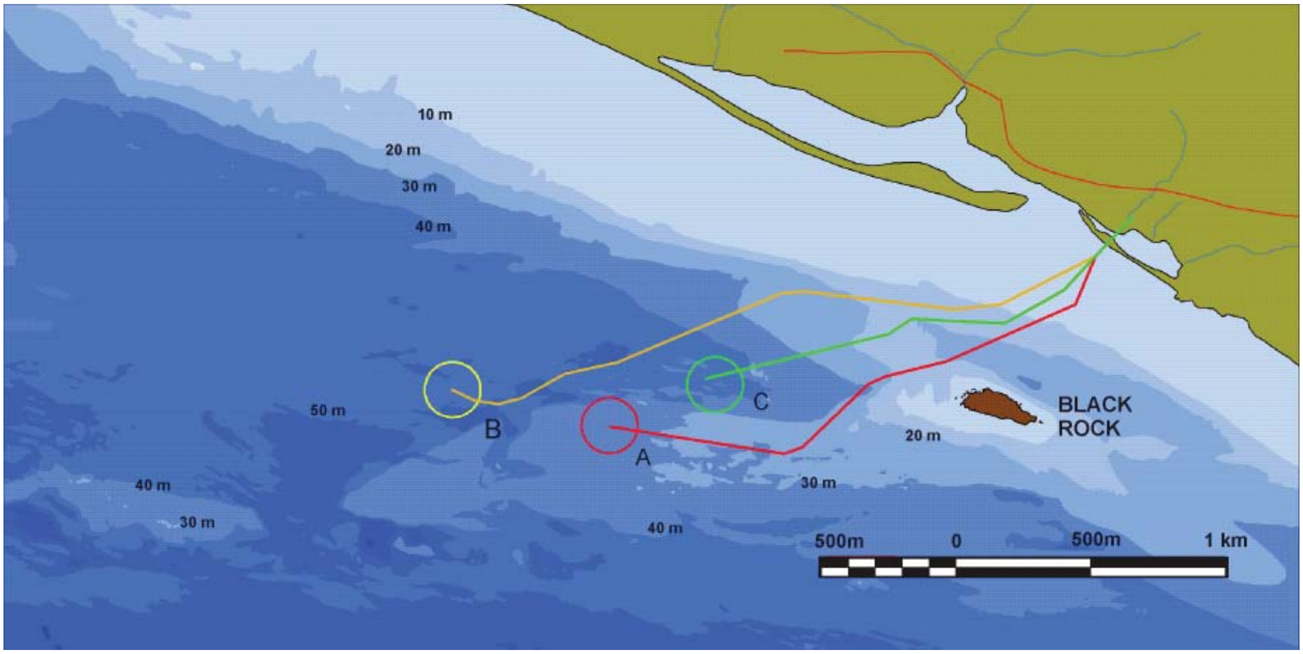

Figure 2. Bathymetry of study area showing proposed installation sites for tidal devices (circles) and proposed transmission cable routes as of August 2009

This study assesses characteristics and distribution of benthic communities and associated habitat based on seabed photography and sampling undertaken during the site selection and environmental baseline phase of this project.

Methods

Geological interpretation used in the present study (AMGC 2009) is based largely on multibeam bathymetric, sidescan sonar, and seismic reflection surveys of the inner Bay of Fundy carried out by the Canadian Hydrographic Service (CHS), Geological Survey of Canada, a dedicated geophysical survey (Seaforth Geosurveys of Dartmouth, Nova Scotia) in 2008, and a review of images obtained in the video and photographic surveys on August 18–20, and September 23–24, 2008. These covered bedrock and surficial geological formations as well as possible sites for tidal device installations and cable routing. A Sony Hi-8 handicam in an Amphibico® underwater housing (field of view of about 52.5 cm wide and 40 cm high (0.2 m^2)) and SLD10 underwater light, both mounted in a protective aluminum frame, or a Benthos® deep-sea 35 mm camera with strobe, mounted on a 225 kg steel frame (1 m^2 area at the typical distance of 1 m above the bottom) were deployed from a lobster boat 30 minutes to up to 1 hour before and after slack tide to moderate current (up to about 3 kts). Both a 2 m scallop drag and an 0.2 m^2 Van Veen grab sampler were used to sample the seafloor at several of the sites. Additional details as well as image captures and DVD video are presented in two field reports (Envirosphere Consultants and Oceans Limited 2008a and 2008b). Stations were assigned primarily to assist geological interpretation and hence were uniformly distributed over major geological features visible in multibeam bathymetry imagery for the area, and at approximately fixed distances along an early proposed (but later changed) cable route, which crossed from shore to major features (Figure 1). At each station, time, differential global positioning system (DGPS) coordinates, and water depth were recorded and the camera was "bounced" to obtain video at three or more sites at each station (video) and typically six sites (Benthos® camera). Due to changing currents, distance between separate bounces could range from 5 m to more than 60 m. Depths below mean low water (MLW) were determined from a digital elevation model for the site provided by Seaforth Geosurveys.

Information on frequency of occurrence of organisms of different seabed types was determined from two hundred and five (205) images from a subsample of 157 of the 241 locations occupied (Figure 1), including all images from August and selected images from the September survey. Abundances of some of the larger, readily identifiable organisms, were determined in images where the surface area viewed was known. Video images used were those taken with the camera frame vertical and sitting flush on the bottom; for the Benthos® camera, images taken vertically at the normal trigger distance. Percent cover of sponges and communities covering surfaces was estimated by eye. No organisms seen in images were physically sampled, so identities obtained from images cannot be confirmed; however many of the prominent species appeared to be those common to northwest Atlantic waters. Turbidity, which is low at the site, was not a problem in obtaining useful images at typical distances of 1 m or less off the bottom.

Results

Bottom type is a major determinant of benthic community distribution and the interpretation of images was closely tied to the geological analysis of the site. The study area extends approximately 2 km from the northern shore of Minas Passage immediately west of Cape Sharp (Figure 1). Subtidal seabed geology at the site has been summarized by AMGC (2009), which documents four main geological zones: 1) a narrow gravel and sand nearshore platform or shelf; 2) a zone of predominantly unconsolidated boulder and cobble immediately seaward of the shelf; 3) a zone of offshore sedimentary bedrock ridges and troughs further seaward; and 4) a volcanic bedrock (basalt) platform/ridge extending southwest from Black Rock (Figures 1 & 2). A complex bottom including sedimentary bedrock ridges extends to the south of the volcanic bedrock platform towards the midline of Minas Passage and the volcanic bedrock ridge extends further to the west. The majority of photographic and video coverage, and all bottom samples, were obtained from the sedimentary outcrop and trough area, with lesser though equal photo and video coverage of both the deepwater boulder/cobble area and the volcanic bedrock platforms.

The subtidal portion of the nearshore shelf is an extension of the broad, gradually sloping gravel intertidal beach. Seaward of MLW, the bottom is predominantly mixed gravel and cobble with occasional boulders, sloping gradually for approximately 150 m, and reaching depths of about 4 m in the west and 8–10 m below MLW in the east, then sloping steeply (1:5) to about 22–23 m (west) and 17–20 m (east). Slumps occur in several places at the shelf edge, mainly in the west (AMGC 2009). Seaward of the toe of the slope for 300 m in the west and roughly 400–500 m in the east, the bottom is dominated by cobbles, pebbles and boulders, but areas of predominantly cobble and boulder occur in eastern parts of the study area, west of Black Rock, that can be formed into gravel waves (AMGC 2009)(Figures 1 & 2). Cobble and boulder bottom meets sedimentary bedrock outcrops with deeper troughs at depths of 38–40 m below MLW in the west, and meets the volcanic platform at up to 30 m in the east (Figures 1 & 2). Outcrops of sandstone ridges alternating with intervening troughs with exposed, softer siltstone and mudstone bedrock, as well as clasts in the cobble to boulder size range (similar to that in the cobble to boulder zone near shore), slope gradually towards the midline of Minas Passage, reaching more than 50 m below MLW in the study area furthest from shore. A prominent topographic feature of the study area is a segmented volcanic bedrock ridge, forming a line of shallow (27–33 m below MLW), volcanic (basalt) bedrock platforms 300–500 m at their widest, rising up steeply from the adjacent, deeper bottom, and extending roughly east-west from Black Rock through the area (AMGC 2009)(Figures 1 & 2). The volcanic bedrock surface is flat with cracks and crevices, supports overlying boulders, and shows a hummocky relief of up to 2 m.

Geological Subdivision	Volcanic Bedrock Platform		Sedimentary Bedrock Outcrops and Troughs		Cobble & Boulder		Nearshore Shelf	
Number of Photos Examined	21		102		46		36	
Depth Range (m)	28-41		38-49		25-47		3-14	
Number and % of images	No.	%	No.	%	No.	%	No.	%
Epifaunal Communities								
Edge fauna[1]	9	42.9	41	40.2	4	8.7	1	2.8
Biolayer[2], Volcanic Bedrock type	9	42.9	0	0.0	0	0.0	0	0.0
Biolayer, Sedimentary Bedrock type	5	23.8	55	53.9	9	19.6	4	11.1
Biolayer, Sedimentary Type, small patches	0	0.0	6	5.9	3	6.5	0	0.0
Linear Biolayer[5]	1	4.8	4	3.9	1	2.2	0	0.0
Encrusting Organisms								
Breadcrumb Sponge (raised form)	7	33.3	12	11.8	2	4.3	0	0.0
Breadcrumb Sponge (flat form)	16	76.2	4	3.9	14	30.4	0	0.0
Yellow encrusting sponge unidentified[7]	0	0.0	19	18.6	4	8.7	4	11.1
White encrusting sponge/patches[3]	2	9.5	33	32.4	10	21.7	1	2.8
White sponge, similar to Breadcrumb	1	4.8	1	1.0	0	0.0	0	0.0
Attached and/or Mobile Organisms								
Barnacles (incl. *Semibalanus balanoides)*	17	81.0	49	48.0	6	13.0	5	13.9
Northern Red Anemone (*Urticina felina)*	15	71.4	11	10.8	9	19.6	0	0.0
Blood Star (*Henricia sanguinolenta*)	6	28.6	23	22.5	3	6.5	1	2.8
Seastar juv. & adult unidentified[6]	9	42.9	22	21.6	15	32.6	4	11.1
Asterias sp.	0	0.0	3	2.9	0	0.0	0	0.0
Tunicate (*Boltenia ovifera)*	0	0.0	15	14.7	3	6.5	2	5.6
Flustra foliacea (erect bryozoan)	0	0.0	2	2.0	6	13.0	12	33.3
Hermit Crab *(Pagurus* sp)	1	4.8	30	29.4	15	32.6	13	36.1
Snail shell (Hermit Crab or Snail)	2	9.5	41	40.2	12	26.1	0	0.0
Finger Sponge (drift)	0	0.0	4	3.9	0	0.0	0	0.0
Boring clams[4]	0	0.0	2	2.0	0	0.0	0	0.0

1. Organisms projecting from sides of rocks, including the bryozoan *Flustra foliacea*, *Boltenia ovifera,* and fine tubes, possibly polychaetes.
2. A thin covering or line of organized detritus of (presumably) tube-building organisms such as amphipods and polychaetes.
3. White patches were observed infrequently on rocks, presumed to be sponges.
4. Living or dead burrows could not be distinguished.
5. Linear biological structures appressed to surfaces.
6. may include *Asterias* sp?
7. Probably Breadcrumb Sponge.

Table 1. Relative occurrence of benthic organisms and communities in seabed photographs from Minas Passage study site, August and September 2008 (includes only organisms or features occurring in two or more images)

Images analyzed for benthic communities included 21 from volcanic bedrock, 102 from sedimentary bedrock outcrops and troughs, 46 from the cobble and boulder zone, and 36 from the nearshore shelf (Tables 1 & 2). Frequency of occurrence in images gave an approximation of how common benthic organisms were on different substrates. In addition, several of the species were clearly identifiable and abundance could be estimated quantitatively in a subset of these images in which the area viewed was accurately known (Table 2). Barnacles and a "biolayer" of tube-building organisms resembling detritus and believed to be tubes and structures constructed by surface-dwelling organisms commonly occurred on sedimentary bedrock, but occasionally on volcanic rock. Interpreting the occurrence of barnacles in the images was difficult because of their generally small size, and the possible confusion with other small, shelled organisms; hence occurrence may be overestimated. Barnacles were most common on volcanic bedrock and sedimentary bedrock, occurring in 81% and 48% of images respectively. The "biolayer" on sedimentary bedrock occurred in all the geological zones, predominantly on sandstone outcrops and associated boulders. Hermit crabs were also relatively common, occurring in all geological subdivisions. Snail-shell-like objects, which were likely to be either living snails or hermit crabs inhabiting snail shells, were also common. "Edge fauna," which included filamentous and tube-like growth and other organisms on the sides of rocks were most common on volcanic or sedimentary bedrock. Unidentified juvenile and adult sea stars were most common on volcanic bedrock platforms (42.9% of images) and on cobble and boulder bottoms (32.6%)(Table 1). White patches on rocks, presumed to be sponges or other encrusting organisms (e.g., bryozoans) occurred on bedrock, boulders, and cobble in all areas but infrequently on the nearshore shelf. Northern Red anemone (*Urticina felina*), Breadcrumb sponge (*Halichondria panicea*), and the Blood Star (*Henricia sanguinolenta*), occurred widely, but the former two species were not observed on the nearshore shelf, while *Henricia* also occurred there, occupying all four areas. *Urticina* and *Halichondria* were particularly common on the volcanic platform (71.4 and 76.2% of images respectively), and abundant (up to 21 /m^2 and 90% cover)(Table 2). *Henricia* was common and relatively abundant on volcanic bedrock, occurring in 28.6% of images and average abundance of 2.5 and up to 9 individuals/m^2 (Table 2).

	Biological Component						
Geological Zone	Biolayer (% cover)	Halichondria panicea (% cover)	*Urticina felina* (#/m^2)	*Pagurus* sp (#/m^2)	*Henricia sanguinolenta* (#/m^2)	Unidentified Seastars/ *Asterias* (#/m^2)	*Boltenia ovifera* (#/m^2)
Volcanic Bedrock Platform (n=11)							
Mean	10	34	7.8	0.2	2.5	0.8	0.0
SD	27	29	6.8	0.4	3.2	1.4	0.0
Max	90	90	21.0	1.0	9.0	4.0	0.0
Min	0	5	0.0	0.0	0.0	0.0	0.0
Sedimentary Bedrock Outcrops & Troughs (n=45)							
Mean	32	3	0.3	1.3	1.8	2.6	0.4
SD	37	6	1.2	2.3	2.6	5.3	1.4
Max	100	20	5.0	10.0	10.0	25.0	5.0
Min	0	0	0.0	0.0	0.0	0.0	0.0
Deep Unconsolidated Sediments - Cobble and Boulder (n=31)							
Mean	5	6	0.2	1.7	0.2	1.2	0.1
SD	14	11	0.5	2.8	0.7	2.2	0.4
Max	70	50	2.0	10.0	3.0	10.0	2.0
Min	0	0	0.0	0.0	0.0	0.0	0.0
Shallow Unconsolidated Sediments – Nearshore shelf (n=29)							
Mean	9	0	0.0	4.1	0.2	0.7	0.2
SD	26	0	0.0	5.8	0.9	1.8	0.9
Max	100	1	0.0	20.0	5.0	5.0	5.0
Min	0	0	0.0	0.0	0.0	0.0	0.0

Table 2. Summary of abundances of identifiable organisms in seabed images from Minas Passage in the present study. SD = Standard Deviation. Based on quantitative images from the analysis summarized in Table 1. Unidentified sea stars (mostly juveniles) and *Asterias* sp were grouped.

The zone of nearshore shelf–shallow water unconsolidated sediments is characterized by sparse and patchy occurrence of *Fucus* sp (rockweed) over a level, well-sorted, predominantly gravel and sand substrate. At the edge of the shelf, the occurrence of cobble increases and seaweeds including *Fucus* sp, dulse (*Palmaria palmata*), and coralline algae (probably *Lithothamnium* sp) encrusting on rock surfaces, as well as hermit crabs (*Pagurus* sp, average 4.1 individuals/m^2 (Table 2)), barnacles, and erect leafy bryozoans (*Flustra foliacea*) commonly occur (Figures 3 & 4). Seaweeds and coralline algae are not present at the bottom of the slope, where substrate transitions into a predominantly boulder and cobble bottom, and where the surface "biolayer" occasionally occurs.

The zone of boulder and cobble–deep water unconsolidated sediments supports relatively few organisms, including occasional hermit crabs, barnacles, and sea stars (*Asterias vulgaris* and *H. sanguinolenta*), the Northern Red anemone (*U. felina*), and encrusting organisms including the yellow Breadcrumb sponge (*H. panicea*) which occurs occasionally on the tops of larger rocks and boulders (Table 2, Figure 5). The leafy bryozoan *F. foliacea* and a stalked ascidian, the Sea Potato, *Boltenia ovifera*, commonly occur on the vertical sides of rocks (Figure 5, lower left image). White flecks commonly observed were interpreted as barnacles, likely *Semibalanus balanoides*, which was sampled and positively identified on cobbles from a nearby sedimentary bedrock area and is a common Bay of Fundy species. Unidentified white patches on the rocks, the "biolayer" community (see paragraph on sedimentary bedrock below), as well as the Breadcrumb sponge *H. panicea*, also frequently occurred (Table 1). Larger rocks were not colonized by encrusting sponges or other organisms within 10–20 cm of bottom, suggesting that bedload of sediment (probably coarse sand to granule-sized sediments) moving with tidal currents within that distance of the bottom, prevents colonization near the seabed.

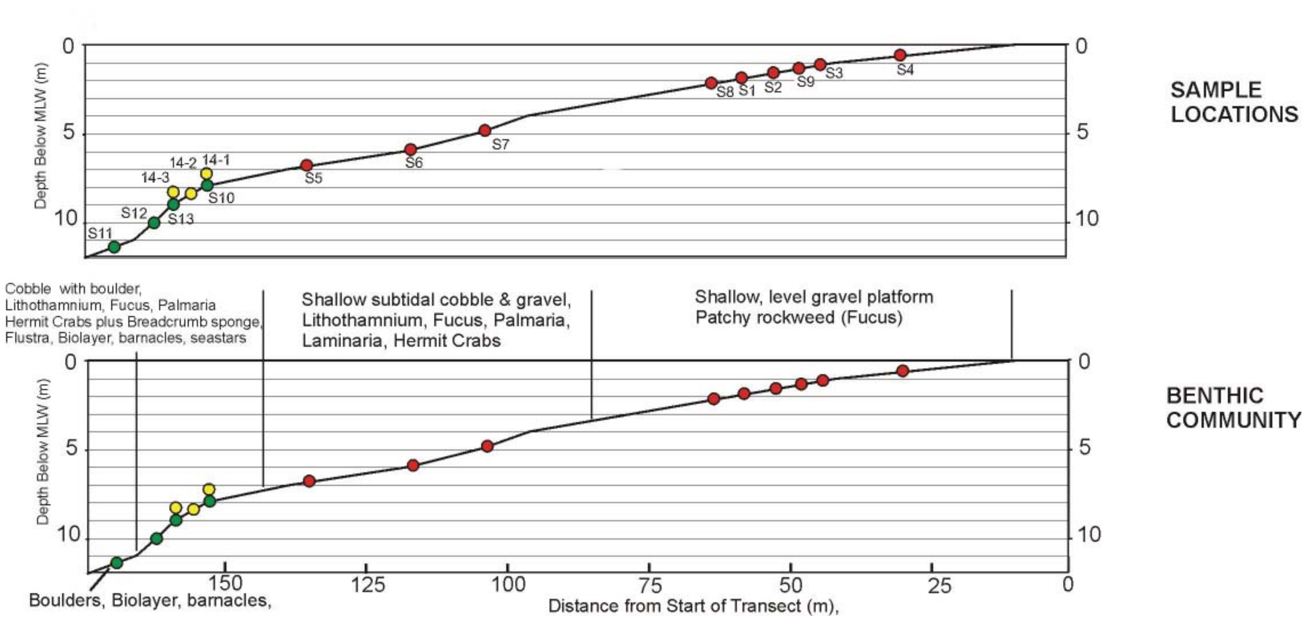

Figure 3. Benthic communities occurring across the nearshore shelf in northern Minas Passage (dots represent photographic and video stations)

Figure 4. Cobble substrate on upper slope of nearshore shelf showing *Fucus* sp, *Palmaria* sp, coralline algae, *Flustra foliacea*, and barnacles (scale units are 10 cm)

Figure 5. Benthic communities in cobble and boulder seabed zone. Upper left (UL): cobbles and boulders with occasional encrusting sponges and hermit crabs. Upper right (UR): Breadcrumb sponge on boulders, bedload scour, hermit crab and Northern Red anemone (*U. felina*). Lower left (LL): boulder with "biolayer" of surface dwelling organisms, leafy bryozoan *Flustra foliacea*, and two stalked ascidians, *B. ovifera*. Lower right (LR): Breadcrumb sponge and *F. foliacea*. Scale units 10 cm in LR image; vertical dimension of other images is 0.7 m

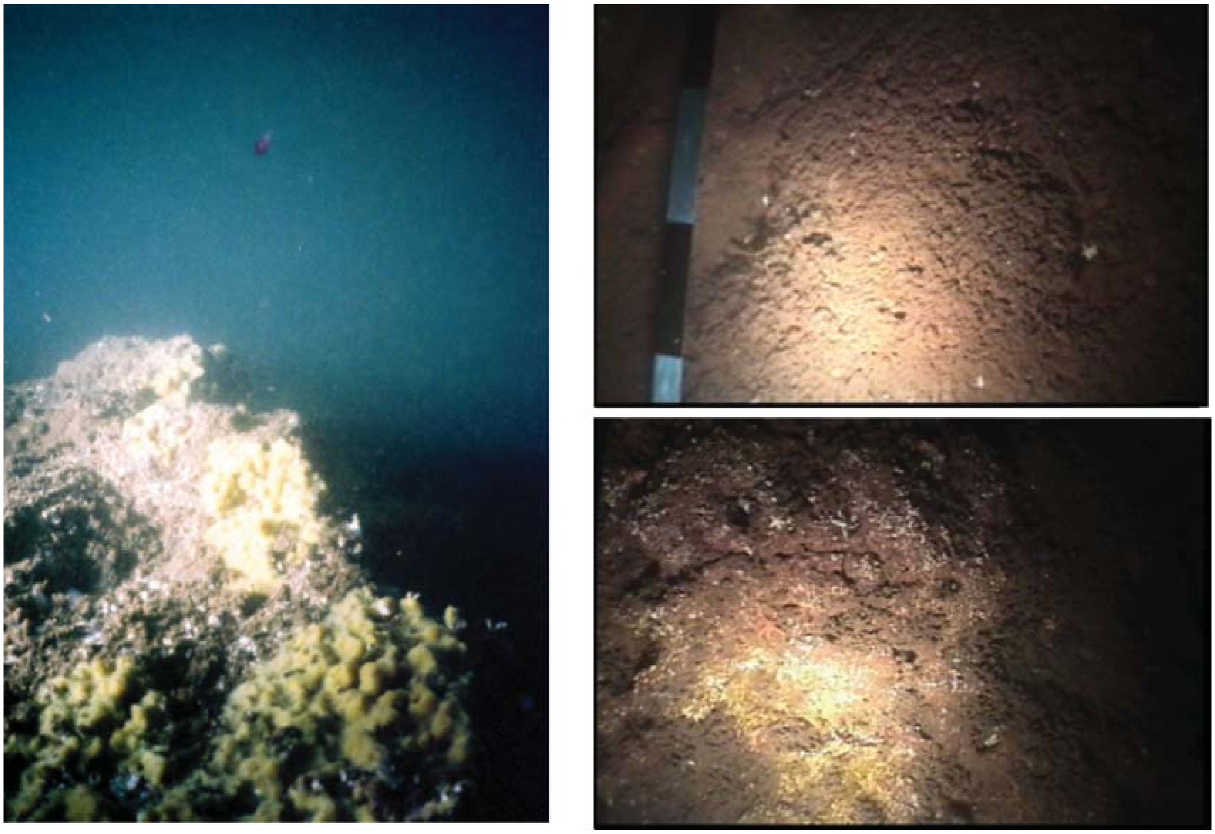

Figure 6. Benthic communities on sandstone outcrops. Left: Breadcrumb sponge and barnacles on bedrock prominence. UR: bedrock covered with "biolayer" of surface dwelling organisms and small sea stars. LR: patches of biolayer and sea stars including *Henricia* and small sea stars, probably *Asterias vulgaris*. Horizontal dimension of left image, and vertical dimension of others, 30 cm

Sedimentary bedrock outcrops and troughs support separate communities associated with either the sandstone outcrops or the intervening flatter troughs with cobble and boulders. Sandstone outcrops, which generally occur in ridges, support encrusting organisms including *H. panicea* (Figure 6), barnacles, and occasional stalked ascidians (*B. ovifera*), as well as tubes and filaments of unidentified organisms extending laterally from the inner surfaces of crevices in the bedrock and off the edges of rock ridges. Most sandstone bedrock surfaces are covered, sometimes almost completely, with a thin, fragile, gray to brown layer of particulate material (referred to here as a "biolayer") (Figure 6), thought to be organism tubes and structures of surface tube dwelling organisms, presumably amphipods and polychaetes, but the exact identity is not known. The biolayer is not detrital material deposited at slack tide as it resists current, appears to exhibit a structure, and in some of the images, presumably where this "biolayer" has been removed or sloughed off, small circular patches occur, evidently in the process of reestablishment (e.g., Figure 6, lower right image). Various other fauna, which dwell on surfaces in this area include barnacles, hydroids, and surface dwelling bivalves (some information was obtained on fauna of rock surfaces from bottom samples in troughs between the bedrock ridges, Table 3). Associated organisms including low densities of hermit crabs and sea stars (*A. vulgaris* and *H. sanguinolenta*), also occur on sedimentary bedrock outcrops.

Station 1, grab contents	Station 7, Sandstone Cobble	Station 7, Basalt Cobble
Bryozoan -*Flustra foliacea*	Hydroid Unidentified	Bryozoan unidentified
Hydroid – *Eudendrium arbusculum?*	Amphipods: *Jassa falcata* (23), *Corophium insidiosum* (1)	Amphipods: *Jassa falcata* (4)
Ascidian – *Ascidia callosa.*	Barnacles: *Semibalanus balanoides (*43)	Hydroid: *Eudendrium? sp*
	Snails: *Anomia squamula* (1); *Anomia simplex* (1).	Polychaete worm fragment
	Clams: Horse mussel spat - *Modiolus modiolus (1)*	Bivalve spat (2)
	Polychaete worms: *Lepidonotus squamatus* (1); Terebellidae (1); Goniadidae (1); Maldanidae (1); *Spirorbis* (1); Ampharetidae (1)	
	Encrusting sponge, white (1); brown (1)	

Table 3. Benthic organisms found on rocks dredged in sedimentary outcrops, August 19 and 20, 2009 (number or organisms in brackets)

Figure 7. Communities of troughs between sandstone outcrops. UL: boulders and cobble over a red mudstone bedrock outcrop (lower right) with Blood Star, sandstone cobble with "biolayer" and other organisms. UR: sandstone boulder with biolayer of surface dwelling, tube-building organisms amid smooth cobbles of other types. LL: boulders embedded in cobble, one with Breadcrumb sponge showing bedload scour, and one with hermit crab. LR: cobble and boulder, including two mudstone cobbles. Vertical dimension of LR photo, 30 cm; all others 0.7 m.

Figure 8. Benthic communities of volcanic bedrock platform. UL: "biolayer" typical of volcanic bedrock, Northern Red anemones (*U. felina*), and unidentified sea star. UR: patches of Breadcrumb sponge on flat bedrock surfaces, including *Urticina*. LL: biolayer, unidentified sponge, and *Urticina*. LR: Breadcrumb sponge, volcanic bedrock "biolayer", red Blood Stars (*H. sanguinolenta*), unidentified sea star, and *Urticina*. Vertical dimension of UR photo approximately 0.7 m, all others 30 cm.

Figure 9. Benthic communities on boulders and bedrock on volcanic bedrock platform. UL: boulder with Breadcrumb sponge and hermit crab. UR and LL: Breadcrumb sponge on basalt bedrock. LR: closeup of Breadcrumb sponge on basalt bedrock

The biological community of bedrock troughs is similar to that of boulder and cobble areas, and bedload scour of the lower parts of rocks is also observed (Figure 7). Encrusting fauna (e.g., Breadcrumb sponge) are common in patches on rocks, and "edge fauna" (e.g., tube building worms, *B. ovifera* and *F. foliacea*) occasionally occur on large rocks. Troughs also support low densities of hermit crabs, sea stars (*A. vulgaris* and the Blood Star *H. sanguinolenta*), and occasional Northern Red anemones (*U. felina*). Red mudstone/siltstone bedrock and cobbles found in troughs frequently show pits reminiscent of holes bored by boring clams. Several species of boring clams are known from Minas Basin in similar rock types in shallow water. Attached organisms on rocks sampled from troughs, included the amphipod *Jassa falcata*, hydroids (*Eudendrium arbusculum*?), jingle shells (gastropods) *Anomia squamula* and *A. simplex*, various polychaete worms, some bivalve spat (early settled and attached stages) and the barnacle *Semibalanus balanoides* (Table 2).

On the volcanic bedrock platform, level surfaces support extensive patches of Breadcrumb sponge (*Halichondria panicea*), with the Blood Star *Henricia sanguinolenta* and another sea star, probably the common sea star, *A. vulgaris*, and Northern Red anemone, *U. felina*, commonly clustered along rock crevices. A type of "biolayer" of surface dwelling organisms distinctive to volcanic bedrock surfaces (Table 2, Figures 8 & 9) also occurs in these areas. Where bedrock highs and boulders occur, high concentrations of sponges, barnacles, *Urticina*, and *Henricia* are found; on some of the rock prominences, a surface "biolayer" resembling the one that occurs on sedimentary bedrock ridges also occurs. Bedload scouring also occurs on the lower portions of boulders sitting on the volcanic bedrock surface.

Discussion and Conclusion

The present study has produced the first visual images and some of the first samples of the seabed of northern Minas Passage, revealing both new and previously unseen geological features and benthic communities which occur under a combination of conditions—depth, substrate, water column stratification, and particularly current—unique in Nova Scotia coastal waters. This has occurred because the move to develop the Minas Passage for tidal energy extraction has provided resources for the necessary baseline survey activities and research in this part of the Bay of Fundy, which is notoriously difficult to study. Benthic animals visible in bottom images are species commonly occurring elsewhere in the Bay of Fundy and Gulf of Maine system. The large water exchange and contiguity between Minas Passage and adjacent areas of Minas Basin, Minas Channel, and the Outer Bay of Fundy, would suggest that these areas should have many species in common, through colonization by early life stages and later movements. Depth is not a major factor in controlling the distribution of benthic communities here, except on the nearshore shelf, where there is a rapid transition with depth in light levels and wave and current energy. Similar transitions may also occur on shallow parts of the volcanic bedrock platform at and around Black Rock (not sampled here), where changing light levels with depth are expected to promote a progression of seaweed and coralline algae development. Other depth-related factors, which normally influence benthic communities in deeper water, including water column temperature and salinity stratification, and seasonal timing and levels of food availability, are mitigated by the rapid mixing at the site, which creates uniform temperatures through the water column (Bousfield and Leim 1958; Envirosphere Consultants 2009) and, possibly, exposure to particle (food) regimes which are likely not dependent on depth.

Breadcrumb sponge (*H. panicea*) was a dominant species in terms of percent cover (Table 2) and characteristic appearance, particularly in volcanic bedrock platform areas, and occurred in all parts of the study area. The typical raised form of the sponge, which resembles broken pieces of bread ('breadcrumbs'), predominated on sedimentary bedrock outcrops, while the species exhibited a flat growth form occasionally with ridges and a geodesic appearance on flat boulders and flat volcanic bedrock surfaces (Figures 7 & 8). It is a common coldwater sponge worldwide, in intertidal to subtidal areas, commonly showing colour variation from yellow (typical) to green, brown and bleached to white (Fuller et al. 1998; McCarthy 2004). It also exhibits variations in morphology that are related to water movement, with a flatter growth form associated with more quiescent conditions in nearshore environments exposed to wave action, and the more erect form with wave-washed crevices and channels (Palumbi 1984). In the present study area, the erect, breadcrumb-like form associates with irregular rock surfaces in both the sedimentary and volcanic bedrock areas, while the sponge has a flatter, smooth form on flat expanses of volcanic bedrock, and boulders in all areas (Figures 7 & 8). The species is also observed on rock ledges in the Gulf of Maine (Witman 1998).

The Blood Star *H. sanguinolenta* is a common echinoderm species on the east coast of North America, and has a Boreal-Virginian distribution (Gosner 1971) occurring in the Gulf of St. Lawrence (Brunel et al. 1998) and from New York to the Bay of Fundy (Madsen 1987 from Brunel et al. 1998). *Henricia* spp occur in the outer Bay of Fundy scallop grounds (Fuller et al. 1998; Kenchington 2000). It was among the most abundant species, locally reaching densities of 10 individuals/m^2, highest in volcanic and sedimentary bedrock areas (Table 2). The species is fairly distinctive both by its typically red colour, and arm shape and surface texture, which are thinner and smoother respectively than *Asterias vulgaris*, a common species in the area. *Henricia* spp have been described as having the ability to survive strong flow and abrasion (Ursin 1960, from Kenchington (2000)). The species occurs on offshore rock ledges at 30–45 m in the Gulf of Maine where sponges are common (Witman 1998); the species is a spongivore, and has been observed in feeding aggregations on Breadcrumb sponge and the sponge *Mycale lingua* at 30 m on Cashes Ledge, a bedrock outcrop in the western Gulf of Maine (Shield and Witman 1993, from Witman 1998). In scallop grounds in the outer Bay of Fundy, *Henricia* spp was more abundant in trawls when sponges were abundant (Kenchington 2000), reflecting a co-occurrence on coarse substrate in the area (Fader et al. 1977) but also a possible feeding association.

Northern Red anemone (*U. felina*) occurs throughout the study area, but most abundantly on the volcanic bedrock platform. It is a common Bay of Fundy species (Bromley and Bleakney 1984), and has been reported on subtidal boulder and rock outcrops near Deer Island, New Brunswick (Tyrrell 2005) and in Head Harbour Passage (Logan 1998). Anemones, including *Urticina*, were the most commonly encountered faunal group in scallop grounds in the outer Bay of Fundy (Fuller et al. 1998). The species is a carnivore, eating a wide range of available species including amphipods, molluscs, worms, shrimps, and brittle stars (MARLIN 2009). The stalked tunicate *B. ovifera*, as well as the bryozoan *F. foliacea*, both of which were relatively common in the present study, typically occurring on vertical sides of boulders and bedrock outcrops, were also locally abundant in outer Bay of Fundy scallop grounds (Fuller et al. 1998; Kenchington 2000). The hydroids *Eudendrium ramosum* and *E. capillare* were among the communities of hydroids colonizing scallop shells in the outer Bay of Fundy (Henry and Kenchington 2004). *Eudendrium* spp. were found on rocks sampled in the present study (Table 2).

The benthic communities observed here, and the geological features with which they are associated, represent unique and previously undescribed elements of the seascape (sensu Day and Roff (2000)) of the Bay of Fundy, largely due to the high currents in which they exist. Deepwater hard bottom benthic environments have not been widely inventoried in Atlantic Canada to allow comparisons, so there maybe similar or parallel communities elsewhere, but it is unlikely they occur under similar current conditions. Apart from their occurrence in the study area, the extensive areas of sedimentary bedrock outcrops and troughs and communities observed here appear to occur more widely in Minas Passage, shown in multibeam imagery (see Figure 1) and these communities may be the dominant ones for the area. Volcanic basalt platforms are smaller and localized in distribution, with several occurring on the outer fringes of the study area, making them potentially more significant for their habitat conservation value. Confirmation of character of the bottom in these areas and their ecological and conservation significance awaits future studies.

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DISTRIBUTION AND MORPHOLOGY OF HORSE MUSSEL BEDS IN THE BAY OF FUNDY IDENTIFIED USING MULTIBEAM SONAR

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The presence of horse mussel (*Modiolus modiolus*) reefs in the Bay of Fundy has been known for the last decade, since their discovery using sidescan sonar and high resolution seismic systems. The reefs are long, thin, and parallel structures covered with epifauna. Since 2006, the Geological Survey of Canada, in cooperation with the Canadian Hydrographic Service and the University of New Brunswick, acquired 12,465 square kilometres of multibeam sonar coverage in the bay. We have identified and outlined mussel beds by visually inspecting the multibeam bathymetry and backscatter strength maps. Horse mussel beds are expressed as elongated and elevated ridges with backscatter strength different from the surrounding seabed. Approximately 1,500 mussel beds were mapped and measured. The beds are located in 40–100 m water depths with a median depth of 76 m. The beds ranged in length from 32 m to 2 km, with median length of 185 m and were on average several meters high. The shape of the beds was more irregular and less linear in areas of multidirectional tidal current. The total area of the horse mussel beds in the bay is approximately 700 ha. Distribution maps and morphological data could be used to design and implement protection measures for this important ecosystem component of the Bay of Fundy.

THE ATLANTIC MUD PIDDOCK (*Barnea truncata*: Family *Pholadidae*) A RELICT WARM-WATER SPECIES IN THE MINAS BASIN

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The Atlantic mud-piddock (*Barnea truncata*), found only in Minas Basin waters, shows an amphi-Atlantic distribution, which cannot be accounted for through any single dispersive mechanism. Overall distribution is in intertidal habitats from Senegal to South Africa and Brazil to Massachusetts, where substrate allows, with a single disjunct population in a restricted formation in the intertidal of the Minas Basin. This candidate Committee on the Status of Endangered Wildlife in Canada (COSEWIC) species is constrained to a total area of distribution of < 0.6 square kilometers and is only found in a one, restricted substrate within the Basin. It may be subject to disruption, not only by land-use practices affecting estuarine water quality, but also by potential tidal power technologies.

THE UNKNOWN SEDIMENT BUDGET OF MINAS BASIN (NOVA SCOTIA, CANADA): IMPLICATIONS FOR CHANGING ENVIRONMENTAL CONDITIONS AS A RESULT OF TIDAL POWER EXTRACTION

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The sediment budget of Minas Basin, a subsidiary basin of the Bay of Fundy / Gulf of Maine system, is very poorly understood (e.g., Jacques Whitford 2008). At present, Minas Basin is considered a sediment sink and thus contrasts with the Cumberland Basin (the other subsidiary basin), which is thought to be a sediment exporting system. Yet both basins are components of the same large estuarine system, governed by comparable conditions on a large scale. This in itself is a puzzling sedimentary phenomenon. Understanding the physical processes that control sediment transport, erosion and sedimentation is crucial for forecasting environmental effects of future large-scale tidal energy extraction.

Human intervention around the Bay of Fundy dates back about 400 years. The most obvious legacy of this intervention is the extensive system of dykes, weirs, culverts and causeways, which has resulted in an estimated 75% of the original intertidal mudflats and marshes being no longer in open exchange with the tides. It is unknown whether the Bay of Fundy's dynamic system as observed today is still in the process of adjusting to these changed boundary conditions (as suggested by Amos and Mosher 1985) or whether these changed conditions are negligible with respect to the natural dynamics of this hypertidal system.

In the Westerschelde, a macro-tidal (5 m tide range) estuary on the border between the Netherlands and Belgium with a length similar to that of the Minas Basin, construction of dykes and causeways during the last 400 years significantly decreased estuarine storage capacity, resulting in a documented increased tide range, decreased phase lag and increased scouring and deepening of the main tidal channel over the 70 km length of the estuary (Van der Spek 1997). In hypertidal Knik Arm, Alaska (a subsidiary basin of Cook Inlet near Anchorage, AK), comparable to Minas Basin in terms of winter ice conditions, massive amounts of soft glacial sediment along its shores and tide range and extensive modeling and monitoring around the proposed location of a bridge suggest that even bridge pylons may change the phase lag and 'back up' high tide on the landward side (HDR et al. 2007) of the projected bridge.

The sediment budget of Minas Basin was last assessed about 30 years ago (Amos 1978): the basin is thought to import a total of about 5 million km^3 of sediment annually, about two-thirds of which is sourced from cliff erosion and about one-third of which enters through Minas Passage. A negligible amount was estimated to be provided by rivers. This estimate is in agreement with the generally accepted paradigm that estuaries fill with sediment during periods of relative stable or slowly rising sea level (the present situation).

The marshes around Minas Basin display varying degrees of lateral shifting over short periods of time (e.g., Van Proosdij and Horne 2006), but it is unknown how these changes in the horizontal plane relate to volumetric sediment shifts.

While lateral shifts of marshes, mudflats and tidal creeks are commonly observed, it is also well documented that the overall sediment distribution of Minas Basin is quite distinct, with most silts and muds accumulating in the southwestern region of the Basin's so-called "Southern Bight," in the Avon River estuary system and in small pockets along the Cumberland shore, whereas the eastern edges (Cobequid Bay and the Cheverie shore) contain mostly sand and (fine) gravels. Suspended sediment concentrations are highest in the areas of mud deposition and lowest in Minas Passage. The specific dynamics that result in this regionally distinct variation in grain sizes populations are not known in detail. These distinctly different sedimentary environments host an immensely diverse ecosystem.

Supratidal or "high" marshes typically are flooded only during perigean spring tides, which means they may be flooded less than 2% of the year. During these short periods, sufficient sediment accretes on these marshes for them to maintain their elevation at mean high water level (MHWL). Perigean spring tides occur typically during early spring and late fall, hence about one-third of high marsh flooding occurs during winter when ice may be present. Suspended sediment concentrations are higher in winter than in summer (Goodman et al. 2007), leading to the notion that winter ice may be an important factor in supplying high marshes with the necessary sediment to maintain elevation at MHWL. But ice also takes up sediment and dead vegetative matter from the marsh surface and redistributes it elsewhere on the marsh and, to some extent, back in the estuary, providing it thus with an important influx of primary production. None of these processes has been quantified for Minas Basin.

A wealth of new data has been collected recently in the area of Minas Passage for the purpose of preparing the environmental assessment for the installation of tidal power turbines in the demonstration area near Black Rock (FORCE 2009). This new data inventory was established especially in order to be able to predict how the demonstration facility would affect and be affected by this uniquely aggressive environment. Much less attention was paid to extending the new knowledge to formulate scenarios for a more distant future when an array of turbines in Minas Passage may generate power for Nova Scotians.

For such a possible future development, the following questions would have to be answered for Minas Basin:

1. Would the level of high tide increase and, if yes, how much?
2. Or would the high tide level decrease because less water would pass through Minas Passage?
3. Would high tide last longer, due to increased phase lag?
4. What is the present-day sediment budget of Minas Basin and to what extent can we determine whether this sediment budget is still in a stage of adjustment to the past 400 years of human intervention?
5. Would sedimentation patterns change as a result of large scale tidal energy extraction, and, if yes, can this be predicted in a quantitative way?
6. Is it possible to construct and maintain turbines with typical winter ice conditions?
7. What is the contribution of winter ice to the overall sediment budget and especially to the accretion of high marsh and how would this change due to tidal power extraction?

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THE CHARACTERIZATION AND TRACKING OF SEDIMENT-LADEN ICE IN MINAS BASIN, NOVA SCOTIA

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Abstract

Submerged sea ice has been suggested to represent a risk to the successful development of in-stream tidal energy in the Minas Passage area of the inner Bay of Fundy. The literature indicates that the density of sediment-laden ice can exceed that of sea water, potentially leading to underwater infrastructure collisions. To test this hypothesis, researchers from Minas Basin Pulp and Power Co. Ltd. collected 93 sediment laden ice samples from 34 locations around the Minas Basin during the period of March 2009 to early April 2009 in an attempt to estimate the occurrence probability of negatively or neutrally buoyant ice. Nine global positioning system (GPS) tracking systems were fixed on separate ice cakes to determine the movement of ice and further study their dynamic behavior.

Ice characteristics from the collected samples will provide insight into the nature of sediment-laden ice in the Bay of Fundy. The result of a trend analysis, which compared ice density against latitude, longitude, and temperature indicate that the ice density can be considered random from area to area, with some localized averaging for samples extracted from a single location. While it was observed during testing that all samples physically floated, the data analysis determined that a small percentage (four samples out of 83) could be considered negatively buoyant. The uncertainty associated with the measurements caused two samples to be neutrally buoyant. Ongoing studies will continue to verify and expand upon the results obtained from this and other associated studies.

Introduction

The Bay of Fundy is the site of the world's highest tides. Twice a day as part of the tidal cycle, approximately 13 billion tonnes of sea water flow in and out of Minas Basin. At mid-tide the current flow in Minas Passage equals the combined flow of all the rivers on Earth. The development of in-stream tidal energy in the Bay of Fundy presents a viable solution to increasing demand on generating electricity from renewable resources. Due to the infant state of the tidal energy industry, there exists a deficit in the understanding of the risks inherent in the development of such technologies. One example is the understanding of the potential impact of sea ice. The existence of submerged ice is of great interest; as such ice could theoretically have devastating effects on underwater infrastructure. Researchers from Minas Basin Pulp and Power Co. Ltd. collected ice samples from the Minas Basin in March 2009 and early April 2009 in an attempt to estimate the occurrence probability of negatively or neutrally buoyant ice.

Formation of Ice

During mid-winter, a few days of low temperatures can form ice within Minas Basin. Frazil ice, the free-forming crystallization of sea water that results from the temperature dropping below the freezing point of water, has the capacity to adhere to itself, the seafloor (becoming anchor ice) and other pieces of ice (Martin 1981). Frazil ice can be compacted to form pan ice, which has the ability to penetrate marsh creeks and can potentially flow into river systems. Thicker accumulations of pan ice (>15 cm), referred to as cake ice, are produced in fast moving ice-packed waters (Desplanque and Mossman 1998).

If the temperature is sufficiently low, the combination of sea water along with runoff and precipitation from rivers and streams can freeze directly onto the bare sediment of the intertidal zone. This creates frozen crust, which will then be either ripped from the sea floor during the following flood tides or become strongly bonded to the sea floor as anchor ice, which will not re-float when covered by the tide. If the frozen crust is carried away, it will transport sediment, grass and rocks, which have been incorporated within the ice. Cake ice tends to migrate with the tides and is often stranded onshore as the tide height recedes. During this time, the cake can become attached to the frozen crust creating a laminated or composite ice cake. Repeated tides have the ability to generate increasingly complex ice blocks. This report will focus on cake ice.

Shore fast ice will form on the banks of rivers that feed into the Minas Basin (Gordon 1983). Ice can quickly accumulate on the banks during high tide, creating ice walls. The lower reach of the ice can be stripped away by the constant flow of the river. Accumulations of ice along thawing riverbanks can become adequately weighted with sediment to drop into the river flow, carrying an eroded portion of the bank with it.

Previous Studies

Ice buoyancy is dependent on many factors including, but not limited to, temperature, sediment content, water salinity, and the geological setting of ice formation. Previous studies (Sanders et al. 2008) utilized basic calculations to determine the required sediment content (total solids by weight) to dictate negatively buoyant ice. The required amount was then compared to the contents of ten previously collected ice samples located on the intertidal mudflats as well as five samples in the headwaters of the Bay of Fundy. The results suggested that three of the ten samples contained sufficient sediment to cause the sample to sink, leading to an estimated 30% submersion rate. Of the five samples referenced from the headwaters, it was determined that all five would be negatively buoyant. The study also provided anecdotal evidence that submerged ice is collected in fishing nets during the spring after severe winters (every 5–6 years).

Methods

To obtain insight into ice density around the Minas Basin, three individual data collecting teams gathered a total of 93 ice samples. Ice was harvested from 34 locations around the north, east and south side of the Minas Basin. Figure 1 displays a map of the ice harvest locations. More than one sample was typically collected from each location. Sites were selected based upon access to the ice. Sample collection locations included beaches, river banks, and the water's edge. Upon arrival at the ice location, information such as the date, time, general region, meteorological conditions, latitude, and longitude were recorded. Multiple pictures were taken of each ice segment to give an indication of the size, shape and composition of the ice block from which a sample would be cut. A section representative of the whole piece of the block was then cut and photographed with a ruler alongside to indicate scale. The sample was then wrapped in two plastic bags and placed in a covered plastic bucket. Qualitative characteristics such as the sediment distribution, presence of voids, ice texture, and sediment layering were also

Figure 1. Sample collection locations

recorded and were referenced in photographs. The samples were then transported to Hantsport, Nova Scotia, for volumetric measurement, weighing, storage, and further analysis.

A report on the density of sea ice (Timco and Frederking 1994) presents three methods for determining ice density, two of which suggest cutting and weighing ice blocks of a known volume. The third technique involves letting the ice melt within an airtight container and measuring the specific gravity of the melted liquid. A clear advantage to cutting the ice to a known volume is the ease of application. However, the method is vulnerable to dimensional errors that could have a significant effect on the final density. The apparatus to perform the specific gravity test was unavailable at the time of collection. Therefore a volumetric displacement approach was used to determine the volume of the ice sample.

The volumetric displacement apparatus included an aluminum container with a spout to transfer displaced volume into a receiving bucket. Prior to each test, the container was filled with fresh water until it began to empty through the spout. An unsealed bag-wrapped ice sample was then submerged in the container and the displaced water was collected in the receiving bucket. Once the bag of ice had been fully submerged and the water had stopped transferring, the depth of the displaced water in the receiving bucket was recorded. The mass of each ice sample was also documented.

Ice Tracking

In addition to collecting ice samples, GPS trackers were mounted on nine ice cakes around the Minas Basin to determine the dynamic nature of the ice. The path of travel could then be cross referenced with the locations of high density ice to determine the likelihood of negatively buoyant ice flowing through the Minas Passage.

Apparatus and Deployment

Simplex MMT transmitters were employed to track ice locations. Each transmitter was inserted into a piece of PVC pipe. A 13 mm (½") diameter pilot hole was drilled approximately 0.3 m (12") into the ice cake, and a 19 mm (¾") threaded steel rod then was inserted into the pilot hole. The GPS assembly was then attached to the rod (Figure 2). Each assembly was fitted with a buoy to ease in recovery. Each tracker was deployed in a different area of the Minas Basin, including rivers and open coastline. Each unit was deployed from the location listed in Table 1.

Figure 2. GPS ice tracking assembly (as installed)

Unit Number	Deployment date	Deployment Area
#622527	March 14, 2009	Five Islands
#622541	March 17, 2009	Kennetcook River
#622324	March 19, 2009	Summerville Beach
#622390	March 19, 2009	Burntcoat
#622241	March 20, 2009	Lower Selma Area
#622838	March 20, 2009	Maitland
#622532	March 20, 2009	Lower Truro
#622235	March 21, 2009	Portapique River
#622346	March 21, 2009	Bass River

Table 1. Sample deployment

Ice Tracking Results

Transmitters were retrieved by representatives of Minas Basin Pulp and Power and by local residents. Two samples were not retrieved as the units had ceased reporting entirely. None of the retrieved transmitters were attached to their ice cakes. Unfortunately, there was no way to determine when the tracker had left the ice. However, the tracking of the ice cakes did provide valuable information regarding the behavior of ice in the Minas Basin. Of the nine trackers that were deployed: one remained stationary, two did not leave the river they were deployed in, one started in a river and moved into open water, two moved along the open coastline, and three ventured into open water and traversed the Minas Passage.

The first transmitter was deployed in the Five Islands area on March 14, 2009. During the first three days of deployment, the tracker did not move. The lack of movement could be the result of being too heavy, anchored to the bottom, or by having been deposited onshore during the spring tide (which occurred on March 12, 2009). In such a case, the tidal height could potentially not return to the same level for an entire 14-day tidal cycle in order to remove the ice.

Two transmitters were deployed on the banks of the Kennetcook and Shubenacadie rivers. Each tracker proceeded to travel up and down river numerous times until they stopped reporting. Unfortunately neither transmitter could be recovered. This may indicate that voyages in river systems are more violent than those in the open water, meaning that the transmitter could have a higher chance of being separated from the ice cake due to collisions. The transmitter that was deployed in Lower Truro on March 20, 2009 ventured up the Salmon River. The sample then changed direction, exited the river and proceeded toward open water. The sample travelled across the Minas Basin and eventually landed onshore in Burntcoat. This shows that river-based ice cakes do have the ability to migrate into open water.

Two samples travelled along the shoreline but failed to enter open water. Sample #622324 was deployed on Summerville Beach on March 19, 2009. The sample travelled north from the deployment site, remaining close to the banks of the Kempt Shore and then spent ten days located approximately three kilometres west of Cheverie before being retrieved on March 30, 2009. Sample #622390 travelled along the coastline from Burntcoat to Pembroke where it was retrieved onshore on April 8, 2009.

Three samples travelled through the Minas Passage. Sample #622241 was deployed in the Lower Selma area on March 20, 2009. Once navigating its way through the Minas Passage, the tracker continued to travel as far north as Apple River before reversing direction and proceeding partially back through the south side of the Minas Passage. Another transmitter was deployed near the Portapique River on March 21, 2009. The sample departed the area three days after it was deployed. It swept back and forth with the tide, edging closer and closer to the Minas Passage until March 29, when the sample entered the passage and travelled in and out with each tide for the following two days. Finally, sample #633346 was deployed near the Wharf Road in Bass River on March 21. The sample crossed the Minas Passage a total of seven times, and last reported on April 8 2009. All three samples were retrieved west of Scots Bay. Assuming that the trackers were attached to the ice for the majority of the time, these samples demonstrate that a single ice piece can cover a vast expanse of area.

Analysis and Discussion

Ten collected samples strayed from the prescribed testing procedure. The samples in question were not measured volumetrically until the day after the ice was harvested, allowing a percentage of the ice to melt. The melted liquid was mistakenly considered to have the same volume as the ice. The result was an underestimate on volume, which lead to a gross overestimate of density. These samples were removed from the analysis. Therefore, only 83 samples were analyzed as opposed to the original 93 that were collected.

Density Calculation

All sample densities were calculated and an uncertainty analysis performed. Density was calculated by using the ratio of mass (grams) and volume (L) measurements. The calculated densities were then shown as a histogram (Figure 3). The uncertainty associated with the measurements, conversions, and approximations was estimated. Both the systematic uncertainty involved with the measurements and the random uncertainty due to variation in results were propagated. The resulting average uncertainty was +/- 15 g/L. Sources of error that were not considered included the leeching of brine from the ice pieces and the partial melt that occurred during the brief period between sample harvest and the volumetric test. For ice that is harvested at air temperatures greater than -15^{o} Celsius, pockets of brine may collect into networks and begin to leech from the ice sample, effectively replacing their volume with an equal amount of air (Timco and Frederking 1996). It is assumed that the error in density due to this leeching would be offset by the error due to the partial melting of the sample. Sea ice densities are typically within the range of 720 g/L to 940 g/L (Timco and Frederking 1996). Of the 83 samples analyzed, the density of one sample fell below that range, 68 were within the limits and 14 had higher densities.

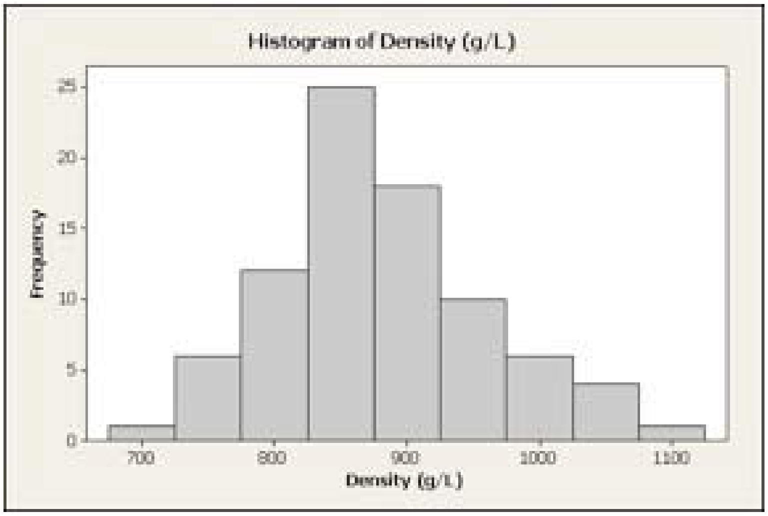

Figure 3. Histograms of ice density

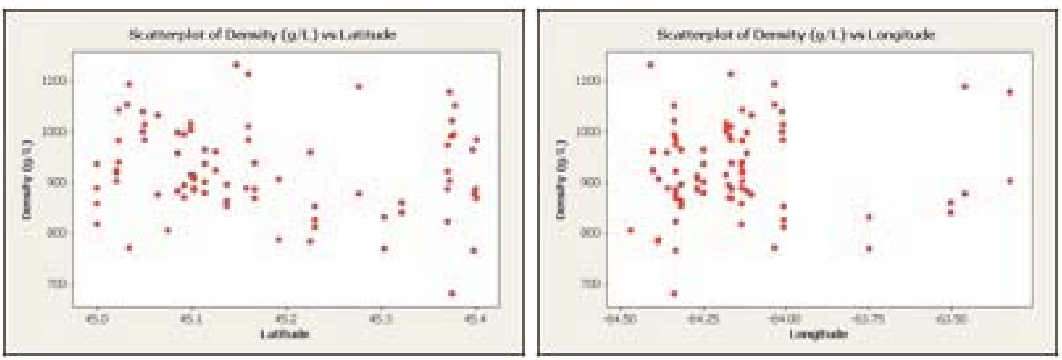

Figure 4. Density vs. latitude and longitude

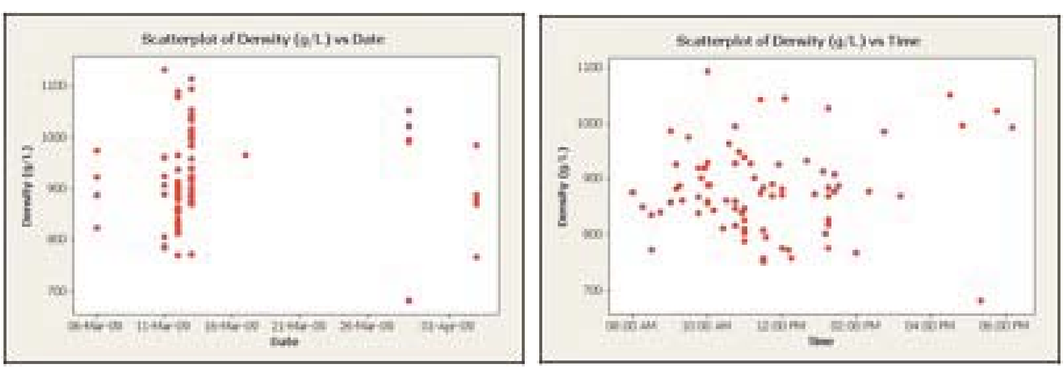

Figure 5. Density vs. date and time

Trend Analysis

A trend analysis was performed to determine if significant localized conditions necessitated separate analysis for each harvesting location, date or temperature. A lack of trends would suggest that the entire data set could be analyzed as a whole. The densities were first compared to their latitude and longitude coordinates to determine if the samples varied depending upon their geological position. According to the results of the regression, no discernable linear trend can be fit to the data (Figure 4). Multiple data points were often collected for each latitude and longitude. The lack of fit test indicated that considering the mean value at each latitude and longitude was preferable to a line of best fit. Upon grouping the samples by location and re-testing the hypothesis, the data continued to indicate no trends. The conclusion is that ice density of the collected samples could be considered independent of the location from which it was harvested.

Density was also plotted versus the collection temperature to test for a linear trend. The regression indicated that temperature had no effect on the density of ice. Finally, the density of ice was compared to the date that the samples were collected. From the regression analysis and the preceding plots (Figure 5), it can be concluded that the ice density value is independent of the date and time it was collected.

Water Density Distribution

The water in the Minas Basin is a well-mixed combination of fresh water, sea water and sediment. Average salinity and temperature statistics from the Department of Fisheries and Oceans (DFO) Hydrographic database suggest that the average seawater density in the Minas Basin during March and April is 1025 g/L +/- 1 (DFO 2007). Incoming tidal flows in the Bay of Fundy have a high sediment carrying capacity. It has been shown that upwards of 2% by weight of sea water can consist of sediment removed from the bay floor, banks and shorelines (Desplanque and Mossman 1998). However, on average, the sediment content of the water is on the order of milligrams per litre and will therefore be disregarded in the calculation of seawater density.

Ice Density Distribution

Treating the data as being randomly distributed allows the data set to be analyzed as a whole. Using error bars to quantify the uncertainty, the densities have been organized into the following plot shown in Figure 6. From the plot of ice density, it can be observed that four samples lie above the density of sea water and two samples are within the error bars of the seawater line. The remainder of the data suggests that the density of the samples are less than that of sea water and would therefore float. The researchers performing the volumetric test observed that every collected sample needed to be forcefully submerged in the aluminum container, suggesting that each sample was positively buoyant in fresh water. This argument disagrees with the six samples that were determined to be negatively buoyant through density calculation.

Risk of Being Negatively-buoyant

The experimental data show that four of the 83 samples would be considered negatively buoyant. This corresponds to a probability that 4.8% of cake ice in the Minas Basin will be submerged. As previously mentioned, the ice density analysis showed that the error bars of two samples spanned the density of sea water, indicating buoyancy uncertainty. This result is significantly lower than the previously estimated submersion rate of 30%. It is believed that the discrepancy can be attributed to the previous method of using total solids by weight to approximate ice buoyancy, which fails to account for the amount of trapped air in the ice, possibly significantly increasing the buoyancy.

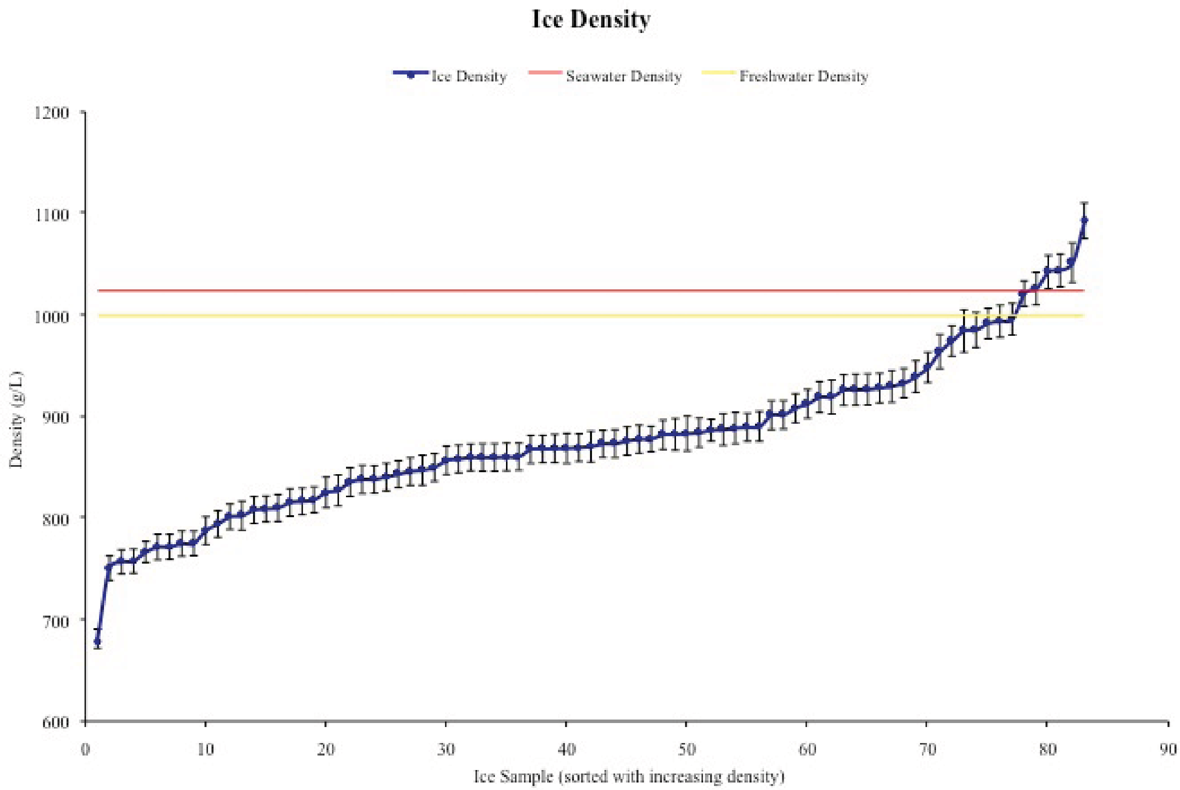

Figure 6. Plot of ice density

Neutrally Buoyant Sample 1 (March 13 #116)

This sample was harvested in Avondale on March 13, 2009. The block was located on grass in an area dense with frozen crust (Figures 7a and b). The crust from which the sample was cut had grass and mud incorporated into it. The analysis indicated that the density of the sample was 1026 g/L +/- 16. Accounting for the uncertainty, this suggests that it is uncertain whether the sample would sink or float. Although there were no trackers deployed in Avondale, tracker #622324 started on Summerville Beach, approximately 10 km north of Avondale. If the ice sample were positively buoyant, it can be estimated that the ice would also travel north along the Kempt shore, as the closely deployed tracker did. If the ice cake is negatively buoyant, the ice would possibly become anchored to the surrounding crust and fail to release from the surface during the next tide.

Neutrally Buoyant Sample 2 (M29#4)

Sample M29 #4 was grounded on gravel near the East Bay Road near Parrsboro. There was no ice formed in the surrounding area, indicating that the ice piece had been stranded onshore. The calculated density of the sample was 1021g/L+/-12. Examination of Figures 8a and b shows that the sample was cut from the far right-hand side of the ice cake. The sample is proportionately darker than the rest of the cake, likely due to a higher concentration of sediment. As the sample is not indicative of the entire ice piece and as there were no other ice cakes or frozen crust located in the area of harvest, it is probable that the ice had been carried with the tide to its location, indicating that the specimen was positively buoyant.

Figure 7a and b. Sample #116

Figure 8a and b. Sample M29 #4

Figure 9a and b. Sample #4, March 11

Negatively Buoyant Sample 1 (March 11 #4)

This sample was collected from the Canning aboiteau area. It was grounded on mud in an area covered with thin frozen crust. This sample had the highest calculated density at 1092 g/L +/- 17. Rocks and grass were incorporated in the sample, which was dark with sediment. Other smaller ice cakes were also stranded in the area (Figure 9a) and were partially covered in thin crust. Under the assumption that the crust was formed by a flood tide, the pieces could be anchored to the seabed. Alternatively, the ice may have been submerged, migrated underwater to its locations, and stranded during the ebb tide.

Negatively Buoyant Sample 2 (M29 #1)

Sample M29 #1 was found stranded on gravel on the shore of the East Bay. Figure 10 shows that the sample was solid and dark with sediment and appeared to have been separated from a larger ice piece. The calculated density was 1051 g/L +/- 16. Of particular interest is the proximity of this sample to M29#4 (see above). A total of five samples were collected from the East Bay, including M29#3 which had the lowest calculated density at 681 g/L +/- 10.

Figure 10a and b. Sample M29 #1

Figure 11. Sample #10, March 13

March 13 #10 and #12

The final two samples with calculated negative buoyancies were gathered from the Kennetcook River. The first sample, #10, was collected from a massive ice formation located under a highway overpass. Figure 11 shows that the sample is pressed against and potentially frozen to the bridge support column. The calculated density of this sample is 1042 g/L +/-16. There is some evidence of melting which could have been caused by sunlight. The presence of numerous icicles suggests that the ice piece had been in this location for a long period of time.

Sample #12 was located close to #10. The sample is a piece of laminated frozen crust. Three distinct layers exist in the ice sample (Figure 12b) and there is evidence of incorporated grass. The reported density of the sample was 1043 g/L +/- 16.

The ice tracker that was deployed in the Kennetcook River remained in the river the entire time. This suggests that even if the ice were negatively buoyant and migratory, the submerged ice chuck would likely remain in the river system. Assuming that the ice could migrate into the Avon River, another tracker deployed from Summerville Beach suggests that the ice would become stranded somewhere around Cheverie.

Figure 12a and b. Sample #12, March 13

Conclusion

Characteristics from the collected samples have provided a clearer picture of the nature of sediment-laden ice in the Bay of Fundy. The result of the trend analysis shows that the collected samples could be considered independent of collection date, temperature, and location. While it was observed during testing that all samples physically floated, the data analysis determined that 4.8% could be considered negatively buoyant. The uncertainty associated with the measurements indicated that two samples were neutrally buoyant. The reported results are limited to the locations and time period of collection. It is recommended that continued studies be undertaken to expand upon the results presented in this study.

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FERN (FUNDY ENERGY RESEARCH NETWORK): FACILITATING COOPERATION IN FUNDY TIDAL POWER RESEARCH

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Abstract

The return of significant interest in Fundy tidal power for the fourth time in the last century demands an integrated research programme comparable to those of the 1930s and 1970s. But times have changed. Governments are no longer the principal proponents of tidal power developments, although the two provincial governments (New Brunswick and Nova Scotia) have encouraged private sector interests to pursue renewable energy options from the Bay of Fundy. Primary focus is on kinetic energy conversion devices, with a demonstration and test site planned for completion in 2010 in Minas Passage, but potential energy options are also still being considered. The complexity of potential environmental responses to energy extraction, the tendency of environmental studies to be limited in scope, the difficulties of sharing information between competitors, and the absence of federal government sponsorship, all could lead to inadequate assessment of the long distance and long-term effects of commercial energy development. The Fundy Energy Research Network (FERN) is being created to promote collaboration and integration of research and monitoring activities conducted by proponents, universities, and government agencies.

Introduction

Tidal power is an old technology. Mechanical mills driven by tidal movements in estuaries have been widespread in Europe for at least a thousand years (Charlier 1982), used variously for grinding grain or pumping water. In the Bay of Fundy, it is believed that Champlain's 1607 grist mill near Port Royal was driven by tidal movements. Next year (2010), however, we reach the centennial of Turnbull's original proposal for generating electrical energy from the tides in Passamaquoddy Bay. In that last hundred years, there have been four major and numerous minor proposals for large scale energy development in the Bay. Most of these involved creation of one or more barrages, but at least one (the Clarkson proposal of 1915) was for a kinetic energy conversion. Apart from the earliest studies of fisheries in the Outer Bay (1898–1911), tidal power proposals were responsible for surges in research activity in the Bay in every decade of the 20th century (cf. Introduction to Session A). It is arguable that most of what we know about the Bay ecosystem has resulted from the dreams of harnessing its energy (Daborn 2007).

In the 1970s, rising oil prices triggered an extensive examination of the potential for barrage-based tidal power development in the upper Bay of Fundy. Three sites were considered as having high potential: the mouth of Shepody Bay (site A6), the mouth of Cumberland Basin (A8), and the mouth of Cobequid Bay (B9) (cf. Figure 1).

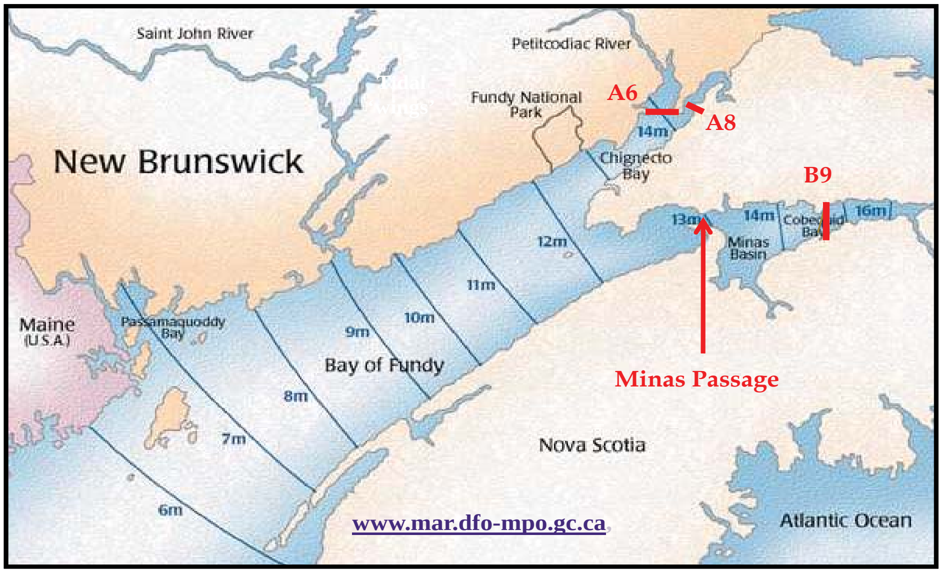

Figure 1. Tidal power proposals in the upper Bay of Fundy 1976–2009

At the instigation of George Baker (see dedication of these Proceedings), the first comprehensive workshop to identify potential environmental issues was held at Acadia University in November 1976 (Daborn 1977). The conclusion of that workshop was recognition of the paucity of basic knowledge about the upper Bay relative to the Outer Bay, and the need for a rapid, collaborative, and comprehensive programme of study. Thus was born the Fundy Environmental Studies Committee (FESC), which, under the sponsorship of the Atlantic Provinces Inter-University Council on the Sciences (APICS), oversaw a broad investigation of the Bay of Fundy from 1978 to 1984. Its final report (Gordon and Dadswell 1984), and the numerous other papers and research projects that followed the FESC approach, constitute an outstanding example of what can be achieved when institutions, agencies and individuals collaborate equitably to address a common problem. Although not identified as such, it was the first of the research networks, which has subsequently become a popular model in Canada.

FESC was terminated in 1984 as interest in construction of a large scale tidal power station had faded along with the price of oil, but it was apparent that the issue might again resurface. In order to continue the integrated, collaborative, multi-institutional programme initiated by FESC, the Acadia Centre for Estuarine Research (ACER) was established at Acadia University in 1985. ACER associates from several universities and government agencies in Canada, the United States, Argentina, and the United Kingdom, have carried out numerous investigations into the Bay of Fundy ecosystem, from sediments to marshes to fish. A theme has always been the implications of tidal power development, for which the pilot plant at Annapolis Royal has provided a good platform.

With renewed interest in Fundy tidal power now, there is a need for a similar enabling organization to enhance cooperation and coordination between scientists at universities, agencies, and in the private sector. That is the purpose of FERN, the Fundy Energy Research Network. FERN is to represent the collective research capacity in the Maritimes region that is interested in the implications of tidal energy extraction. It thus complements three other initiatives: two, the Offshore Energy Environmental Research Association (OEER) and the Offshore Energy Technical Research Association (OETR), are government–university consortia that represent the public interest in tidal power; and the consortium of private companies that is presently involved in developing the Fundy Ocean Renewable Centre for Energy (FORCE). FERN's relationship to these three Nova Scotia energy initiatives is shown in Figure 2.

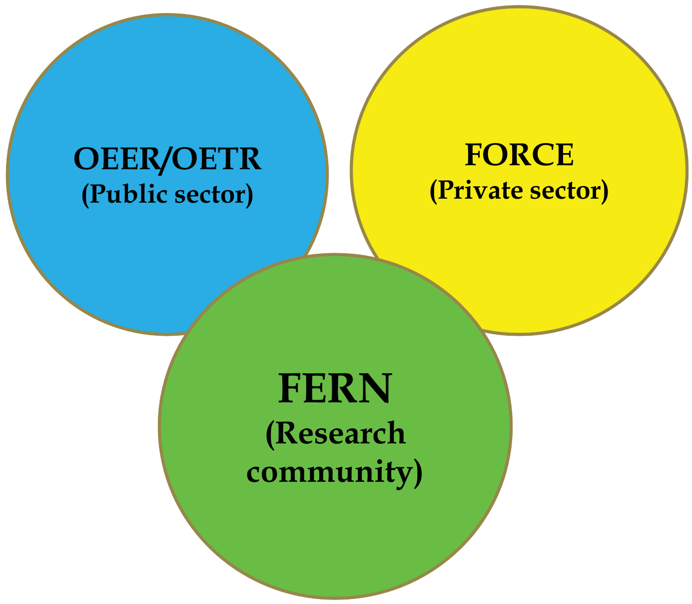

Figure 2. Putative relationship between FERN, FORCE and OEER/OETR (a description of OEER is to be found in the Introduction to Session A)

FERN Mission and Objectives

Mission: *To work towards the effective communication, coordination, and collaboration of marine energy-related research activities in the Bay of Fundy conducted by universities, colleges, government agencies, environmental non-government groups, and the private sector.*

Objectives:

- To provide a forum for communication and collaboration among those involved in marine energy research in Atlantic Canada;
- To review and identify environmental issues raised by the marine energy sector and regulators of the industry in Atlantic Canada;
- To facilitate collaborative research initiatives to address these issues (including assessment of potential environmental impacts, monitoring and mitigation practices), maximizing the use of financial, human and infrastructure resources;
- To identify and facilitate collaborative research in support of FORCE and other energy-related developments in the Bay of Fundy;

- To advise the joint OEER/OETR Area Sub-Committee on emerging and priority issues related to marine energy in the Bay of Fundy;
- To assist the OEER/OETR in the preparation of draft guidelines for Requests for Research Proposals, and, where needed, identify expertise to assist in evaluation of research proposals;
- To enable creation of research teams capable of obtaining funding from diverse sources;
- To develop and maintain connections with national and international groups involved in marine energy research; and
- To communicate research results through meetings, seminars, reports, or other forms of public presentation.

Research Priorities

FERN held its inaugural meeting on 16 October 2008. Its purpose was to identify priority research needs that require long-term and/or large-scale, collaborative approaches that would build the knowledge base required for assessing the potential for commercial-scale marine renewable energy from the Bay of Fundy. Primary interest at the present time is focussed upon tidal in-stream energy converter (TISEC) devices; however, there are other concepts for the creation of a lagoon or other impoundment that would capture some of the *potential energy* of the tides as with previous barrage proposals. To date, no formal application has been made for such a development in the Bay of Fundy. It is recognized that the planned tidal test facility in Minas Passage, which will accommodate only three TISEC turbines, will not be adequate to assess all of the environmental effects questions relevant for commercial scale operations, and that the latter will have to be addressed through the development and use of appropriate models.

Research challenges were seen to fall into three general areas: a) technology and grid integration; b) resource assessment and modeling; and c) ecosystem responses to energy extraction. It was recognized that very little background information existed for the sites of highest priority for TISEC devices, especially the Minas Passage. Some new research is under way as part of site characterization by the consortium involved in building the tidal power test centre (FORCE), but the footprint of the facility is very small, and there have been numerous ecological changes noted since the studies of the 1980s (Daborn 2007), that indicate our limited understanding of the Bay of Fundy ecosystem. This affirms the great need for further baseline studies in order to underpin the assessment of tidal power development potential (Jacques Whitford 2008; OEER 2008). Primary research questions include the following:

a) Technology and grid integration

i) How much of the available energy can be extracted?

ii) What design features or changes to the devices are necessary/beneficial for application in the Bay of Fundy?

iii) How can more marine renewable energy be integrated into the existing grid?

iv) Is local use more practical or appropriate than integration into the existing or future grid?

v) What risks to the technology are represented by environmental conditions in the Bay of Fundy (e.g., ice and debris)?

b) Resource assessment and modeling

i) How much energy is available?

ii) How will energy extraction affect hydrodynamics in the near-field and the far-field?

iii) What are the effects of energy extraction on stratification and turbulence?

iv) What are the effects of energy extraction on sediment dynamics?

v) What are the effects of energy extraction on ice formation and dispersion in the upper Bay of Fundy?

c) Ecosystem responses to energy extraction

i) How do fish and mammals respond to TISEC devices?

ii) What environmental signals (e.g., noise, vibrations) might affect fish and mammal behavior?

iii) Where, in relation to turbine sites, do fish migrate through Minas Passage?

iv) What are the effects of electromagnetic fields associated with subsea transmission cables on benthic fish or invertebrates?

v) What will be the effects of changed sediment distributions on marine benthos?

vi) What will be the effects of passage through turbines on larger plankton and ichthyoplankton?

vii) What ecosystem effects will be expected as a result of changes in turbulence and/or stratification resulting from energy extraction?

viii) What are the relative risks of energy extraction on local fisheries and other marine activities?

The complex and interactive nature of many of these research questions is illustrated in Figure 3.

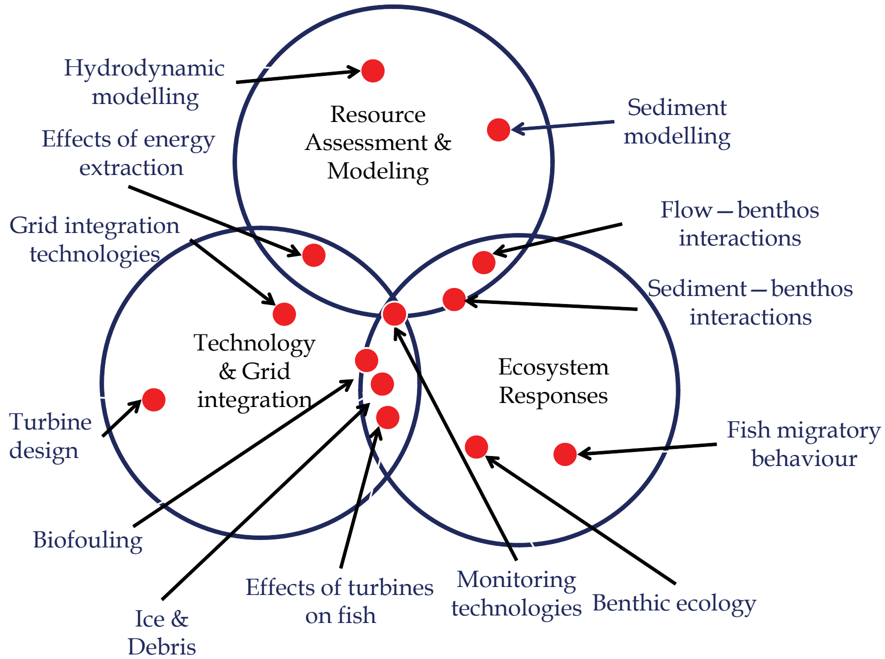

Figure 3. Priority research issues related to TISEC development in the Bay of Fundy

While the region possesses all the skills and experience needed in its institutions, it is currently lacking a coherent mechanism for providing that integration. That is the purpose of FERN. At the same time, marine energy developments are occurring elsewhere in Canada, other than the Bay of Fundy, where conditions are suitable for TISEC or wave energy devices. The same need for effective mobilization of research resources – human, financial and institutional – and integration of the research activities applies in other areas. For that reason, a proposal is in development for creation of a national research network, to be called the Canadian Marine Energy Research Network (C-MERN), which can build a larger national capacity for relevant research in the marine energy field. FERN may be seen as a regional precursor for such a national network. A proposed structure for FERN is shown in Figure 4. Membership on the Steering Committee is intended to include representatives from academia, government agencies, and the proponents (as currently represented by FORCE).

As shown in Figure 3, many of the questions are physical and/or technical and/or biological in nature, and therefore demand effective integration and cooperation between scientists from different disciplines, including engineers and social scientists. There are, however, tremendous challenges in monitoring and measuring important environmental parameters under the conditions such as those of the Minas Passage. Monitoring of turbine environmental effects has been extremely sparse at other test sites, such as the European Marine Energy Centre (EMEC) in Scotland, and Strangford Lough in Northern Ireland. In some cases, it appears that technologies that have proved serviceable in more benign test areas (such as the East River, New York) may not be effective in the Bay of Fundy; at the very least, the robust oceanographic conditions in Minas Passage represent a real challenge for deployment and retrieval of monitoring equipment. On the other hand, such challenges also represent opportunities for new technologies to be developed – opportunities the significance of which is not lost on the technology companies in Nova Scotia. It is to be hoped that success in the research, monitoring, analytical, and coordination approaches developed here will indeed set the “Fundy Standard” to which other marine energy interests around the world will aspire.

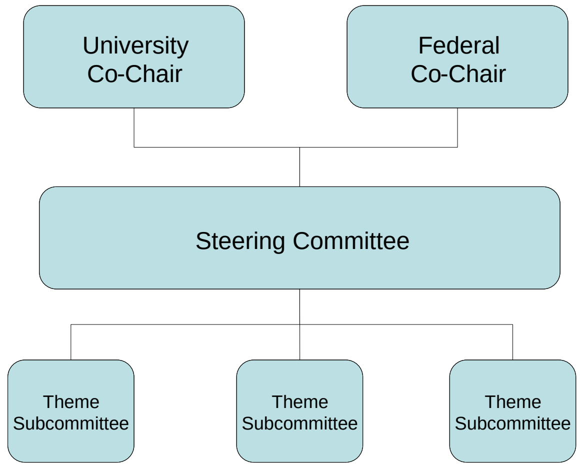

Figure 4. Organization of FERN

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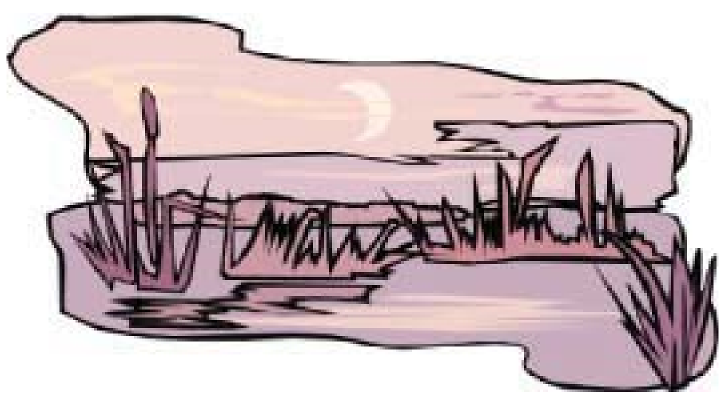
Session B

SALT MARSH RESEARCH AND RESTORATION

Chairs: Gail Chmura, Global Environmental and Climate Change Centre and McGill University, Montreal, Quebec



COMPARISON OF VERTICAL AND TEMPORAL VARIATIONS IN HYDRODYNAMICS ON MACRO-TIDAL SALT MARSH AND MUDFLAT SURFACES IN THE BAY OF FUNDY

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Abstract

Coastal salt marshes are ecologically significant environments found in temperate intertidal zones, providing crucial habitat for wildlife and halophytic vegetation as well as playing valuable roles as buffer zones available to absorb incoming energy brought by storms. A vertical profiling method was employed for investigation of vertical and temporal variations in macro-tidal salt marsh and mudflat hydrodynamics through comparison of vertical velocity and turbulent kinetic energy (TKE) profiles from vegetated and non-vegetated sites, as well as the associated turbulence intensities (i_u, i_v, i_w) and 2D and 3D Reynolds stresses. Acoustic velocity data were collected at adjacent vegetated and non-vegetated sites in the Minas Basin region of the Bay of Fundy for the duration of 4 complete tidal cycles. Results show consistently slower velocities within the vegetated canopy compared to the non-vegetated mudflat, and the occurrence of skimming flows and secondary velocity maxima above the densest portion of the canopy. A good correlation was also found regarding the location of accelerated flow zones, relative to the water surface, above vegetated and non-vegetated sites.

Introduction

A large portion of salt marsh and related studies have concentrated on micro- and meso-tidal marsh systems in Europe (e.g., Neumeier and Amos 2006; Möller 2006; Neumeier and Ciavola 2004; Möller and Spencer 2002; Allen 2000; Boorman 1999) and on the southern and eastern U.S. coasts (e.g., Leonard and Croft 2006; Voulgaris and Meyers 2004; Morris et al. 2002; Christiansen et al. 2000; Leonard and Luther 1995). High-latitude macro-tidal environments have not been studied to such an extent, although small-scale analyses have been completed for isolated marsh bodies in the Bay of Fundy area of eastern Canada (e.g., Davidson-Arnott et al. 2002, van Proosdij et al. 2000). Analysis of marsh-scale processes in the intertidal zone is important for the development of a better regional understanding of larger scale macro-tidal basin dynamics, and expertise in natural hydrodynamic and sedimentary processes in salt marshes can be applied to increase the overall success rate of restoration efforts, which, given rising sea levels, is critical for effective coastal management and defense strategies (Klötzli and Grootjans 2001).

Vegetation plays an influential role in intertidal hydrodynamics and the resulting sediment transport on salt marshes, and has been assessed by a number of researchers. There is a general consensus in the literature that the presence of vegetation within the water column reduces over-marsh flow velocity and turbulence through increased drag (Neumeier and Amos 2006; Leonard and Croft 2006). However, it is not as clear whether this influence acts to enhance sedimentation (Leonard and Reed 2002) or results in protection against subsequent erosion (Neumeier and Ciavola 2004). It has been shown that mean flow velocity and turbulent kinetic energy (TKE) are reduced by 50% within 5 meters of the canopy edge (Leonard and Croft 2006), and the most rapid reduction in wave height occurs within 10 meters of the canopy edge (Möller and Spencer 2002). Canopy influence can be modified by vegetation type, density, height, and distance to the canopy edge (Leonard and Croft 2006; Neumeier and Ciavola 2004).

Classic fluid dynamic theory describes flow above bare sediment as typically showing a logarithmic shaped velocity profile where flow is fully turbulent, occurring above a millimeter-scale layer laminar flow layer at the bed. However, it has been demonstrated that flow profiles in vegetated zones deviate from the logarithmic shaped profiles occurring above bare sediment (Leonard and Luther 1995; Christiansen et al. 2000). Under high water levels, the development of a logarithmic velocity profile has been identified above fully submerged vegetation, known as skimming flow (e.g., Neumeier and Ciavola 2004; Neumeier and Amos 2006; Leonard and Croft 2006), where flow is fully turbulent above the densest portion of the canopy.

The purpose of this research was investigation of vertical and temporal variations in hydrodynamics on a high macro-tidal salt marsh under vegetated and non-vegetated conditions. High-resolution (16 Hz, 2MHz) velocity data were collected for the duration of individual tidal cycles under a variety of tide conditions. Objectives for completion of this approach included comparison of profile shape, turbulent kinetic energies (TKE), turbulence intensities (i_u, i_v, i_w), and 2D and 3D Reynolds stresses from vegetated and non-vegetated sites, as well as investigation of skimming flows and the overall efficiency of vegetation in velocity reduction.

Study Area

Approximately 80 kilometers wide at the mouth, the funnel-shaped Bay of Fundy narrows toward the head, where it splits into two inner-bay systems: the Minas Basin and Chignecto Bay. Salt marshes in the area are routinely exposed to high suspended sediment concentration and a large tidal range, as well as ice and snow for up to three months of the year (Desplanque and Mossman 2004; van Proosdij et al. 2000). In the Avon River estuary, marshes are mature and fully developed, although pioneering growth is still underway in direct response to major changes in local ecomorphodynamics due to construction of the Windsor Causeway in 1969 (van Proosdij and Townsend 2006; van Proosdij et al. 2009).

Research presented here was conducted at Elderkin marsh, a fully developed salt marsh and mudflat complex high in the Avon River estuary (409195 E, 4984006 N). This site shows full inundation of the low marsh surface at high tide, and flow is not confined to channels on or adjacent to the marsh surface. Dominant low- and high-marsh vegetation types are *Spartina alterniflora* and *Spartina patens*, respectively. The low-marsh shows signs of a progressing marsh edge with new growth of *S. alterniflora* occurring seaward of the current vegetation limit. This area of the Avon River estuary was chosen on the basis of local setting, where conditions were provided that were comparable to those investigated by other researchers (e.g., Leonard and Croft 2006; Neumeier and Amos 2006; Leonard and Reed 2002). Accessibility also played a role in general site selection, as Elderkin marsh is near the 101 highway and a municipal access road. Specific site selection on the marsh surface and adjacent mudflat was completed using a high-resolution digital elevation model (DEM) and predicted tide levels (Canadian Hydrographic Station 4140), which were interpreted through GIS overlay analysis (ArcGIS 9.2).

Methodology

A total of 7 deployments were attempted during the summer and early fall of 2008 for completion of this study, with 4 being fully successful, which all happened to be spring tides. Acoustic measurements of in-canopy flow velocity were made with an acoustic Doppler velocimeter, or ADV (model Vector by Nortek), while flow velocity over the adjacent non-vegetated mudflat was measured using an acoustic Doppler current profiler (ADCP) (model Aquadopp HR by Nortek). Both of these instruments' operation is based on the Doppler shift, where instrument-borne acoustic 'pings' are reflected by particulate matter traveling in the water column (typically zooplankton, suspended sediment or small bubbles), returning to detectors on the instrument and producing a measure of velocity (Nortek 2005). This method is validated by a basic assumption that the velocity of suspended particulate matter is relatively equal to flow velocity (Lane et al. 1998). However, acoustic signals used for measurement are easily disrupted by the presence of larger objects (e.g., vegetation, fish) near the sensor during sampling, and as a result, measurement within the canopy necessitated the removal of a small area of vegetation (~0.5 m^2) immediately below and around the ADV probe. The ADV was attached to a manually operated vertical sliding mechanism (Figure 1) to move the instrument throughout the water column for independent point measurements at 5 cm increments, for the development of vertical velocity profiles beginning at 9 cm above the bed. This mechanism was modified from a design by Neumeier and Ciavola (2004), and was fabricated in conjunction with the In_CoaST Research Unit at Saint Mary's University. Point measurement duration with the ADV was limited to 30 seconds to allow for collection of a complete profile over the course of a 10–20 minute portion of the tidal cycle, while tidal flow could be assumed to remain relatively constant and maintaining collection of sufficient data for turbulence calculations. A maximum of 25 points were collected per profile during higher tides, for a profiling height of 145 cm at the vegetated site, starting from 9 cm above the bed. Profiling ran continuously with sufficient water level at 16 Hz during individual tidal cycles to characterize the flood, slack, and ebb stages of the tide.

Figure 1. Photographs of the vertical sliding mechanism (left) and the personnel stand on the marsh surface

The ADCP was deployed on the mudflat looking up, with an anticipated water level of 2 meters expected above the instrument at high tide, and sampled continuously at a rate of 1 Hz and a frequency of 2 MHz. Cell size was set at 3 cm, and the ping distance was matched to the expected water level (2 m) to avoid measurement contamination by unwanted instrument noise. This resulted in a maximum profiling height of 1.92 m above the bed at the mudflat site.

Data were downloaded using supplied instrument-specific software (Nortek Vector 1.28; AquaPro HR 1.03), cables and USB-to-serial converter. The software converts raw binary data sets into ASCII formatted files for use in data processing or numeric data spreadsheet programs (e.g., MATLAB, Microsoft Office Excel). Excel 2007 was used for all data analysis, and was found to work quite well for the smaller in-canopy data sets that were the focus of this study. Data was filtered using correlation (%) and signal-to-noise ratio (SNR) (dB) scores that accompany downloaded velocity data (ADV and ADCP). The correlation score describes how well the measured sample agrees with adjacent samples, while SNR relates the ratio of the emitted acoustic signal to ambient background noise; a high correlation coupled with a low SNR defines quality data. ADCP data was filtered using the Storm (1.06) software package (Nortek AS), while ADV data was manually filtered in Excel. Threshold (3 dB) and spike rejection (70 dB) values based on SNR scores were enforced in both cases.

Parameters such as turbulence intensity, turbulent kinetic energy (TKE), relative roughness and Reynolds stresses require calculations to be performed on raw velocity data. Turbulence is derived from decomposed time-averaged velocities (*U, V, W*), and turbulent components (i_u, i_v, i_w) were calculated as the root mean square of u_t, v_t *and* w_t, respectively. TKE was computed using

$$TKE = \frac{1}{2}\,\rho\,(ut^2 + vt^2 + wt^2)TKE = \frac{1}{2}\,\rho\,(ut^2 + vt^2 + wt^2)$$

where ρ is water density at 20°C. Two and three dimensional Reynolds stresses (τ_{xz} and τ_{xyz}) were calculated with $\tau_{xz} = \rho\, u_t w_t \tau_{xz} = \rho\, u_t w_t$ and $\tau_{xyz} = \rho\,(u_t w_t{}^2 + v_t w_t{}^2)^{0.5}$

where w_t is positive in an upwards direction (Neumeier 2007; Neumeier and Amos 2006). Finally, a value of relative roughness was developed through division of vegetation height by water depth.

Vertical velocity and turbulence profiles from vegetated (ADV) and non-vegetated (ADCP) areas were assembled and compared using a per-profile spreadsheet created for Excel 2007, where raw data was inserted into a formula-laden spreadsheet for automatic processing, including plotting of velocity and TKE profiles. Variation between ADV and ADCP profiles and the associated calculated values gives a tide-specific indication of the influence of vegetation on tidal flow velocity. It should be noted here that investigation of near-bed processes was not a goal of this study, as the deployment techniques employed for vertical profiling were not effective for near-bed measurement. Near-surface profiling with the ADV was limited to a height where the instrument probe remained full submerged, to reduce the effects of surface waves on profile measurements. Profile limit on September 27th was highly varied due to active weather and wave conditions.

Results

Vertical velocity profiles collected within both vegetated and non-vegetated areas show variation in flow velocity and TKE throughout the water column, independent of water level, prevailing weather conditions, and variations in canopy height. In general, velocities measured within the vegetated canopy were low (under 5 $cm \cdot s^{-1}$), and were consistently well below those measured at the non-vegetated mudflat site (Table 1), where velocity peaked around 50 $cm \cdot s^{-1}$. Turbulence intensities (i_u, i_v, i_w), TKE, and two and three dimensional Reynolds stresses (τ_{xz} and τ_{xyz}) were all seen to reduce for flow within the vegetated canopy relative to the mudflat. Of the 7 deployments attempted for this study, a total of 4 deployments were fully viable, producing quality data at both sites. A total of 31 in-canopy profiles were plotted, analyzed and compared with 4 rich data sets from the mudflat, which yielded hundreds of profiles.

Date	Tide Level (m)			Velocity ($cm \cdot s^{-1}$)		Max. Vegetation Height (m)		
	CHS	Canopy	Mudflat	Canopy	Mudflat	Marsh	Near ADV	Mudflat
Jul-18	5.86	1.01	1.51	2.14	12.31	1.25	1.00	0
Jul-30	6.34	1.36	1.86	1.29	6.06	1.50	0.75	0
Aug-28	6.25	1.43	1.93	1.52	6.88	1.00	0.50	0
Sep-27	6.61	1.93	2.43	1.51	6.13	1.00	0.25	0

Table 1. Tide levels, mean velocities and estimated vegetation heights for the duration of the study period. CHS values are predicted for nearby Hantsport (CHS station 4140), and velocity values are averaged over complete tidal cycles. Maximum vegetation height shows estimated values for the general marsh surface and the immediate vicinity of the ADV.

Low marsh vegetation conditions during the study period ranged from fully mature, dense *S. alterniflora*, to a slumped and mud-compacted bed of plant material (Table 1). Straight standing plants showed natural variation in canopy height across the marsh surface, and as the growing season progressed and plants increased in height, this variability in overall canopy height was dramatically increased as slumping occurred over large patches of marsh. The high-density growth resulted in large areas of slumped vegetation, as tall stems encouraged their neighbours to slump as well. Some of the resulting patches form what appear to be channels for tidal flow to pass through the dense vegetation. The end of the growing season showed near-compete flattening of the low marsh and a large amount of mud caked onto vegetation leaves and stems, with only isolated standing patches remaining upright.

Vertical velocity profiles indicate discernable variation in velocity with changing height above the bed, both within and above the vegetated canopy, as well as above the non-vegetated mudflat. Mudflat profiles generally do not display the anticipated logarithmic shape, and instead showed variable increases and decreases in velocity with increasing height above the bed. Profiles from the vegetated site show two independent zones of accelerated flow where vegetation is fully submerged: one generally below 40 cm above the bed, and another in close proximity to the surface, above 60–80 cm above the bed. Both of these zones show fluctuation in velocity across individual tidal cycles, with changing tide, vegetation and weather conditions. Between these two accelerated flow layers, a generally slower flowing zone was frequently identified, developing at approximately 25 cm above the bed. This slower zone is repeatedly seen to develop mid-profile during submerged conditions, at or around high tide, and shows velocities as low as 0.4 $cm{\cdot}s^{-1}$, where near-bed and near-surface velocities are as much as 1-2 $cm{\cdot}s^{-1}$ greater (Figure 2). A number of velocity profiles indicate an abrupt increase in velocity between neighbouring data points within the region located 15–30 cm above the bed. The ‘spikes’ commonly occur on profiles collected within the vegetated canopy, and are typically generated by a single data point, representing velocities 1-2 $cm{\cdot}s^{-1}$ faster than neighbouring data points.

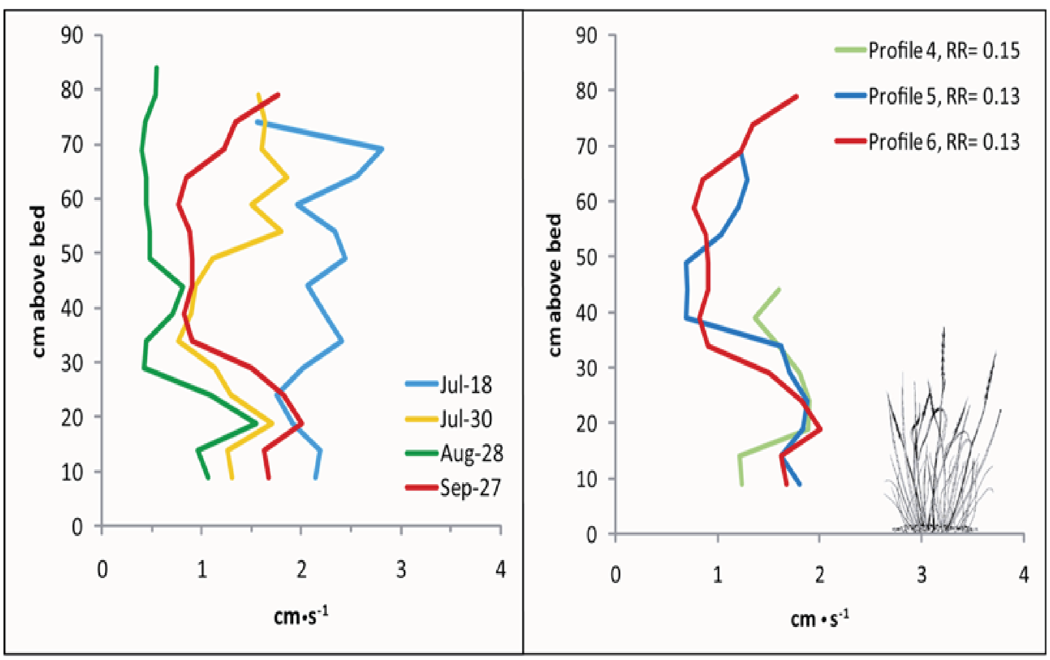

Figure 2. Vertical velocity profiles from the vegetated site. At left, high tide profiles show a good agreement in near-bed velocity and increase variability higher in the water column. At right, profiles leading up to high

tide on September 27 (high tide @ profile 6) show a similar agreement

High tide profiles from the vegetated site consistently showed a higher degree of variability in near-surface flow velocity compared with near-bed velocity (Figure 2b). A relative stability was noted to occur at several points in the water column from one profile to the next on those collected immediately before, during, and immediately after high tide, and the overall shape of these profiles shows preservation of independent flow layers across this portion of the tidal cycle. Some indication of skimming flow was noted on all high tide profiles, but no evidence of a decrease in water velocity related to slack tide was identified on in-canopy profiles.

TKE values derived from velocity data were generally less than 1.0 $j \cdot m^3$ within the vegetated canopy, while values were up to magnitudes greater on the mudflat. TKE profiles from both sites reflected the general shape of corresponding velocity plots, although several in-canopy profiles showed little or no change in TKE with increasing height above the bed, where values are near zero. Mudflat TKE profiles were highly variable with a large amount of fluctuation throughout the water column. TKE calculations for derivation of mudflat flow that occurred near or at high tide revealed values that were higher than the associated velocity values; a TKE value of approximately 140 $j \cdot m^3$ was derived from velocity data describing flow of 52 $cm \cdot s^{-1}$. General TKE values were also decomposed into horizontal (TKE_{horiz}) and vertical components (TKE_{vert}), showing that TKE_{horiz} was consistently the dominant contributor to turbulence within and above the vegetated canopy, where the occurrence of TKE_{vert} was very low (0.01 $j \cdot m^3$). Mudflat TKE profiles saw a greater contribution from the vertical component, where TKE_{vert} was seen to peak at approximately 1.15 $j \cdot m^3$; however, the horizontal component was still seen to dominate overall.

Discussion

Velocity profiles of over-marsh flows yielded results generally similar to those presented by studies of other salt marsh systems (e.g., Leonard and Croft 2006; Neumeier and Amos 2006; Christiansen et al. 2000), showing a mean flow velocity of approximately 2 $cm \cdot s^{-1}$; however, similar salt marsh studies focused in the Cumberland Basin portion of the Bay of Fundy region (e.g., van Proosdij et al. 2000) show notably higher mean velocities (up to 20 $cm \cdot s^{-1}$). Still other studies within *S. alterniflora* canopies report velocities below 1 $cm \cdot s^{-1}$ (Christiansen et al. 2000). This range of 'normal' velocities shows variability that is linked to canopy characteristics (e.g., height, density, vegetation type) as well as the nature of the tidal zone (e.g., macro-tidal) and the associated energy. This study showed that flow velocity within the vegetated canopy was consistently lower than mudflat velocity, and vertical profiles from both sites demonstrate that velocity and TKE are not uniform throughout the water column.

In general, vertical velocity profiles presented in other studies (e.g., Neumeier and Amos 2006; Neumeier and Ciavola 2004) show minor variations in velocity throughout the water column with submerged vegetation, and a definitive trend toward increasing velocity with increasing distance above the bed. Velocity profiles from the vegetated site considered here show comparatively greater variations throughout the water column, under fully submerged conditions, with no repeated near-bed trend visible toward higher or lower velocities. Resulting profiles show several abrupt changes in velocity with increasing height above the bed, which is noted to occur most frequently on profiles collected under submerged conditions with straight-standing vegetation (e.g., July 18th), which occupied a large portion of the water column. Compared with July 18 profiles, others collected under slumped or degraded vegetation conditions show a lesser degree of velocity variation across the majority of the water column.

Overall, profiles from the vegetated site tend to show less variability with decreasing influence from vegetation, as was reported by Leonard and Croft (2006), as high tide profiles showed greater variability in flow velocity and TKE above the maximum influence of vegetation compared with flow passing through the canopy. This division of water column activity was seen to correlate well with the seasonal decline in canopy height, where the lower limit of highly variable flow velocity and TKE was seen to decrease over the three month study period. This is a good indicator of the role of vegetation, even under degraded canopy conditions, of influencing near-bed flow velocity and turbulence.

The location of accelerated flow zones (relative to the water surface) was found to generally correlate well between the vegetated and mudflat sites. Profiles collected within the canopy show relative flow variations throughout the water column that reflect variation in velocity above the mudflat, a relationship best made visible by removing the lower 50 cm of the mudflat profile to correct for the elevation difference between the two sites (Figure 3). Although flow velocity is slower within the canopy, the location of faster flowing layers remains relatively constant across profiles from both sites. In-canopy flows show less drastic peaks and subtler variation, suggesting an overall removal of energy from the water column.

The occurrence of skimming flow was detected on many velocity and TKE profiles collected under fully submerged conditions, and skimming flow profiles were seen to adopt a logarithmic shape and demonstrate increased turbulence above the densest portion of the canopy, in accordance with other studies (e.g., Leonard and Croft 2006; Neumeier and Ciavola 2004). However, the lower limit of skimming flow was seen to vary within one individual tidal cycle on August 28th, ranging from 20–80 cm above the bed at various stages during the tidal cycle, seemingly independent of vegetation conditions (~50 cm). This relationship suggests that the lower limit of vegetation influence on flow dynamics can be variable with consistent vegetation height, potentially related to maximum water depth on the marsh surface or overall tidal characteristics.

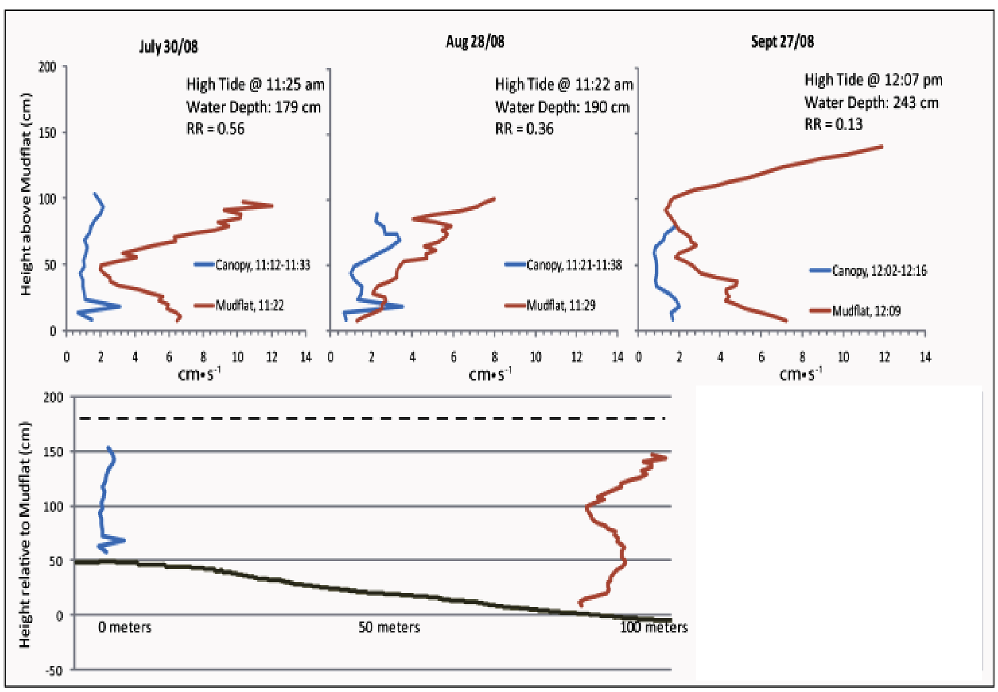

Figure 3. Elevation-adjusted high tide velocity profiles for canopy and mudflat sites, July 30, August 28, and September 27, 2008. Mudflat profiles (lower 50 cm removed) show some general similarity with in-canopy profiles with respect to accelerated flow layers, relative to the water surface. Bottom: A generalized schematic showing the elevation difference between the two sites and the position and extent of profiles in the water column. Data for July 30 are shown; black dashed line indicates water depth (179 cm) at time of profiling.

Profiles collected in the vicinity of high tide on September 27th (Figure 2) show three distinct flow layers, with faster flows near the bed (10-30 cm) and the profile top (50-60 cm). Flow patterns of this nature have been reported with well submerged canopies (e.g., Neumeier and Ciavola 2004), and are generally associated with skimming flows. However, the vertical distribution of independent flow layers for September 27 profiles does not reflect field observation of vegetation conditions (approximately 25 cm canopy height). Alternatively, this type of flow regime may develop where relative roughness (RR) values are sufficiently low (0.1-0.2). Leonard and Croft (2006) suggested that significant variations in vertical biomass distribution may encourage the development of secondary velocity maxima and zones of elevated TKE.

Low mean velocities (less than 5 $cm \cdot s^{-1}$) on in-canopy profiles were seen to remain relatively constant during individual tidal cycles, with the exception of minor increases during initial flood and latter ebb stages noted in other studies (e.g., van Proosdij et al. 2000). Velocity values from the vegetated site did not show reduction or change in velocity that would be indicative of slack tide (Neumeier and Ciavola 2004; Christiansen et al. 2000); in-canopy profiles show velocities in the vicinity of high tide that are typically in line with the rest of the tide. Mudflat velocities did show a velocity reduction in association with high tide, corresponding with a potential period of slack water; there were numerous exceptions to this, however, and a definitive point of 'zero' velocity could not be pinpointed, possibly due to local topography and basin-scale influences. Mudflat directional data was found to show a definitive shift in overall flow direction corresponding with high tide, but it cannot be said with certainty whether this resulted from a large, basin-scale gyre created by tidal flow moving up and back down the estuary, or a more local, small-scale influence of topography and tidal creeks.

Conclusion

Salt marsh canopies demonstrate substantial influence on tidal flow patterns across a marsh surface by decelerating flow and reducing vertical turbulence. Flow velocity, TKE and Reynolds and shear stresses were found to be lower at the vegetated site compared with the incoming tidal flow measured above the bare mudflat, showing the effectiveness of vegetation in attenuation of turbulence and reduction of overall flow velocity. With submerged conditions, skimming flows were identified above the densest portion of the canopy, where increased flow velocity and TKE occurred above slower and less turbulent flow within the canopy. The lower limit of skimming flows were found to correlate well with the seasonal decline of *S. alterniflora*, although variation in this limit was seen during individual tidal cycles under slumped and degraded vegetation conditions. With sufficient submergence of a low canopy (RR= 0.12-0.15), secondary velocity maxima were seen to develop high in the water column (50–80 cm).

Characteristics of incoming tidal and wave energy were evident in flow within the canopy, where profiles from mudflat and canopy sites showed general similarities in shape and form after adjusting for elevation. This relationship is suggestive of incoming tidal energy and large-scale basin influences on over-marsh flows.

The ability of vegetation to influence flow velocity and turbulence is significant for a better understanding of sedimentological marsh processes related to restoration efforts in general coastal remediation or defence strategies. Comprehension of small-scale marsh processes is important for the maintenance and continuance of valued protective coastal buffers in an era of rising seas and increased storminess.

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THE INFLUENCE OF VEGETATION ON SEDIMENTARY PROCESSES IN A MACRO-TIDAL SALT MARSH

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Abstract

Salt marsh systems are ultimately dependant on the accumulation of sediment for survival. Within a macro-tidal environment such as the Bay of Fundy where vegetation may only occupy a small portion of the water column, knowledge of salt marsh sediment dynamics is still evolving. The purpose of this research was to investigate the degree of influence that vegetation has in increasing rates of sedimentation within the vegetative canopy.

This research took place on a natural macro-tidal salt marsh in the upper Bay of Fundy. Three 1 m^2 plots were established on the study site, one on the mudflat and two in the low marsh vegetation. One vegetated plot was trimmed and maintained throughout the entire study period to represent an area of lower roughness within the vegetative canopy. Rising stage bottles were used to measure suspended sediment concentrations, and sediment traps were used to measure sediment deposition. Due to an expected decrease in velocity within the vegetated canopy, it was hypothesized that the highest degree of sedimentation would be observed at the sediment traps within the vegetated plot. Results of this research indicate that while deposited sediment was higher in the vegetated canopy than on the adjacent mudflat as hypothesized, areas of lower roughness within the vegetated canopy had the highest recorded values of deposited sediment and the lowest values of suspended sediment throughout the entire study period. This suggests that the spatial distribution of vegetation may exert a greater role in sedimentation than previously studied areas.

Introduction

Salt marshes are coastal wetland ecosystems which are renowned for their biodiversity and high primary productivity. They are located along coastal areas which are sufficiently sheltered from physical wave energy to permit the deposition of sediment and the establishment of halophytic vegetation within the intertidal zone (Allen 2000; Friedrichs and Perry 2001). The elevation of a salt marsh surface within the tidal frame is the result of the delicate balance between changes in relative sea level, sediment deposition, below ground organic matter production, and surface subsidence (Allen 2000; Christiansen et al. 2000). Accordingly, salt marshes are highly sensitive to fluctuations in any of these parameters.

Salt marsh sedimentation is the result of the complex relationship between physical and biological factors (Leonard and Reed 2002; van Proosdij et al. 2006a). Most importantly, sedimentation is controlled by the availability of sediment and its opportunity for deposition (van Proosdij 2001). The availability of sediment is influenced by many factors, including suspended sediment concentration (van Proosdij et al. 2006a), meteorological conditions (Allen 2000; Friedrichs and Perry 2001), wave activity (Boorman 1999), and ice rafting (Chmura et al. 2001; van Proosdij et al. 2006b). Suspended sediment concentration refers to the amount of sediment in the water column available to be deposited on a salt marsh surface, and it is affected by proximity to the sediment source (e.g., tidal creek or open mudflat) (Christiansen et al. 2000). In ideal conditions, sediment settles out of the water column according to mass as predicted by Stokes Law. However, in marine environments with significant levels of salinity and organic matter, sedimentation is often complicated by flocculation, which removes a significant amount of sediment from the water column which would otherwise remain in suspension due to its small grain size (Kranck 1993). An accurate understanding of the process of flocculation is critical in determining the short-term behaviour of sediment, and the long-term evolution of fine grained environments (Milligan et al. 2007).

Marsh vegetation almost always decreases water velocity sufficiently to allow sedimentation to occur (Petticrew and Kalff 1992; Boorman 1999; Allen 2000; van Proosdij et al. 2006a). Sediment begins to settle from suspension within close proximity to the sediment source (e.g., the tidal creek) in response to the decrease in velocity experienced immediately upon entering the marsh canopy (Friedrichs and Perry 2001). By the time the water has propagated to the interior of the marsh, a significant amount of its sediment load has already settled out of the water column (Christiansen et al. 2000). Vegetation reduces the flow velocity of water in proportion to the increase in surface roughness that it creates (Boorman et al. 1998). The extent of the decrease in velocity, and thus the extent of sedimentation, is influenced by the density of vegetation and the vegetation height relative to the water column; velocity and turbulence within the vegetative canopy decrease with an increase in stem density and vegetation height (Friedrichs and Perry 2001).

The purpose of this research is to investigate the influence of vegetation on suspended sediment concentration and sedimentation in a macro-tidal salt marsh. The objectives developed to achieve this purpose were:

- Examine the amount of sediment deposited on each sediment trap, and compare the amount of sediment deposited between vegetated, clipped, and mudflat surfaces.
- Compare the suspended sediment concentration (0.20 m and 0.80 m above the bed) between all three plots.
- Compare vertical variations in vegetation density throughout the field season.
- Examine sediment characteristics (e.g., organic and inorganic content) of trapped and suspended sediment.
- Determine the correlation between the suspended sediment concentration and the amount of deposited sediment, in relation to changes in vegetation density and variations in hydrometeorological conditions.

Methodology

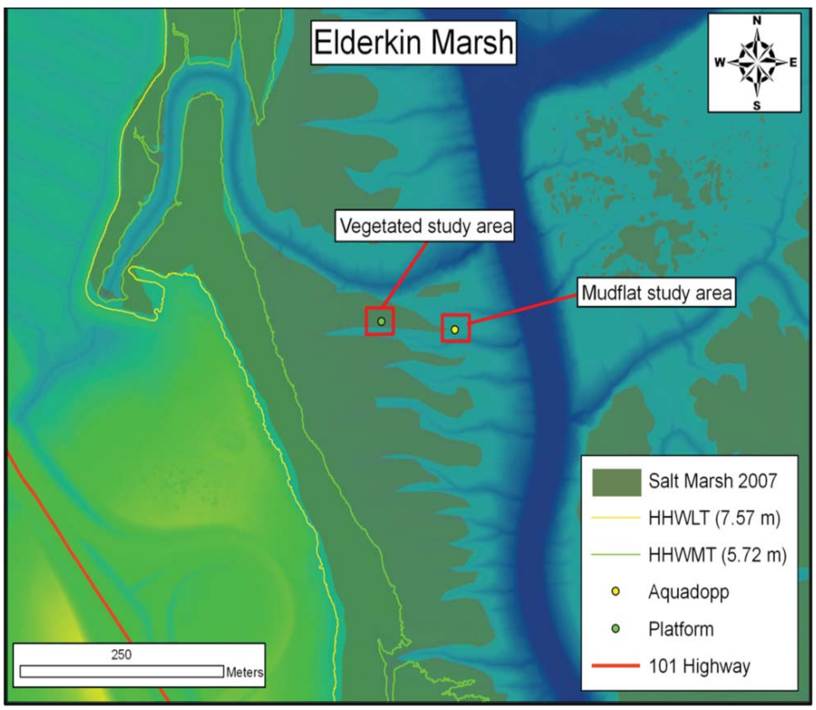
This research took place on the Elderkin salt marsh within the Avon River estuary. The Avon River estuary is a diurnally flooded system within the inner Bay of Fundy that experiences tidal ranges up to 14 m. The Elderkin Marsh is located at approximately 45° 00' 21.11 N and 64° 08' 08.01 W, where the Avon and the St. Croix rivers converge (Townsend 2002). This salt marsh is a macro-tidal system which is dissected by a number of tidal creeks, and contains three distinct zones: mudflat, low marsh, and high marsh. The low marsh is dominated by the cordgrass *Spartina alterniflora*, whereas the high marsh is dominated by the salt meadow hay *Spartina patens*.

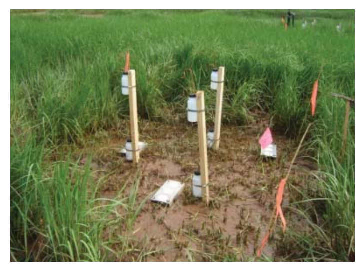
Three 1 m^2 plots were established on the study site, one on the mudflat and two in the low marsh vegetation (Figure 1). Each plot was located at a similar elevation, and was positioned at a comparative distance to a tidal creek. One vegetated plot was trimmed and maintained throughout the entire study period to represent an area of lower roughness within the vegetative canopy. Each plot contained three rising stage bottles at two different elevations above the bed (0.20 m and 0.80 m) to measure the suspended sediment concentration, and three co-located sediment traps to measure the amount of deposited sediment. In order to preserve the integrity of the marsh surface in the immediate vicinity of the vegetation plots, a 0.5 m high plank boardwalk was built running from the edge of the study area to the edge of the vegetated plot. Data collection took place throughout the month of July, 2008, and in total there were ten successful deployments of the rising stage bottles and eight successful deployments of the sediment traps.

Results

Sediment Deposition

Within trap and within plot variability for sediment deposition was not statistically significant with the exception of the trimmed plot in which one trap had significantly more sediment deposited than the other traps on six out of the eight tides. This trap was found to be at a slightly higher elevation than the other two traps in the trimmed plot. Between plots, the least amount of sediment was deposited on the mudflat plot, while the most sediment was deposited in the trimmed plot on six out of the eight tides. The vegetated plot had the median value of deposited sediment for all eight tides, and had consistently less deposited sediment than the trimmed plot for the entire study period (Table 1).





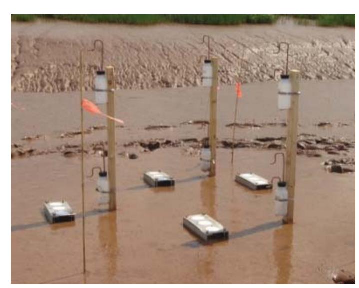


Figure 1. A schematic of the study site with the trimmed, vegetated and mudflat plots

Tide	Deposited Sediment ($g \cdot m^{-2}$)			Suspended Sediment ($mg \cdot l^{-1}$)					
				20 cm above the bed			80 cm above the bed		
	M	T	V	M	T	V	M	T	V
Tide 1	119.4	108.3	98.5	79.4	64.2	67.3	59.4	35.2	29.7
Tide 2	15.1	94.1	68.3	77.6	42.8	64.9	62.4	41.2	41.9
Tide 3				129.7	83.1	110.3	88.5	77.0	88.5
Tide 4	25.6	177.9	121.5	112.7	59.0	87.9	99.4	46.7	55.2
Tide 5				119.4	57.2	105.5	95.2	68.5	78.2
Tide 6	56.9	100.5	85.3	66.1	32.3	63.6	45.5	17.0	23.6
Tide 7	48.9	26.7	22.6	35.2	26.1	29.1	23.7	0.00	0.00
Tide 8	16.5	34.7	29.9	87.3	192.1	67.9	60.9	43.0	47.3
Tide 9	14.9	45.9	30.8	138.2	45.5	78.2	55.2	49.1	48.5
Tide10	13.0	87.0	53.7	114.6	64.0	96.4	84.2	38.8	59.4

Table 1. A comparison of the deposited sediment and suspended sediment for each tide. Values for deposited sediment are trap averages (g·m-2) for the (m)udflat, (t)rimmed, and (v)egetated surfaces. Suspended sediment values are listed in mg·l-1 at two elevations, 20 cm above the bed and 80 cm above the bed.

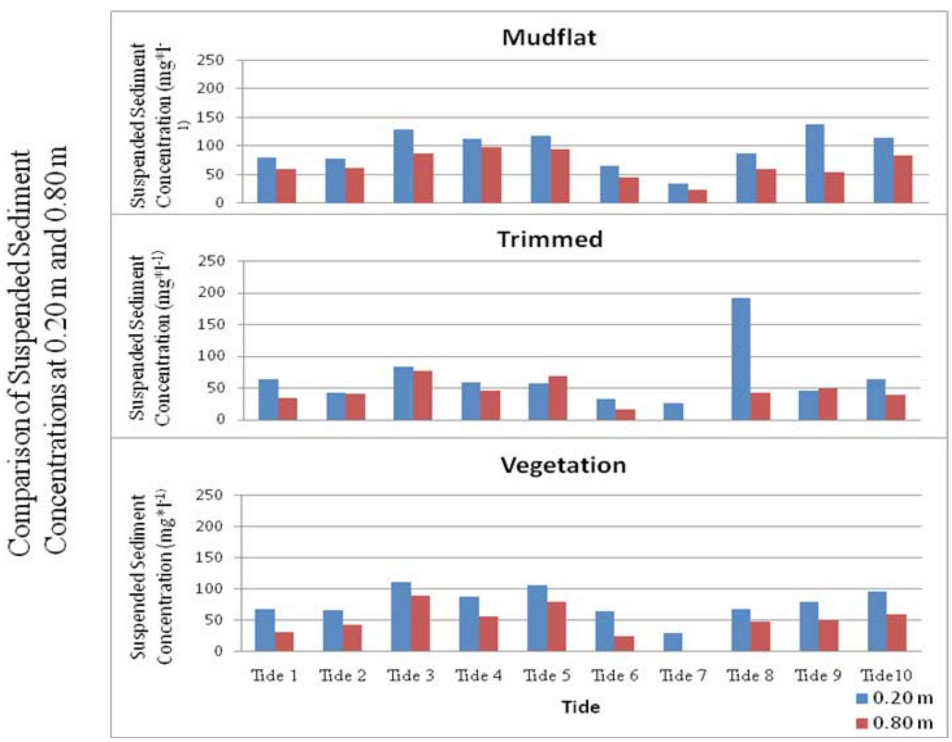


Figure 2. Comparison of suspended sediment concentrations at 0.20 m and 0.80 m between all three plots

Suspended Sediment Concentration

The highest suspended sediment concentrations were consistently recorded at 20 cm above the bed within the mudflat plot (112.7 – 138.2 $mg \cdot l^{-1}$), with the exception of a single tide on July 18th (192.1 $mg \cdot l^{-1}$). On this tide, the highest suspended sediment concentration occurred within the trimmed plot; this value is also the highest recorded suspended sediment concentration for the study period, and is 48% higher than the next greatest value, 129.7 mg·l^{-1}, recorded on July 3rd. The lowest suspended sediment concentrations consistently occurred 80 cm above the bed within the trimmed plot, with the exception of the tide on July 18th. The vegetated plot had the median suspended sediment concentration value for every collection date. In addition, suspended sediment concentrations were consistently lower at 20 cm above the bed than at 80 cm above the bed for all three plots during all ten tides (Figure 2).

Comparison of Suspended and Deposited Sediment

The mudflat plot had the lowest values for deposited sediment on six out of the eight tides (13.0–25.7 g·m^{-2}), and the highest values for suspended sediment at both 0.20 m and 0.80 m on nine out of ten tides. In comparison, the trimmed plot had the highest values for deposited sediment on six out of the eight tides, and the lowest suspended sediment concentration on nine out of ten tides (Table 1). It is likely that the higher deposited sediment values within the trimmed plot is a reflection of the lower suspended sediment concentrations within the trimmed plot. The vegetated plot had neither the highest nor the lowest values for either the suspended sediment or the deposited sediment. This directly contradicts the study's hypothesis which predicted that the highest amount of deposited sediment would occur within the vegetated plot.

Inorganic and Organic Content

Inorganic content constitued the majority of the sample masses for both the trapped and suspended sediment samples. However, organic matter content of the sediment fell within the high upper range presented by other studies from the same area (van Proosdij et al. 2006; Davidson-Arnott et al. 2002). High amounts of organic matter in saline environments can result in high degrees of flocculation, which can remove a significant amount of sediment from the water column. Thus, the higher than anticipated organic matter content may be a contributing factor to the high amount of sedimentation observed within the Elderkin marsh. It is important to note, however, that despite high amounts of organic matter on the mudflat, sediment deposition was lower than was observed within the marsh canopy.

Vegetation

Vegetation collected on July 4th had an average height of 73 cm, an average stalk density of 17 stalks, and an average density of 400 g per layer^{-1} m^{-2}. Vegetation collected on September 1st had an average height of 137.5 cm, an average stalk density of 31 stalks, and an average density of 2140 g layer^{-1} m^{-2}. Interestingly, the four highest values of deposited sediment were observed on the first four days of data collection (94.1 g·m^{-2} – 177.9 g·m^{-2}), while the four lowest values were observed on the last four days of data collection (34.7 g·m^{-2} – 87.0 g·m^{-2}). The first four days of data collection coincided with a canopy height of approximately 67.5 cm ($H_{99\%}$), while the last four days of data collection coincided with a canopy height of approximately 100 cm ($H_{99\%}$). Vegetation for the last four days of data collection also experienced a marked amount of slumping and matting due to its height and density.

Discussion and Conclusion

Understanding the behavior of sediment in fine-grained environments, such as the Bay of Fundy, is challenging. The complex interaction between sediment, vegetation, hydrodynamics, morphology, and climate creates a dynamic environment that is difficult for scientists to accurately model. It is critical to understand how sediment behaves over short time scales (e.g., single tidal cycles) if a broader understanding of sediment dynamics is to be achieved. The suspended sediment concentrations recorded during this study were within the lower range of measurements conducted by other studies in the same area, excluding Amos and Mosher (1985) (Table 2). In contrast, the amount of sediment deposited during the study was comparable to other studies conducted within the same region (e.g., Davidson-Arnott et al. 2002; van Proosdij et al. 2006a). This indicates that the sedimentation may becoming more efficient in this area. Suspended sediment concentrations are affected by many factors, including distance to the tidal creek, inundation time, vegetation, and wind/wave activity. It has been noted that sediment concentrations within proximity to a tidal creek are greater than those in the marsh interior (Christiansen et al. 2000). The data from this study confirm this finding, as the mudflat plot had the highest suspended sediment concentrations on nine out of the ten tides. However, previous research also indicates that the highest amount of deposited sediment within the vegetated canopy will occur within close proximity to the tidal creek and with longer inundation periods (Christiansen et al. 2000; van Proosdij et al. 2006a). This was not the case with this research on the scale of single tidal cycles. Instead, the mudflat plot, which was inundated longer due to its lower position in the tidal frame and (marginally) closer proximity to a main creek, consistently had the least amount of deposited sediment throughout the study period. As sediment deposition is a function of variables controlling the availability of sediment as well as the variables controlling the opportunity for sediment to be deposited (van Proosdij et al. 2006a), it is hypothesized that the lower values may be due to the lack of vegetation in the proximity of the mudflat plot. The lack of vegetation may have resulted in flow velocities which exceeded those required for optimal settling conditions.

It was also found that suspended sediment concentrations for all three plots were higher at 0.20 m than 0.80 m, which suggests that suspended sediment decreases over the rising tide. This finding is confirmed by previous research (e.g., Temmerman et al. 2003), and indicates that suspended sediment is continuously settling throughout the rising tide. Previous research also indicates that suspended sediment concentration should be lowest in the vegetative canopy (Christiansen et al. 2000; Allen 2000; Temmerman et al. 2003). If the trimmed plot is disregarded, then this is the case; the mudflat plot had the highest suspended sediment concentration, and the vegetation plot had the lowest. However, when the trimmed plot is considered, then the vegetation plot had neither the highest nor the lowest suspended sediment concentration. That the lowest suspended sediment – and the highest deposited sediment, for that matter - was found in the trimmed plot is interesting, and further study is required to determine what factors cause an area of lower roughness within the canopy to display such sediment characteristics. Although this study lacks the quantitative data to prove it, it is hypothesized that vegetation, which slows water velocity and creates turbulent eddies above the canopy, keeps some sediment in suspension. This suspended sediment is then able to settle out of the water column in areas lacking vegetation within the vegetation canopy (“quiet zones”). This resulted in the high values of deposited sediment and the low values of suspended sediment recorded within the trimmed plot. Further research is required to fully understand the influence of vegetation on sediment dynamics outside of the vegetation boundaries.

Study	**Comments**	**SSC** ($mg \cdot l^{-1}$)
Amos and Mosher (1985)	Range	26 - 94
van Proosdij et al. (1999)	Mean	300
Davidson-Arnott et al. (2002)	Range	180 - 260
Daborn et al. (2003)	Range	100 - 1700
van Proosdij et al. (2006a)	Range	118 – 346
Silver (2009)	Range (Mean)	17 – 192 (68)

Table 2. A comparison of suspended sediment concentrations recorded in the vicinity of the Windsor mudflat

A third factor influencing the amount of sediment in the water column is the interaction between wind and waves (Davidson-Arnott 2002; van Proosdij et al. 2006a). High wave activity can result in a high suspended sediment concentrations, whereas low wave activity is optimal for deposition. Regrettably, the two days during this research which were closest both in terms of tide height and wave activity had no depositional data (Tide 3 and Tide 5). However, they had very similar values for suspended sediment concentrations. When wind speed and suspended sediment concentrations for the entire study period were plotted, the two variables were shown to have a very low correlation.

Another factor which influences the amount of sediment in the water column is the process of flocculation. Flocculation removes a significant amount of sediment from the water column that would otherwise remain in suspension due to its small grain size. Many factors influence flocculation, including salinity, turbidity, and organic matter content. The higher than anticipated organic matter content within the trapped and deposited sediment samples is likely the result of the Falmouth sewage treatment plant, which drains into the Elderkin marsh. This high amount of organic matter content may promote flocculation, which would explain the high degree of sedimentation within the marsh canopy. The low amount of sedimentation on the mudflat is likely the result of high water velocities, which could either break-up the flocs as soon as they form, prevent their deposition, or prevent the formation of flocs altogether. Additional research is required to investigate the process and extent of flocculation on sedimentation within the Elderkin salt marsh.

As has been noted above, vegetation plays a critical role in determining the amount of sediment deposited over a salt marsh surface. However, there is a notable lack of research completed to study the “slumping” phenomenon that occurs in many salt marshes. When vegetation grows to a certain height, it becomes incapable of remaining erect, and begins to slump. Due to the nature of marsh vegetation, *Spartina alterniflora* in particular, once one plant begins to slump it brings down the other plants around it. This phenomenon was first noted during the July 17th field excursion, and was widespread by July 30th. By the end of the field season, around the beginning of September, the vegetation was completely matted to the marsh surface. Although the length of stems exceeded 130 cm at this time, the actual height of the vegetation canopy was only 20–30 cm.

Data obtained from the field excursions during the end of July (Tide 7–Tide 10) when slumping was widespread showed a significantly lower amount of sediment deposited within all three plots. However, rates of suspended sediment concentration were not significantly lower during this time. It is hypothesized that when vegetation slumps, especially once the slumping has become profound, much of the sediment can no longer deposit directly onto the marsh surface. It is important to note, however, that Tides 7–10 were also the four lowest tides during the study period. As it has been noted that hydro-period is a major factor influencing the amount of sediment deposited over a salt marsh surface, further research is required to determine the relative influence of slumping versus tide height in controlling sediment deposition.

This study quantified and compared deposited and suspended sediment among three plots of differing vegetation roughness over a range of tidal cycles and hydro-meteorological conditions. The results of this study provide important quantitative data that will be useful in examining the influence of vegetation outside of vegetation boundaries, as well provide a solid foundation upon which further research into the phenomena of “quiet zones” and slumping may occur. The major findings of this research are as follows:

- Quiet zones, or areas of lower roughness within the vegetative canopy, have lower suspended sediment concentrations and higher values of deposited sediment than similar areas within the vegetative canopy.
- Although the mudflat plot had the highest suspended sediment concentration, it had the lowest values of deposited sediment despite being closer to the sediment source and lower in the tidal frame.
- Suspended sediment concentrations are higher at 0.20 m than at 0.80 m, indicating that sediment settles out of the water column throughout the rising tide.

- Suspended sediment concentrations were positively correlated to tidal amplitude over a range of tidal cycles.
- Days in which vegetation slumping was present are also the days with the lowest values of deposited sediment.

Salt marshes are vital components of any coastal ecosystem. However, the fate of coastal marshes in the face of human interference and global climate change is uncertain. A firm grasp of sediment dynamics is important to gain a broader understanding of how salt marshes will react to coastal change in the coming decades. Although all salt marshes are unique, the information within this study may be useful for coastal planners and hazard mitigation that seek to utilize the numerous benefits of salt marshes within the inner Bay of Fundy and other macro-tidal environments.

Acknowledgements

The authors would like to sincerely thank those who have contributed to this project over the last year. Specifically, our appreciation goes out to Ken Carroll of the Nova Scotia Department of Agriculture, Greg Baker of the Maritime Provinces Spatial Analysis Research Centre (MP_SpARC), and Casey O'Laughlin, Ben Lemieux and Sarah Weston of the Department of Geography at Saint Mary's University. Thank-you also to Canadian Foundation for Innovation (CFI) and the National Sciences and Engineering Research Council of Canada (NSERC), as well as the Intertidal Coastal Sediment Transport (In_CoaST) Research Unit at Saint Mary's University.

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MACRO-TIDAL SALT MARSH ECOSYSTEM RESPONSE TO CULVERT EXPANSION

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This paper examines the vegetative, sedimentary, nekton and hydrologic conditions pre-restoration, and the initial three years post-restoration, at a partially restricted macro-tidal salt marsh site. Replacement of the culvert increased tidal flow coverage from 5 ha to 43 ha. This was instrumental in altering the geomorphology of the site, facilitating the creation of new salt marsh pannes, expansion of existing pannes in the mid and high marsh zones and expansion of the tidal creek network by incorporating relict agricultural ditches. In addition, the increase in area flooded resulted in a significant increase in nekton use, fulfilling the mandate of a federal habitat compensation program to increase and improve the overall availability and accessibility of fish habitat. The restoration of a more natural hydrological regime also resulted in the die-off of freshwater and terrestrial vegetation along the upland edge of the marsh. Two years post-restoration, *Salicornia europea* (glasswort) and *Atriplex glabriuscula* (marsh orache) were observed growing in these dieback areas. Similar changes in the vegetation community structure were not observed at the reference site however, the latter did contain higher species richness. This study represents the first comprehensive, quantitative analysis of ecological response to culvert replacement in a hyper-tidal ecosystem. These data will contribute to the development of long-term data sets of pre- and post-restoration, and reference marsh conditions to determine if a marsh is proceeding as expected and to help with models that are aimed at predicting the response of marshes to tidal restoration at the upper end of the tidal spectrum.

A TALE OF TWO MACRO-TIDAL ESTUARIES: DIFFERENTIAL MORPHODYNAMIC RESPONSE OF THE INTERTIDAL ZONE TO CAUSEWAY CONSTRUCTION

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This paper examines the spatial and temporal variability in the intertidal morphodynamic response of two macro-tidal estuaries to tidal barrier construction. Contemporary bathymetric surveys of the Petitcodiac River and the Avon River in Canada were compared with historical surveys (1960s and 1860s). Both rivers underwent very rapid sedimentation during construction and rapid infilling downstream of the causeway during the first year after causeway completion. At both sites, there was an unexpected decrease on the order of 90% in intertidal cross sectional area within the first 1–2 km downstream of the causeway as extensive mudflats rapidly developed. Once sufficiently consolidated, these were quickly colonized by *Spartina alterniflora.* The response of the remainder of the intertidal zone in the two systems has differed significantly downstream of the area of initial sedimentation. In the Avon, no significant decreases in cross sectional area were recorded and seasonal cycles of changes in bed elevation exceed differences recorded between years. In the Petitcodiac however channel infilling continues up to 21 km downstream of the causeway. It is hypothesized that the response of the Avon system is mainly attributable to the connecting St. Croix River and associated hydrodynamics, as well as the position of the causeway within the broader estuary. A significant change in the calculated critical velocity in the Petitcodiac system before and after causeway construction implies that the actual physics of sediment erosion and deposition were altered. These results demonstrate the importance of considering the broader estuary when developing management guidelines.

Full citation: van Proosdij, D.; Milligan, T.; Bugden, G. and C. Butler. 2009. *A Tale of Two Macro Tidal Estuaries: Differential Morphodynamic Response of the Intertidal Zone to Causeway Construction.* Journal of Coastal Research SI 56 (Proceedings of the 10th International Coastal Symposium, Lisbon, Portugal.): 772–776. ISBN 0749-0258.

SEA LEVEL RISE AND SALT MARSH RESTORATION IN THE BAY OF FUNDY, CANADA

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Over the next century and beyond, societies will face significant increases in temperature and sea level, which pose a threat to coastal communities. To protect these communities, sustainable adaptation strategies are needed. Recent events, like Hurricane Katrina in the United States, illustrate how vulnerable and under-prepared many coastal regions are for natural disasters. The purpose of this paper is to explore the ability of Bay of Fundy marshes to self-adapt to changes in sea level, their function as a buffer to coastal processes, and their cost-effectiveness relative to traditional, static, man-made defences. The viability of salt marsh restoration around the Bay is considered using a marsh in Musquash, New Brunswick, as a case study. This 19 ha marsh was restored in early 2005 and data collected so far suggest that the restoration is a success. The marsh is being completely flooded with salt water at spring high tide. The drainage network is continuing to evolve and expand and is draining the marsh effectively after flooding. Sediments are arriving at the marsh in the water column and settling out; they are also arriving contained in ice blocks.

The amount of sediment arriving is sufficient to allow the marsh to grow vertically at a rate which keeps pace with the current rate of relative sea level rise. The density of halophytic plants is increasing. Our data indicate that the restored marsh will continue to develop into a fully functional salt marsh and that within a decade or two it will be difficult to tell, without digging, that a dyked, agricultural field once existed in the location.

RESTORATION OF ECOSYSTEM SERVICES IN SALT MARSHES

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Some would maintain that conservation and restoration activities are justified on ethical grounds alone, but economic limitations can force choices amongst restoration activities, and demonstrating economic value can be critical to government support of restoration activities. A commonly used approach is to assess ecosystem services provided through restoration. Daly (1996) defined ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life." Although tidal salt marshes were included in the valuation of global ecosystem services by Costanza et al. (1997) and later reviews, the lists of services vary and none have addressed all the ecosystem services that can be attributed to tidal salt marshes. This presentation reviews the ecosystem services attributed to salt marshes and suggests additional services that have been overlooked. It then describes a "restoration performance index" (RPI) that can be used to calculate benefits of a restoration project based upon the value of ecosystem services. The RPI can employ any number of indicators to assess restoration success. It calculates the proportion to which the indicator has been restored, as compared to one or more reference marshes. By multiplying this proportion times the value of ecosystem services per unit area of reference marsh, the RPI can be used to calculate annual monetary benefits accrued from a restoration project.

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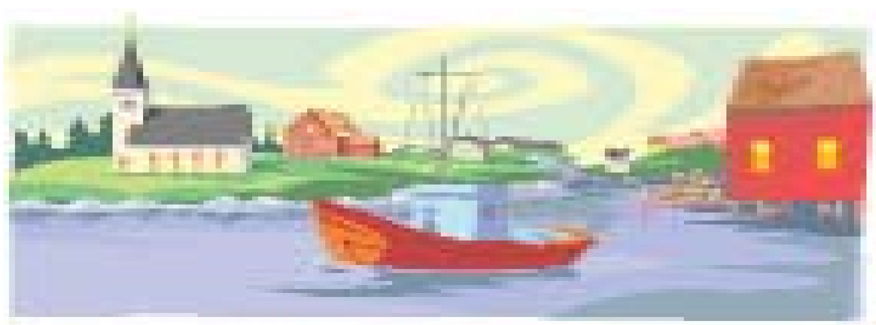
Session C

INDICATORS AND DECISION SUPPORT TOOLS

Chair: Kathryn Parlee, Environment Canada, Halifax, Nova Scotia



COASTAL ECOSYSTEM HEALTH AND INTEGRITY – SELECTING A CORE SET OF INDICATORS FOR LONG-TERM MONITORING AND REPORTING

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The need for coordinated longer term coastal monitoring and environmental reporting for this region is briefly discussed, as an introduction to the other papers in this session. Coastal ecosystems worldwide, and especially in the Northwest Atlantic, are under many stresses, natural and anthropogenic. A set of primary indicators is required for periodic environmental reporting, moving from a full suite of measures, often specific to a stressor and used for measuring short-term ecosystem or ecological health, to an abbreviated set of indicators, common across stressors, that measures coastal ecological integrity over the long term. Conceptually, the available indicators converge towards a smaller set, as with commonly used economic indicators. This indicator convergence process (ICP) considers commonality, practicality, importance and quantification. That is, it includes: a) identifying the common measures, across stressors; b) identifying measures practical for the longer term; c) identifying key measures that describe ecosystem/ecological integrity; and d) showing how a shorter set could produce quantitative indices of health (status of the system today) and integrity (status of the system over time, relative to an appropriate baseline). Such indicators and indices would be the basis for frequent and publicly visible environmental reporting on coastal waters of the Northwest Atlantic, and in this workshop's context, the Gulf of Maine and Bay of Fundy.

ECOSYSTEM INDICATORS AND TOOLS IN THE GULF OF MAINE

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The Ecosystem Indicator Partnership, a committee of the Gulf of Maine Council on the Marine Environment (GOMC) which formed twenty years ago as a U.S.-Canadian partnership of government and non-government organizations, has responded to increasing evidence in numerous scientific reports that common business practices related to water use, waste management, community development, fisheries, recreation and tourism have long-residence-time impacts on the health, environmental quality and productivity of the Gulf of Maine. Due to raised awareness and user needs, the Council mobilized regional resources to devise clear, scientifically objective methods to provide an assessment of the state of the environment of the Gulf of Maine and to evaluate the short and long-term response of the environment to best management practices. To this end, the Ecosystem Indicators Partnership (ESIP: www.gulfofmaine.org/esip) was established in 2006 to develop indicators for the Gulf of Maine and to integrate regional data through a Web-based reporting system for marine ecosystem monitoring. Activities of ESIP initially centered on convening regional practitioners in six indicator areas: coastal development, contaminants and pathogens, eutrophication, aquatic habitat, fisheries and aquaculture, and climate change.

At the present time more than 100 volunteers from academia, regional alliances, provincial and state agencies, federal departments focused on the environment, fisheries and oceans, and community groups have identified top priority indicators for the six indicators areas (see Table 1). Indicators were selected using a structured process to evaluate the issues of major concern for a suite of users, what data sets are publicly available and cover the Gulf of Maine region as whole, and what data sets meet Open Geospatial Consortium (OGC) data standards.

Following the indicator selection process, ESIP developed an Indicator Reporting Tool (Figure 1) to provide technical and non-technical practitioners with the ability to easily access and manipulate data on the priority indicators. The ESIP Indicator Reporting Tool was built with two distinct features. The first is a database that collects and caches data automatically on a weekly basis for many of the data sets. This feature is especially useful for members of the scientific community who are looking at event-specific impacts (such as response to a rain storm) on regional indicators. The second feature of the tool is a database aggregator that averages data. This feature is especially designed for non-technical users who are looking at broad trends. The tool allows users to find data using geospatial and search tools. The map view provides standard pan and zoom options, as well as selection using a bounding box. Users can retrieve data and associated metadata, use look up tables, and select a suite of graphic tools to graph data sets singly or in relationship to each other. In this way, users can visually assess data and, using the graphing function, assess status and trends. Output from the tool can be in different formats, including PDF. The tool can be accessed at www.gulfofmaine.org/esip/reporting.

For ESIP, the release of the Indicator Reporting Tool is just one step toward achieving a vision of delivering easy-to-use, easy-to-understand scientific information about the Gulf of Maine. During the next twelve months, in addition to training targeted users, ESIP will undertake a region wide effort to leverage remotely-sensed assets in the provinces to build land use/land cover data for the coastal development indicator effort. After assisting local (New Brunswick and Nova Scotia) organizations to build impervious surface data layers for 2000 and 2005, the data will be incorporated in the Indicator Reporting Tool. This will result in a seamless data set that merges with those layers currently available for the Maine, New Hampshire and Massachusetts. Coastal and ocean managers will have a powerful toolbox to assess potential impacts of planned building and development on watersheds, erosion, and water quality and ultimately on the quality of the Gulf of Maine environment for aquatic resources.

ESIP Focus Area	Identified Indicators
Aquatic Habitat	1. Extent of salt marsh 2. Extent of eelgrass 3. Number and locations of tidal restrictions
Climate Change	1. Precipitation trends and anomalies 2. Air temperature trends and anomalies 3. Sea level change
Coastal Development	1. Density (population and employment) 2. Impervious surface (as a land use proxy) 3. Point sources
Contaminants and Pathogens	1. Sediment triad data 2. Mussel tissue data (Gulfwatch and Mussel Watch) 3. Shellfish sanitation data
Eutrophication	1. Nitrogen loading 2. Dissolved oxygen 3. Chlorophyll a 4. Secchi depth
Fisheries and Aquaculture	1. Mean length for all fish sampled 2. Economic value of fisheries 3. Proportions of stock at or above targeted abundance 4. Production/leased areas for all forms of aquaculture 5. Economic value of all aquaculture

Table 1. ESIP's list of identified priority indicators for the Gulf of Maine

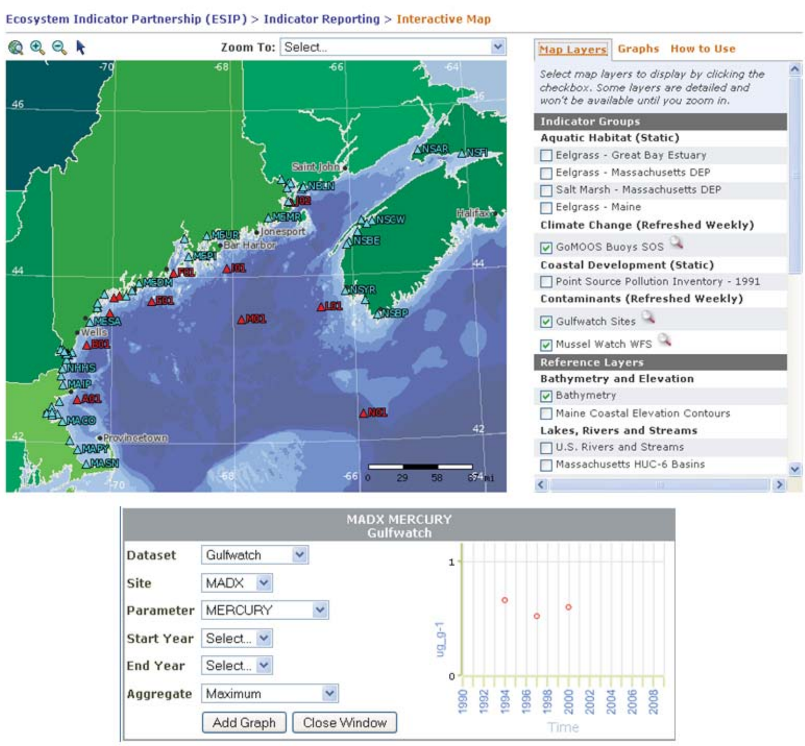

Figure 1. ESIP Indicator Reporting Tool

UNDERSTANDING ECOSYSTEM CHANGES IN THE GULF OF MAINE MARINE ENVIRONMENT THROUGH CLIMATE CHANGE INDICATORS

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Abstract

Ecosystem and resource management has become quite complex since managers have identified the need to incorporate climate change information into their decision-making processes. To aid in understanding the potential impacts on Gulf of Maine ecosystems, the Ecosystem Indicator Partnership (ESIP) of the Gulf of Maine Council on the Marine Environment is developing a set of climate change indicators.

Proper indicator evaluation using a pressure state response model is revealing what aspects of the Gulf of Maine are sensitive to climate change and therefore which indicators should continue to be monitored. Thirty potential indicators were assessed to determine their theoretical location in the pressure state response framework, and then assessed against a series of pragmatic questions, resulting in the top three indicators: air temperature change, precipitation anomalies, and sea level rise.

These results feed into the greater ESIP effort to provide baseline data and information about ecosystem conditions against which future changes can be compared and provide consistent, scientifically-sound, credible information that can be used to strengthen environmental policy and guide management decisions with environmental and social implications.

Background

The Gulf of Maine Council on the Marine Environment is a transboundary organization that has been working towards protecting and enhancing information exchange for the Gulf of Maine since 1989. In 2006, as a result of various workshops and user needs assessments (Pesch and Wells 2004; Della Valle 2006; RARGOM 2006) the Ecosystem Indicator Partnership (ESIP) was formally created within the Council. This partnership is composed of over 100 individuals from government, non-profits, academia, and industry. The members form subcommittees focused on six theme areas (aquatic habitats, climate change, contaminants, coastal development, eutrophication, and fisheries/ aquaculture). Specifically, the ESIP Climate Change subcommittee is composed of 18 individuals from both Canada and the United States (Table 1).

Indicator development in Canada and the United States is a relatively new process that began in the late 1970s. Indicators have increasingly been utilized by the scientific and management communities for ecosystem work and state of the environment reporting (Niemeijer and de Groot 2008). As the field of indicator research has expanded, multiple processes have been documented for narrowing down extensive lists of possible indicators to shortened lists of useful indicators which meet the needs of specific users (UNEP 2006). The users for the ESIP indicator work are defined as coastal law makers and decision makers (GOMC 2006).

This work builds upon a previous effort by the Gulf of Maine Council's Climate Change Task Force (http://www.gulfofmaine.org/council/publications/cross-border-indicators-of-climate-change.pdf). Approximately a dozen environmental indicators for which phenological historical data were available, including air temperature, precipitation, sea surface temperature, and sea level rise, were chosen and analysed. In general, the indicator findings were consistent with observed changes in temperature and precipitation over the same period and with what one would expect from a warming climate. Because they demonstrated that the Gulf of Maine region is sensitive to climate change in many ways, these indicators should continue to be monitored and their sensitivity taken into account by ecosystem and resource managers in the future.

Organization	*Member*
Bigelow Laboratory	Peter Larsen
Gulf of Maine Council on the Marine Environment	Christine Tilburg
Environment Canada	Gary Lines (Chair)
	Al Hanson
	Peter Johnson
	Kyle McKenzie
Fishermen and Scientists Research Society	Patty King
New Brunswick Lung Association	Eddie Oldfield
Ouranos	Luc Vescovi
Provincetown Center for Coastal Studies	Theresa Barbo
Town of Bar Harbor	Steve Perrin
University of Maine, Maine Sea Grant	Esperanza Stancioff
University of New Hampshire	Verna Delauer
	Andy Rosenberg
	Cameron Wake
University of New England	Charles Tilburg
U.S. Environmental Protection Agency	Marilyn ten Brink
	Hal Walker

Table 1. Members of ESIP's climate change sub-committee (April 2008)

Climate Change and the Gulf of Maine

In its fourth assessment of climate change science, members of the Intergovernmental Panel on Climate Change (Christensen et al. 2007) looked at future climate projections from a number of models and emission scenarios. They concluded that over the remainder of the century average annual temperature along the east coast of North America could rise 2°C to 3°C. Average annual precipitation is expected to increase over northeastern North America, particularly in the fall and winter (Christensen et al. 2007).

As the oceans do not change in step with the atmosphere, separate projections are required for the marine environment. Sea surface temperature may increase 1.5-2.6°C on average globally by the end of the century, resulting in changes to circulation and increased stratification (Nicholls et al. 2007). Increased dissolved CO_2 will lead to increased ocean acidity (Nicholls et al. 2007).

One impact of climate change on the marine environment is sea level rise. A best estimate of average, global sea level rise by the end of the century, based on a moderate scenario of greenhouse gas emissions, is 0.35 m (Nicholls et al. 2007). Changes in ocean salinity, density, and circulation will lead to higher than average sea level rise in the vicinity of the Gulf of Maine over this century; possibly 0.05–0.1 m (Meehl et al. 2007).

Climate Change Indicators

The United Nations Environment Programme (UNEP 2006) released a status report aiming to determine the status of environmental indicators being used in Canada and the United States of which some are specifically addressing climate change issues. More specifically for Canada, a set of indicators identifying changes in the country's climate during the last 100 and 50 years as well as an evaluation of particular impacts of these changes is presented in the Canadian Council of Ministers of the Environment (CCME) (2003). Indicators show that, at such large scale, specific impacts on nature and climate are complex and a regionalized response is necessary for stakeholders. Thus, many regional organisations (e.g., the State of the Lakes Ecosystem Conference (Bertram and Stadler-Salt 2000; SOLEC 2006); Northeast Coastal Indicators Workshop (NCIW) (2004); and Ouranos (Vescovi et al. 2005; Yagouti et al. 2007)) are developing specific regional indicators more relevant to the regional and local scale at which human response is being developed to cope with any evolving situation.

Recent climate change indicators work for the Gulf of Maine region was undertaken by Clean Air-Cool Planet and Wake (2005) and Wake et al. (2006). Indicators chosen were mostly for the terrestrial environment. These included timing and magnitude of meteorological, hydrological, and phenological events over the last century. In general, they indicated a trend toward a warmer, wetter climate for the region. Sea level rise and sea surface temperature were the two marine specific indicators chosen. Both show upward trends.

Use of a Pressure State Response Model

In the climate change community one challenge is to adequately address long-term climate change trends with short-term managerial commitments to cope with climate change (Corfee-Morlot 2003). For example, ecosystem managers developing metrics (or indicators) that attribute ecosystem changes to identifiable forcing factors (e.g., sea level rise) is of great interest in order to provide an adaptation response in terms of ecosystem conservation (OECD 2006).

The OECD (1993) pressure state response (PSR) framework is now widely used and is continuing to evolve. As stated by Füssel (2007), the PSR framework is one among the available tools to assess pragmatically climate change vulnerability. The PSR framework states that human activities exert pressures (e.g., pollution) on the environment that can induce changes in the state of the environment (e.g., changes in ambient pollutant levels, climate characteristics, water flows). Society then responds to changes in pressure or state with environmental and economic policies and programs intended to adapt, prevent, reduce or mitigate these pressures and/or environmental damages.

An important requirement within the climate change context is the need to clearly differentiate between pressure and state indicators. Indeed when one is looking at the climate system, greenhouse gas increase is the pressure factor increasing global temperature and affecting precipitation patterns causing environmental problems. Conversely, when one is looking at the natural and/or human systems climatic changes are the driving factors, causing environmental impacts and affecting human responses to adapt to a novel situation.

Another way to look at the question is to keep the set of indicators as simple as possible and to tailor the PSR framework for specific managerial issues and thus look at the specific context relevant for stakeholders. This PSR grouping of indices and indicators of climate change vulnerability distinguishing climate and natural and human systems is illustrated in Figure 1.

Assessment of Potential Indicators

Determining indicators for a specified audience is an intricate and time-consuming process. Frequently indicator selection results in extensive lists of possibilities which are too cumbersome for users to asses and utilize. Likewise, indicators can over-simplify ecosystems if limited to too few a number (UNEP 2006). There is also a perception that indicator use is being slowed down due to the lack of a clear process for narrowing down potential indicator lists (Neimeijer and de Groot 2008).

Despite these and other issues, indicators provide an excellent tool for assessing status and trends in ecosystems and further allow for useful communication of needs or issues to various users. With this in mind, the Climate Change Subcommittee created a list of 30 potential indicators. After determining their appropriate location in the pressure state response framework, each indicator was assessed for each of the following questions:

Is the indicator scientifically valid?
Is the indicator responsive to change?
Is there a potential cause and effect link?
Are accurate data available?
Is the indicator relevant to users?
Is the indicator comparable regionally?
Is the indicator useful at different scales?
Is the indicator comparable to targets, thresholds, or standards?
Does the indicator have value other than as just a measurement?

After collaborative discussion and careful consideration, the committee chose as its top three indicators: air temperature change, precipitation anomalies, and sea level rise. Further indicators may be chosen as the committee's work continues.

Conclusion

The impact of invasive species and the future viability of commercial species are of great concern in the Gulf of Maine, so with both a better understanding of how climate change is affecting the marine environment and how species will react, managers will have a better idea of how the marine environment will evolve and what decisions should be taken to best manage for the future. Careful choice of climate change indicators, along with interpretation assistance by ESIP, is expected to greatly aid decision makers' ability to comprehend how the Gulf of Maine's climate is changing.

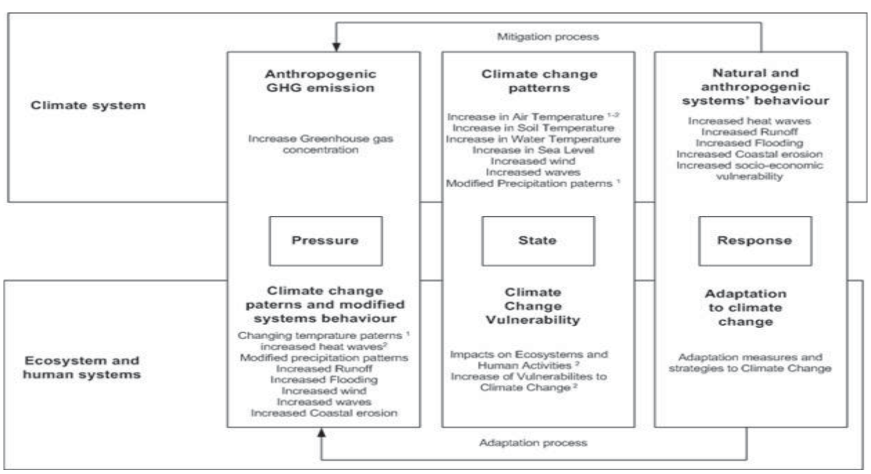

Figure 1. PSR grouping of indices and indicators of climate change vulnerability

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BAY OF FUNDY NEAR-SHORE BIODIVERSITY: NOW PART OF THE 'BIG PICTURE'

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NaGISA *(the Japanese word nagisa, refers to the narrow coastal zone where the land meets the sea)* is a world-wide collaborative effort (http://www.coml.org/projects/natural-geography-shore-areas-nagisa) aimed at inventorying and monitoring coastal biodiversity. Started in 2002, there are now regional centers in Japan, the United States, Italy, Venezuela, Kenya, and since 2007 at the Huntsman Marine Science Centre (HMSC) in St. Andrews, New Brunswick (http://www.nagisa.coml.org/region/ao/atlantic). As one of the first Census of Marine Life (CoML) field projects, NaGISA has an ambassadorial role linking CoML goals and local interests, encouraging international cooperation and capacity building in coastal monitoring and research. Inventorying and monitoring biodiversity are crucial tasks for identifying and clarifying activities that impact ecosystems. NaGISA provides baseline data for long-term monitoring, and information needed to answer fundamental questions concerning changes in biodiversity with latitude and longitude. Implementation is through a simple, cost efficient, low-tech sampling protocol adopted by many research groups and countries, with the intent of promoting local community involvement. Based on a series of 30 m transects from the high intertidal zone to a depth of 10 m, the target habitats are rocky shore and soft bottom seagrass communities, chosen for their global distribution, community complexity and poor state of current knowledge. Data is being incorporated in the Census' Ocean Biogeography Information System (OBIS), an online global atlas for accessing, modeling and mapping marine biological data. NaGISA activities include three partnership sites within the Bay of Fundy, with data from two successive years submitted for global analyses for presentation in October 2010 as part of the CoML "Decade of Discovery" public release.

HABITAT MAPPING FOR SPECIES AT RISK IN THE BAY OF FUNDY

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The Bay of Fundy is home to a variety of species at risk, ranging from invertebrates to birds to marine mammals. Definition of essential habitat is important in managing the distribution and abundance of those species. Due to stresses of development, resource extraction, shipping, fishing, etc., areas where various species can feed and reproduce are also at risk. Habitat mapping and prediction are powerful approaches for defining essential life history areas and mapping potential habitat for species at risk. Many data are available for the distribution of various species in the Bay of Fundy. We attempted to define ecogeographic variables based on bathymetry, substrate type, and circulation for the entire Bay. Remote sensing was used to quantify further habitat layers based on turbidity, salinity, and temperature. The variables were used with Biomapper, a type of factor analysis, to produce habitat suitability maps for several species. This approach will yield important tools for the Department of Fishieres and Oceans to manage habitat in the region. The success of this approach relative to species type and habitat variables is discussed in light of ongoing research in this area.

BAY OF FUNDY SPECIES AT RISK MAPPING TOOL: A COMPILATION OF AQUATIC SPECIES AT RISK DISTRIBUTION DATA FOR THE PURPOSE OF PREDICTING SUITABLE HABITAT

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The Bay of Fundy (BoF) constitutes a dynamic habitat for many migratory and resident species at risk. Such species are now receiving increased attention, with the coming into affect of the *Species at Risk Act* (SARA) in 2003. However, there exists a significant knowledge gap in terms of habitat use, distribution, and the biodiversity of the BoF. We produced distribution plots of ten species listed on Schedule 1 and found to occur in the BoF and surrounding watershed. With a focus on Atlantic wolffish (*Anarhichas lupus*), we then utilized the distribution plot to produce a habitat suitability map utilizing Biomapper software. We found that areas of high suitability for Atlantic wolffish were consistent with the distribution of coarse sediment texture. The results of this predictive modelling study may be used to advise issues of sustainable development as it pertains to Atlantic wolffish. However, issues of limited ecogeographical coverage, particularly in coastal areas, renders this method appropriate only for defining areas of suitable habitat, and inappropriate for designating areas of unsuitable habitat.

Session D

COASTAL ZONE INFORMATION MANAGEMENT

Chairs: Michael Butler, Altantic Coastal Zone Information Steering Committee, Halifax, Nova Scotia, and Peter G. Wells, School for Resource and Environmental Studies, Marine Affairs Program, and International Ocean Institute, Dalhousie University, Halifax, Nova Scotia

Editor's Note: The paper presented by Chang et al. at the Workshop in this session was inadvertently missed in compiling these Proceedings and is found as an Addendum at page 357 in this volume. Our apologies to the authors.

THE ATLANTIC COASTAL ZONE INFORMATION STEERING COMMITTEE'S ROLE AS A CATALYST AND INCUBATOR

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Abstract

The Atlantic Coastal Zone Information Steering Committee (ACZISC) was established in 1992 under the auspices of a former agency of the Council of Maritime Premiers (now the Council of Atlantic Premiers). The ACZISC is working to foster cooperation in integrated coastal and ocean management (ICOM), coastal mapping and geomatics in Atlantic Canada. The success and longevity of the Committee is, in large part, due to the engaged membership who represent the majority of the major coastal stakeholder groups: eleven federal departments, the four Atlantic Provinces, the private sector, academia and non-governmental organizations (NGOs). A small and deliberately neutral Secretariat is based at Dalhousie University. The ACZISC has no "authority" per se, but it can exert considerable influence by virtue of its membership. The Committee has been described as an exemplar of "horizontality" by the Treasury Board of Canada Secretariat (2003). One of the unique features of the ACZISC has been its ability, to incubate, facilitate and champion some important regional projects and programmes, the focus of this paper. All of the projects and programmes described are dependent on interagency collaboration.

The ACZISC

The Atlantic Coastal Zone Information Steering Committee (ACZISC) was established in 1992 under the auspices of a former agency of the Council of Maritime Premiers (now the Council of Atlantic Premiers). The ACZISC is working to foster cooperation in integrated coastal and ocean management (ICOM), coastal mapping and geomatics in Atlantic Canada (ACZISC Secretariat 2008).

A small and deliberately neutral ACZISC Secretariat is based at Dalhousie University in Halifax, Nova Scotia. It is staffed by the Director (half-time), the Research Project Officer and the COINAtlantic Project Manager (full-time), and the Finance Officer (part-time). The Secretariat is funded via membership dues and contract revenue.

The success and longevity of the Committee is, in large part, due to the engaged multidisciplinary and multi-sectoral membership who represent the majority of the major ICOM stakeholder groups: eleven federal departments, the four Atlantic Provinces, the private sector, academia and NGOs. The ACZISC has no 'authority' per se but it can exert considerable influence by virtue of its membership. The Committee has been described as an exemplar of "horizontality" in reports published by the Treasury Board of Canada Secretariat (2003) and by the Canadian Centre for Management Development (Rounce and Beaudry 2002).

One of the unique features of the ACZISC has been its facility to catalyze and subsequently facilitate, incubate and participate in some important regional projects and programmes. All of the projects and programmes are dependent on interagency collaboration; examples include the following:

Atlantic Coastal Zone Database Directory

The Directory, prepared by the ACZISC Secretariat with the support and cooperation of ACZISC members, was first published in 1992. It built on other similar initiatives in the Atlantic Region including the

Directory of Marine Data Sets, published by the Champlain Institute in 1991; the *Catalogue of Environmental Data in Atlantic Canada,* published by Environment Canada in 1991; and the *Data set Directory*, developed in the early 1990s by the Data and Information Management Committee of the Gulf of Maine Council on the Marine Environment. However, unlike these initiatives, *the Atlantic Coastal Zone Database Directory* was updated on a regular basis by the ACZISC. The Directory was made available in hard-copy, in digital format (WordPerfect 5.1) and later in a text searchable format on the WWW.

In addition to identifying data and information and providing metadata, the Directory promoted the development of a network of distributed databases, the foundation for a regional information infrastructure and the raison d'être of the ACZISC. The level of effort required to regularly update the Database Directory eventually exceeded the capacity of the ACZISC Secretariat and in 2005 the ACZISC Secretariat collaborated with the GeoConnections Secretariat to transfer the content of the Directory to the GeoConnections Discovery Portal (GDP) (http://geodiscover.cgdi.ca).

Coastal Zone Canada (CZC) Conference Series

The concept of the Conference series was developed in the early 1990s by members of the ACZISC to promote ICOM development and implementation in Canada. The Coastal Zone Canada Association (CZCA) was subsequently formed in 1993 to organize the first CZC Conference, held in Halifax in 1994. Sponsored by the CZC Association, the Conferences have subsequently been held biennially in all marine regions of Canada: Rimouski, Québec in 1996; Victoria, British Columbia in 1998; Saint John, New Brunswick in 2000; Hamilton, Ontario in 2002; St. John's, Newfoundland in 2004; Tuktoyaktuk, Northwest Territories in 2006; and Vancouver, British Columbia in 2008.

Coastal Zone Canada 2010 will be held on 25–29 July 2010 at the University of Prince Edward Island in Charlottetown. The theme is Healthy Oceans ─ Strong Coastal Communities. The Conference will review the advances and the setbacks in our understanding and management of coastal and ocean systems, both in Canada and globally, and will recommend actions for the immediate future and the next thirty years (http://www.gov.pe.ca/czc2010).

Through this conference series, the CZCA has made and continues to make a significant contribution to Canadian ICOM by providing a forum for coastal and ocean experts and practitioners, by producing tangible outputs that have focused upon actions for policy and decision making; and by developing mechanisms and tools to support capacity building for coastal communities, ICOM practitioners, and stakeholders (Ricketts et al. 2004).

East Coast of North America Strategic Assessment Project (ECNASAP)

ECNASAP was a project (1994–1996) undertaken by researchers from Canada and the United States. The Project was jointly coordinated by the ACZISC in Canada and by National Oceanic and Atmospheric Administration's (NOAA) Strategic Environmental Assessments Division in the US. The aim was to compile a comprehensive database of coastal and offshore living resources which could be used to characterize and monitor the ecosystems of the east coast of North America. ECNASAP consisted of an Inshore and an offshore Case Study (Butler et al. 1996).

The objective of the Inshore Case Study was to support the management of inshore coastal resources by assessing the condition and harvest status of molluscan shellfish beds. In Atlantic Canada these form a major living resource and provide significant economic benefits to local communities. They are also key indicators of environmental stress. The Case Study was aimed at evaluating the causes of problems and options for remediation.

The objective of the Offshore Case Study was to support multi-species management of groundfish resources on the Continental Shelf, within an ecosystem context. It attempted to identify demersal fish and invertebrate assemblages using benthic trawl catch information. The geographic area of the study extended from Cape Hatteras, North Carolina to Cape Chidley, Labrador. Scientists were able to analyze the relationships of fish distributions with habitat, inshore ecosystems, key exploited species, other major species groups, and environmental parameters. A Groundfish Atlas of composite distribution maps was produced for the 99 most abundant species of groundfish (http://aczisc.dal.ca/96ecnasap_groundfish.pdf).

High Resolution Coastal Mapping and Sea Level Rise

A number of ACZISC activities have contributed to the implementation of high-resolution coastal mapping programs in Atlantic Canada in the context of sea level rise and climate change, beginning with a workshop entitled "Natural Disasters in the Coastal Zone and their Mitigation: Rising Sea Level, Hurricanes, Storm Surges and Erosion." The Workshop, organized by the ACZISC, was held on 7 April 1999 at Mount Allison University in Sackville, New Brunswick (http://aczisc.dal.ca/natdisaster.pdf).

The ACZISC subsequently organized a workshop entitled "Remote Sensing Technologies for Coastal Zone Mapping" in conjunction with a meeting to discuss collaborative opportunities on 30 September 1999 in Fredericton, New Brunswick. At the meeting it was agreed that the ACZISC would 'facilitate' a High Resolution Coastal Mapping project. Accordingly the ACZISC, together with the Champlain Institute and the Centre of Geographic Sciences (CoGS) played a coordinating role with regard to a High Resolution Coastal Mapping Project (2000–2002). The Project partners pooled resources to reduce the cost of acquiring imagery, including: funding from the Government of Nova Scotia; a grant from the Canadian Foundation for Innovation to COGS for terrestrial LiDAR, CASI and IKONOS coverage in the Annapolis Valley; a Climate Change Action Fund (CCAF) grant to the Canadian Hydrographic Service of Fisheries and Oceans Canada (DFO) and the Geological Survey of Canada-Atlantic of Natural Resources Canada (NRCan) for terrestrial LiDAR and CASI coverage of a major section of Prince Edward Island's North Shore and the Charlottetown area; and funding from DFO Science for CASI coverage of the Bras d'Or Lakes in Cape Breton.

The Environment Canada-led project on the "Impacts of Sea-Level Rise and Climate Change on the Coastal Zone of Southeastern New Brunswick" followed in 2003. The overall objective of the 3-year study was to quantify the impacts of climate change on the coastal zone and to support sustainable management, community resilience and the development of adaptation strategies (http://www.adaptation.nrcan.gc.ca/projdb/final_coastal_e.php).

Economic Studies for Coastal and Marine Resources in the Atlantic Provinces

The rationale for the economic studies is to assist policy formulation that aids economic development and the management of the coastal and ocean environment. In Atlantic Canada, the process was initiated by the ACZISC with a study entitled "Estimating the Economic Value of Coastal and Ocean Resources: The Case of Nova Scotia" (Butler and LeBlanc 1998). This was followed by studies for New Brunswick (Mandale Consulting et al. 2000), Prince Edward Island (Canmac Economics et al. 2002) and Newfoundland and Labrador (Department of Finance, Government of Newfoundland and Labrador 2002), using a similar template. Updates have been produced for Newfoundland and Labrador (Department of Finance, Government of Newfoundland and Labrador 2008) and for Nova Scotia (Gardner Pinfold Consulting Economists Ltd et al. 2005 and Gardner Pinfold Consulting Economists Ltd 2009). The studies are accessible via the ACZISC website at http://aczisc.dal.ca/docs.htm#ECON.

The following table indicates the value of the ocean sector and coastal resources to the economies of each of the four Atlantic Provinces, as previously referenced.

Value of the Ocean Sector and Coastal Resources		
Province	***Benchmark Year(s)***	***Total Impact as a Percentage of Gross Domestic Product***
New Brunswick	1995-1997	7.2 % (average per year)
Newfoundland and Labrador	2001-2004	41.3 % (average per year) [1]
	1997-1999	26.5 % (average per year)
Nova Scotia	2002-2006	15.5 % (average per year)
	1996-2001	14.5 % (average per year)
	1994	17.5 %
Prince Edward Island	1997-1999	17.1 % (average per year)
[1] The % increase from the earlier study is primarily as a result of increased offshore oil production and further oil project development.		

Table 1. Value of the ocean sector and coastal resources

COINAtlantic, the Coastal and Ocean Information Network for Atlantic Canada

COINAtlantic is a major initiative of the ACZISC to develop, implement and sustain a network of data providers and users that will support secure access to data, information and applications in support of ICOM in Atlantic Canada. Phase 1 of COINAtlantic (January 2008 to June 2009) has been implemented with funding support from the GeoConnections Program, Fisheries and Oceans Canada, ACZISC members and other partners.

The challenge addressed by COINAtlantic is the need to find and search the plethora of portals and URLs for desired data and information. A logical approach was to encourage data providers to register the metadata for their geospatially-referenced data sets (maps, peer reviewed papers, grey literature, etc.) on the GeoConnections Discovery Portal (GDP) (http://geoconnections.ca), a component of Canada's Geospatial Data Infrastructure (CGDI). This enables users to locate data sets and other information without foreknowledge of their location. Another prerequisite was the posting of geospatial data by the data providers using open source standards, namely Web Mapping Service (WMS) and Web Feature Service (WFS).

Additional details are provided in the paper entitled "COINAtlantic: An Initiative of the ACZISC to Facilitate and Promote the Application of Available On-Line Information to Coastalshed Management" (Boudreau et al. 2009) in the proceedings of the 8th BoFEP Bay of Fundy Science Workshop and in the COINAtlantic website at http://COINAtlantic.ca.

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COINATLANTIC: AN INITIATIVE OF THE ACZISC TO FACILITATE AND PROMOTE THE APPLICATION OF AVAILABLE ON-LINE INFORMATION TO COASTALSHED MANAGEMENT

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Abstract

COINAtlantic – the Coastal and Ocean Information Network for Atlantic Canada (see http://COINAtlantic.ca) – is a major initiative of the Atlantic Coastal Zone Information Steering Committee (ACZISC) (see http://aczisc.dal.ca). The goal is to develop, implement and sustain a network of data providers and users that will support secure access to data, information and applications, for decision making by coastal and ocean managers and users of coastal and ocean space and resources.

COINAtlantic

Integrated coastal and ocean management (ICOM) is a complex and difficult task as it requires information from land, estuaries and marine domains, i.e. the coastalsheds (Figure 1). As a result, information is required from a wide range of organizations including federal and provincial departments, academia, community groups, etc. No one agency can, or should attempt to, manage all of the information.

Figure 1. A map of Canada's coastalsheds

To address this issue, the Atlantic Coastal Zone Information Steering Committee (ACZISC) (Butler and LeBlanc 2009) initiated the Coastal and Ocean Information Network for Atlantic Canada (COINAtlantic) in 2008 with funding from GeoConnections and in-kind contributions from the Department of Fisheries and Oceans and other ACZISC member agencies. Guided by the ACZISC, COINAtlantic is a network of people, information and technology.

The key to the success of COINAtlantic is the willingness and ability of people to contribute information. The ACZISC provides the network through the long-term efforts of its members to facilitate information exchange in support of ICOM. The work of the various agencies in Atlantic Canada has resulted in a large number of on-line data sets that are applicable to ICOM. However, in many instances, the information is published on stand-alone Web sites using mapping engines to display and work with the information. This often makes it impossible for the non-technical user to overlay and compare the information with relevant data from other sources.

The ACZISC is working with collaborators to publish this information via COINAtlantic using established open source standards such as Web Mapping Services (WMS) and Web Feature Services (WFS). Data providers use a variety of available GIS software to provide their information in these easy to use formats. Once published as a WMS or WFS, the information can be accessed through a number of mapping engines such as GoogleEarth.

The existence of a lot of information on-line for the Atlantic Region is a real strength. The availability of an increasing number of WMS/WFS data sets continues to improve the information base for ICOM. However, this multitude of sources is also a weakness because it is difficult for the average user to find and access the best possible information amongst the plethora of mapping services. To address this need, COINAtlantic has worked within the Canadian Geospatial Data Infrastructure (CGDI - http://www.cgdi.ca) to put in place a method for finding and accessing the published on-line information using the existing GeoConnections Discovery Portal metadata catalogue (GDP - http://geodiscover.cgdi.ca).

With data published by COINAtlantic contributors, using established WMS/WFS standards and registered in the GDP, a simple COINAtlantic user interface has been developed that allows users to search for relevant information by both descriptive text and geographic area. This COINAtlantic Search Utility (CSU - http://coinatlantic.ca/searchutility.html) has been implemented so that it will run from any standard internet browser such as MS Explorer or Mozilla Firefox. Once information sources are identified, the CSU allows users to display the information and overlay information from various distinct sources onto a single map image. By so doing, users can assess the area of interest and generate map images for use in word processing or GIS software. Figure 2 shows an example of information from Natural Resources Canada and the Department of Fisheries and Oceans.

Most of the COINAtlantic effort to date has been on improving the search function and access to mapped information. However, the network will also support access to other types of information required for ICOM, for example, textual products such as primary publications and grey literature. See Figure 3.

In addition to the need to encourage people to publish and register their information, it is important for the ACZISC to engage people to participate in the ongoing use and development of the information and technology. To this end efforts have been made to develop a COINAtlantic training curriculum and on-line help tools to specifically promote the CSU and, more generally, on-line geomatics resources. Training has been delivered at 9 workshops throughout Atlantic Canada to 85 participants. Additional training was delivered during a workshop on Geomatics at the 2009 BoFEP Workshop (See Workshop report, Appendix 1, in this publication).

For more information on COINAtlantic, please consult the website at: http://COINAltantic.ca.

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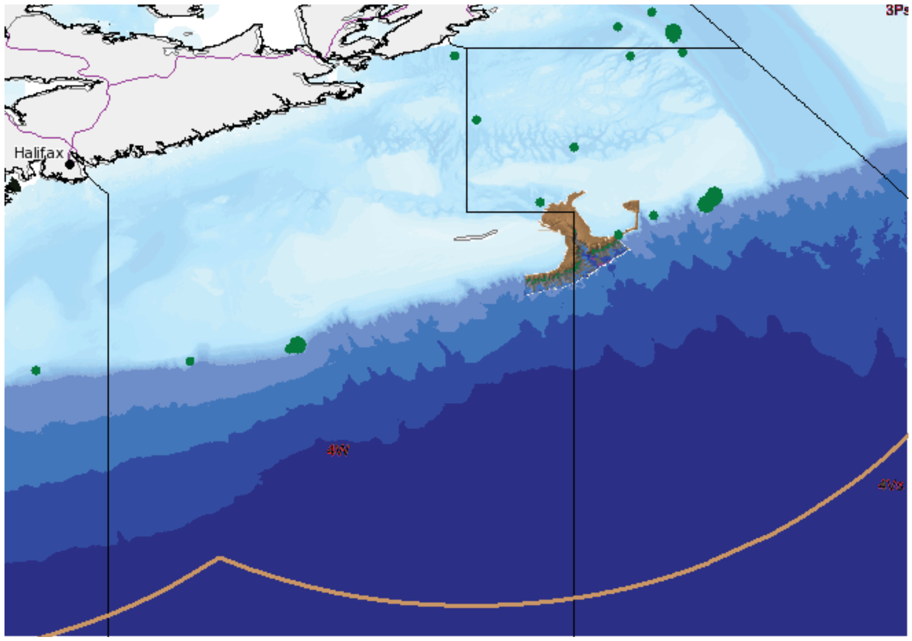

Figure 2. A map image generated using the COINAtlantic Search Utility displaying NAFO areas and locations of northern wolffish catches from the Department of Fisheries and Oceans, along with an image of the Natural Resources Canada multibeam for the Gully

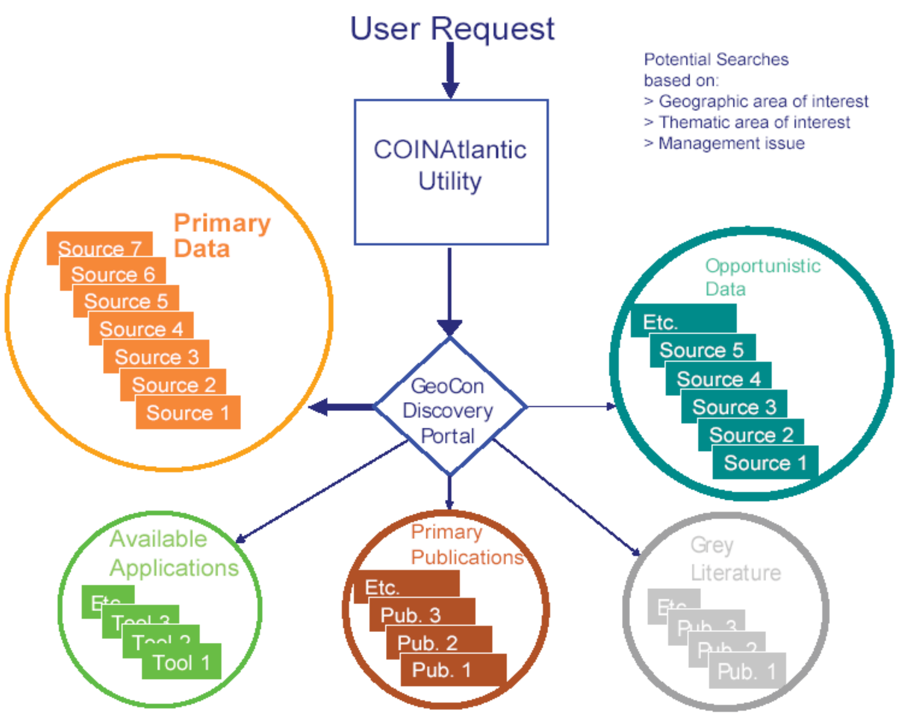

Figure 3. An image of the conceptual goal of COINAtlantic to provide easy access to a wide range of information types through a single user interface

WWF-CANADA'S INFORMATION PRODUCTS IN THE SCOTIAN SHELF AND GULF OF MAINE

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WWF-Canada has identified the need for several information products in support of the Scotian Shelf and Bay of Fundy marine protected area (MPA) network planning process. The first of these products is the seabed feature classification. Developed with marine geologist Gordon Fader, this classification defines and delineates major seabed features in the Northwest Atlantic. Drawing on a range of data sources, including scientific research, multibeam mapping and sediment samples, a GIS product was developed which will serve as a proxy for habitat types during the MPA design process. The second product focuses solely on the Bay of Fundy and Gulf of Maine. Our aim is to compile geographic information from various sources in an effort to present areas of high conservation value. This product will serve to educate others about these unique areas and will be developed into a GIS database and presented as an atlas of Marine Areas of High Conservation Value.

ENHANCING THE USE AND INFLUENCE OF BAY OF FUNDY INFORMATION: RESULTS AND INSIGHTS FROM RECENT STUDIES OF THE BOFEP FUNDY INFORMATICS WORKING GROUP

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Abstract

The Bay of Fundy region is rich in living and non-living resources but it has many resource and environmental issues to consider and manage. Regional policy and decision makers continually need relevant information to consider options, make informed decisions, and take action to manage resources and risks effectively. The Bay of Fundy is a data and information rich area, with many data banks and thousands of publications produced over the past 150 years. BoFEP has a major goal to make this information more accessible and influential within the whole Fundy community, through the BoFEP Web site, through bibliographies, and through an on-line "Information Collaboratory." In a parallel study, several group members been examining the diffusion, use, and influence of information produced by two international organizations responsible for giving strategic advice on current issues affecting the ocean. The research team has utilized a suite of established methodologies (e.g., citation analysis, content analysis), and is embarking on surveys and interviews of key informants, and developing new measures of information influence in the environmental management realm. This paper describes the Fundy Informatics Working Group initiatives; introduces the study of grey literature of the international organizations and ongoing research (tracking new literature, conducting interview with users, paramatizing information production and use interactions—social and scientific); summarizes insights on use and influence of information from the working group; and proposes a guiding framework for informatics (access, use, and influence) research for the Bay of Fundy.

Introduction

The Bay of Fundy region is rich in living and non-living resources. However, after 400 years of settlement and increased industrialization during the twentieth century, there are many resource and environmental issues to consider and manage (Percy et al. 1997; Pohle et al. 2007). Regional policy and decision makers continually need relevant information to consider options, make informed decisions, and take action to manage the resources and risks effectively.

The Bay of Fundy is a data and information rich area, with many data banks and thousands of publications produced over the past 150 years. Too often though, published information is under-utilized (Wells 2003; MacDonald et al. 2007). One of BoFEP's major goals is to make Fundy information more accessible and useful to policy makers in government and to the wider Fundy community. Improved access is important for all stakeholders concerned with the Bay's sustainability (scientists, environmental and resource managers, decision and policy makers, educators, non-government organizations, members of coastal communities, and the interested public). The need for improved access was described at recent BoFEP workshops, in the context of a potential digital geolibrary for the Gulf of Maine region (Boxall et al. 2005), and in a paper on the Fundy Collaboratory given by Toms et al. (2007).

In Figure 1, major information challenges in the Bay of Fundy region are presented as barriers in the communication process. For example, the volume of data (number of databases) and information (primary publications, monographs, and grey literature) on the Bay of Fundy and Gulf of Maine ecosystem and its watersheds presents a significant information access and use problem. The magnitude of the problem is illustrated by the size of the Fundy bibliography brought together at the time of the proposed tidal power project on Cumberland Basin in the late 1970s and early 1980s, which contains more than 3000 references (Plant 1985). Further evidence of the problem is seen in the extent of the Department of Fisheries and Oceans technical report literature relative to primary publications by the early 1990s (Toms 1994), and the sizeable body of literature reviewed for the first Bay of Fundy Science Workshop in 1996, sponsored by the Fundy Marine Ecosystem Science Project, the forerunner to BoFEP (Percy et al. 1997). The Fundy and related Gulf of Maine literature, largely grey (defined as scientific information published outside of peer-reviewed journals in MacDonald, Cordes, & Wells 2007; MacDonald et al. 2009 March), grows by hundreds to sometimes thousands of publications each year, with additions now largely digital and Web-based. Hence, gaining awareness of the information becomes more and more difficult, notwithstanding the increased efforts required to access, read, and act upon the information when it is relevant and needed for resolving an immediate problem, or contributing to a policy on the Fundy environment and resources.

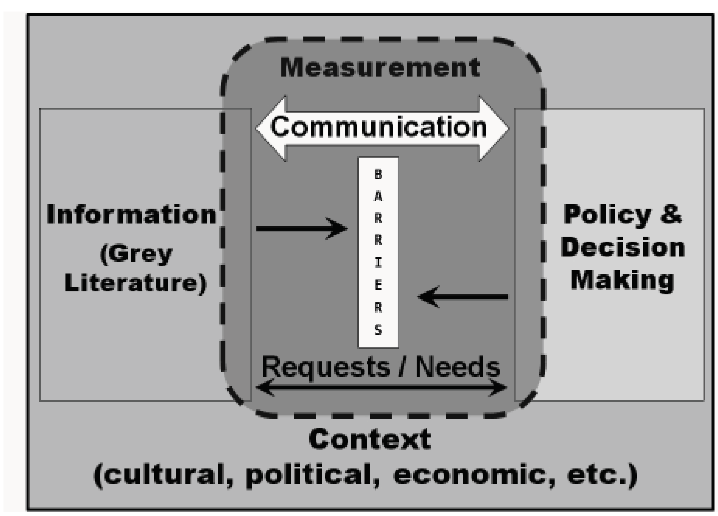

Figure 1. Information communication framework

One view suggests that factors complicating information awareness, access, and use will only worsen as the quantity of information increases over time. This perspective is especially relevant with regard to the volume of new, Web-based, grey literature. Awareness may not be enhanced by publishing documents to the Web since the large volume of publications available simply may not allow relevant information to “rise to the top” in searches. An alternate argument has been made that access should be easier because more information is Web-based, rather than solely available as poorly disseminated print documents, the transient nature of some Web sites notwithstanding. Recent studies show that factors influencing use vary considerably, and use can increase/improve if a publication’s structure and language style makes the information more accessible to potential readers (Holmes and Clark 2008; McNie 2007).

It is important to note that considerable interaction occurs between information access and use, which can influence the communication process. Access to the literature (primary or grey) can drive its use. Access should be influenced by use, but current search systems do not allow for this iterative interaction. For example, the search algorithms operating within Google or Google Scholar are not modified based upon individual usage (E. G. Toms, personal communication, 4 May 2009).

This paper briefly describes various Fundy Informatics Working Group (FIWG) initiatives addressing the information barriers noted in Figure 1. The paper summarizes some insights on use and influence of information arising from research by members of the group. A guiding framework for informatics (information awareness, access, use, influence) research for the Bay of Fundy is also proposed.

The Fundy Informatics Working Group

The Fundy Informatics Working Group was created in 2005 as BoFIP (Bay of Fundy Information Project, later FIWG). The group met several times during 2005–2006, exchanging information on current projects, and since that initial briefing members of the the group have networked on specific research projects and research proposals. The group includes Bertrum MacDonald (Dalhousie University), Elaine Toms (Dalhousie University), Ruth Cordes (information consultant, Halifax), Peter Wells (Dalhousie and Acadia universities), Patricia Hinch (Dalhousie University), Susan Rolston (Seawinds Consulting Services), Michael Butler (International Ocean Institute and Atlantic Coastal Zone Information Steering Committee), and Jon Percy (Sea Pen Communications, BoFEP). The group’s early objectives aimed to describe individual activities relevant to the topic of Fundy information and communication, formulate terms of reference for the group, and initiate new projects.

The terms of reference for FIWG developed in 2006 are:

1. To facilitate dissemination and use of scientific information on the Bay of Fundy and greater Gulf of Maine;
2. To initiate new informatics research pertaining to more effective use of data, information, and knowledge for resource and environmental management of the Bay of Fundy;
3. To communicate with other information-oriented, research and management groups, such as the Atlantic Coastal Zone Information Steering Committee (ACZISC); and
4. To secure funding to advance the above objectives and activities.

The work of FIWG is evolving as the team interacts, learns, and generates ideas for new studies. Both a paper and a poster were presented at the 2006 BoFEP Workshop (Toms et al. 2007; Wells et al. 2007); the paper in particular generated considerable interest. Early work of FIWG members consists of the BoFEP Web site, which is continually being developed by Jon Percy; production of fact sheets on Fundy issues; a comprehensive bibliography of all of the publications of the Gulf of Maine Council on the Marine Environment (GOMC) (Cordes, MacDonald, and Wells 2006); the Cumulative Index to all of BoFEP’s publications (Rolston and

Wells 2006); specialty bibliographies on topics specific to the activities of working groups (e.g., the Corophium Bibliography; Diana J. Hamilton, personal communication, 1 May 2009); the early prototype of the digital library and Fundy Information Collaboratory accessible via the BoFEP Web site in the FIWG section (http://www.bofep.org/informatics.htm) (Toms, MacDonald, and Wells 2007); and the Environmental Information: Use and Influence research initiative, focusing on the grey literature of marine intergovernmental organizations including GOMC, funded by a Social Sciences and Humanities Research Council (SSHRC) grant (2007–2010) to Bertrum MacDonald and Peter Wells.

The initiatives and projects on the Bay of Fundy information base, outlined above, are part of a larger vision for Fundy scientific information management (the Fundy Information Collaboratory). This vision has been discussed numerous times within BoFEP at its workshops, and by FIWG members. The primary objective is to move beyond standard indexes and bibliographies to fully searchable, digital, cross-referenced, GIS-linked, full text versions of most or all of Fundy publications. This system would be accessible to key government policy makers as well as wider audiences. In particular, we need to move from the situation of a researcher, manager, or policy maker being able to find "something" when conducting a search, to finding information in a form that is directly useful and salient to the problem at hand. Current research shows clearly that information needs to be in a form that the user can work with directly (McNie 2007). Simply finding "something" on a topic is not good enough, even when it is the best available information, if the reader cannot understand and assimilate the information easily. Several recent studies have shown that crossing disciplinary boundaries can be problematic when information is not easily understood (Holmes and Savgård 2008; Tribbia and Moser 2008).

Moving towards a fully functional Fundy Information Collaboratory and understanding of an applicable Fundy Information Life Cycle would utilize many technical advances in the field of informatics (Boxall et al. 2005; E. G. Toms, personal communication, 4 May 2009) and the integrated coastal and ocean management (ICOM) tool box (M. Butler, personal communication, 29 April 2009). The focus would be on improving access to the extensive information and knowledge base of the Bay of Fundy–Gulf of Maine region (Parker et al. 2007; Percy et al. 1997; Plant 1985).

The Fundy Information Collaboratory

All of our current projects and studies combined contribute to the Fundy information life cycle and individually and collectively they form part of the Fundy Information Collaboratory. The Fundy information life cycle can be visualized as shown in Figure 2.

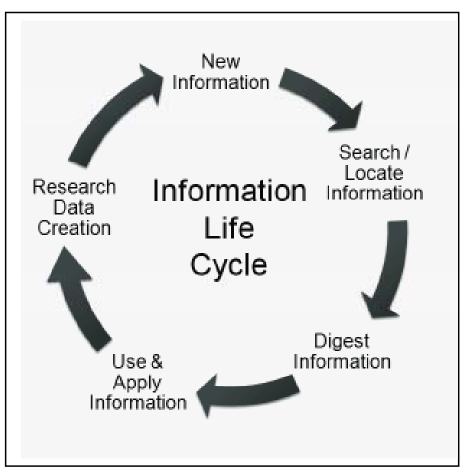

Figure 2. Information life cycle

We currently are engaged in three Fundy information projects, all of which contribute to the Collaboratory. In addition, members of FIWG contribute to the biennial Fundy workshops and the research of other working groups.

Project One is the continued development of the BoFEP Web site (design and content) and preparation of new and timely BoFEP information products, such as the Fundy Issues fact sheets, a proposed book on Fundy issues, and the biennial Workshop proceedings (with author and subject indexes).

Project Two is the on-line “Fundy Information Collaboratory” (Toms) as demonstrated and discussed at the 7th Bay of Fundy Science Workshop (Toms et al. 2007). The prototype digital library is currently accessible from the BoFEP Web site (http://www.bofep.org/informatics.htm). The objective is to see this Fundy information displayed in a GIS context (as with COINAtlantic, or Coastal Ocean Information Network Atlantic project, P. Boudreau, personal communication, 7 April 2009). However, this project has been stalled since 2007 due to insufficient funding and staff capacity.

Project Three is the SSHRC-funded information use and influence study, focusing on the grey literature of several marine environmental bodies (Cordes et al. 2006; Hutton 2008; Hutton 2009; MacDonald et al. 2004, 2007; and MacDonald et al. 2009 May). The research team of faculty and students at Dalhousie University has utilized a suite of established methodologies (e.g., citation analysis and content analysis), and is embarking on surveys and interviews of key informants, and developing new measures of information influence in the environmental management realm. In this brief paper, we note, particularly, the results and next steps of the study of the Gulf of Maine Council on the Marine Environment (GOMC), and its relevance to the Bay of Fundy. We have assembled evidence of use of GOMC publications, both of the grey literature and primary publications emanating from the group, but access to and distribution of their reports has been variable until recently (now improved with new reports being placed on the well-developed Web site – www.gulfofmaine.org) (MacDonald et al. 2007, 2009 May). The access issue to GOMC publications may now be improved, but awareness may not be; just because documents are placed on a Web site does not mean that potential users became aware of their existence or that the publications are easily accessible as some Web sites are difficult to navigate.

Discussion

The research briefly outlined above offers a variety of insights regarding access, use, and influence of information. Information is accessed as has been shown through the citation analysis study of GOMC publications (MacDonald et al. 2007). It is important to emphasize that access to information will drive its use, and that access could be influenced by use. However, as noted above, current information search systems do not modify the mechanisms or algorithms governing access to information based on its use patterns. This interaction behavior between access and use needs further study.

In the GOMC study, as well as in a related investigation of the use of grey literature publications of the United Nations-based Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (Hutton 2009; MacDonald et al. 2004), information use has been determined via one significant indicator, namely citations. Many citations were obtained from searches in Web of Science, and more recently from the open Web through searches in Google and Google Scholar. The evidence concerning the GOMC publications uncovered so far shows use mostly within scholarly peer-reviewed literature, with different citation patterns for grey literature and peer-reviewed GOMC literature (MacDonald et al. 2007).

Accessibility is only one factor as to whether information is used. Other important issues are mentioned in Holmes and Clark (2008) and McNie (2007), such as, the value of review papers over research papers on a topic, the need for databases that include summaries in accessible language as well as the original technical reports, management of the information boundary between science and policy making, and access to experts on the topic who can provide syntheses and interpretation.

A more detailed guiding framework for Fundy informatics research (awareness, access, use, influence, barriers) is needed. The initial conceptualization of information use and influence in the grey literature study is illustrated in Figure 1. This research on the communication of information focuses on the development of measures of use and increasing understanding of the nature and barriers to influence of information (MacDonald et al. 2009 March, 2009 May).

Moving forward, the guiding framework will need to incorporate further details about use and influence and additional elements of the information life cycle from different perspectives. Since information use is complex and context plays a major role, a "one-size-fits-all" approach is bound to be faulty. The contexts in which Bay of Fundy information is or can be used vary considerably, making it unlikely that a single framework of information use and influence will encompass this multifaceted variety.

Conclusion

Developing the Fundy Information Collaboratory at this time coincides with increased Canadian effort at the federal level to produce an ecosystem overview and assessment report for the Bay of Fundy, and a broader state of the environment report for the Bay of Fundy and Gulf of Maine, with the United States. The Canadian Department of Fisheries and Oceans is also now establishing a process under the *Oceans Act* for implementing ICOM for the Bay of Fundy (T. Hall, Department of Fisheries and Oceans, personal communication with P. G. Wells, May 2009). Making Bay of Fundy information more accessible and demonstrating its use and influence is/could be a key part of moving towards effective ICOM for the Bay. Hence, with appropriate support, the work of the Fundy Informatics Working Group has the potential to be very timely and relevant to developing and implementing a Fundy ICOM program, contributing to the Bay's long-term future and sustainability. Recognizing the crucial role of Fundy informatics in ICOM for the Bay of Fundy may be a lasting legacy of our collaborative studies.

Potential next steps of the research of the FIWG and development of the Fundy Information Collaboratory include:

1. Enhancing the BoFEP Web site and tracking its usage;
2. Tracking new GOMC literature in the Environmental Information: Use and Influence research, and conducting interviews with key stakeholders, identifying and describing social and scientific information production and use interactions;
3. Securing funding for further development of the Collaboratory, enabling its role in Fundy integrated coastal and ocean management;
4. Linking the individual studies more directly to the Fundy Collaboratory and to the Fundy information life cycle, as they develop; and
5. Soliciting input from the wider Bay of Fundy coastal community, by presenting our research, and seeking comments on its usefulness and future direction.

Acknowledgements

The activities and research of Fundy Informatics Working Group members have been supported, financially and/or in kind, by the Social Sciences and Humanities Research Council of Canada, the Gulf of Maine Council on the Marine Environment, the UN International Maritime Organization, Environment Canada, and BoFEP. The International Ocean Institute, Dalhousie University, is especially thanked for various in-kind support to P. G. Wells while engaged in research at Dalhousie University.

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NOVA SCOTIA'S SUSTAINABLE COASTAL DEVELOPMENT STRATEGY: WHAT, WHEN, HOW AND WHAT'S NEXT?

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This presentation will provide an overview and analysis of Nova Scotia's process to develop a Sustainable Coastal Development Strategy from the perspective of the many community and environmental groups that have been actively involved in coastal issues over the last decade. The talk will review some key events that shaped public interest and concern around coastal management in Nova Scotia, including the White Point Expert Panel Review, which recommended the province develop a coastal management policy as soon as possible. The Nova Scotia provincial government commitment to developing a sustainable coastal development strategy by 2010 and its efforts to date will also discussed. The focus will be on how local and provincial groups work together on coastal issues and in the process have built themselves into a vigorous and active coalition. This is part of ongoing efforts by the EAC to document and understand the role of civil society in environmental change. The presentation will end with some conclusions about how community groups, scientists, government, and the general public can work together towards the creation and implementation of a sustainable coastal development strategy for Nova Scotia.

COASTAL CURA – COMMUNITY INVOLVEMENT IN COASTAL MANAGEMENT

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Abstract

The Coastal CURA is a long-term project that is building knowledge and capacity across the Maritime Provinces, to support community involvement in managing our coasts and oceans. It is a partnership that brings together First Nations communities, fishery-related organizations and university participants. A key goal of the Coastal CURA is to build local-level capacity to analyze policy options, articulate alternatives and explore alternative management structures, such as integrated management that facilitates linkages between community and government. In this way, we are exploring what works and what does not in community-focused management of fisheries and other coastal resources. Thus our work includes (a) comparative research to monitor and assess a set of coastal management initiatives in the four key areas of the Maritimes where our community partners are located, (b) capacity building in media techniques, community GIS and mapping, (c) policy research, such as studies of how different provincial management strategies affect local fisheries, and (d) "reflection research", to understand varying models of integrated management, and thereby to create a vision for community-centred integrated management. This paper presents insights from our partners on a set of fundamental integrated management values and attributes. The lessons we have collectively learned and are sharing in this paper demonstrate ways that communities can work together with academics and government toward a "sustainable and prosperous future in ocean and coastal management."

Introduction

The Rio Declaration of the 1992 UN Conference on Environment and Development (UNCED) flagged integrated management (IM) as vital to sustainable development, whether focused on coasts, oceans, watersheds, forests, or upland areas. In the seventeen years since IM language became accepted in international conventions and national policy, however, the concept has come to have many meanings. For example, it has been defined as a multidisciplinary approach to reconcile sustainability of the biophysical environment with economic growth and prosperity (Olsen 2003), and as a collaborative planning approach that addresses social, economic, institutional, environmental and legal interests of multiple stakeholders and of the resources being managed (Christie et al. 2005). International guidelines for IM emphasize the principle of participatory governance, in addition to those of sustainable development and environmental protection (e.g., UNEP 2009). As Tobey and Volk (2002: 290) illustrate, a great deal of research around the globe has demonstrated that wide public participation is the key to success. But as other research has shown, this remains one of the most neglected areas of integrated management (Kearney et al. 2007).

This paper, which focuses on ocean and coastal areas, explores the challenge of public participation by discussing the role of communities in IM. We draw on a decade of collaborative work between academics and community partners to outline the community perspective on both the limiting factors and the opportunities, a "state of the art" survey of community involvement in IM, particularly within the Canadian Maritime provinces. The community-focused insights provided in the paper, based on years of experience with IM at the local level, highlights the importance of linking communities and governments, and the need to overcome a growing disconnect between these, which is creating community 'push back' in the form of non-cooperation and outright opposition. We illustrate the experiences local coastal communities have had with IM through the examination of a case study from Malpeque Bay, PEI. This and other examples from our partners have lead to the development of a set of fundamental IM values and attributes from a community perspective. We conclude this paper by identifying four key insights needed to support community involvement in integrated management.

Integrated Management and Canadian Coasts

Globally, coastal zones are under increasing pressure. A growing proportion of the world's human population lives on the coast, together with a majority share of human infrastructure and activity in industry, transportation and trade, energy processing, communications and services, and a disproportionate share of global consumption and waste production (Tobey and Volk 2002: 287). But as coasts and oceans are also generators of vital ecological services, and home to much of the world's fish stocks, rapid coastal development is threatening environmental quality and human welfare. It is also squeezing out long-time users of coastal areas, which leads to competition and conflict. Global climate change has added additional challenges, as has cumulative ecological degradation (Worm et al. 2006). These concerns are common to much of the world, and Canada is no exception.

Management of coasts is guided by international conventions and declarations, including the United Nations Convention on the Law of the Sea (1982), the Convention on Biological Diversity (1992) and the Rio Declaration noted earlier (Cicin-Sain and Belifore 2005). These conventions have highlighted various forms of needed integration. Canada responded with guidelines for coastal and ocean IM mandated under the *Oceans Act* (Government of Canada, 1996, Chapter 31), an act which authorizes the Department of Fisheries and Oceans (DFO) to work "in collaboration" with other persons and bodies, including local stakeholders. However, this need is often unmet in practice, a concern identified by, amongst others, Canada's Auditor General, the Senate Committee on Fisheries and Oceans, and various academic researchers. Indeed, as we shall illustrate, IM approaches implemented without community support and buy-in can lead to push-back opposition. Fortunately, such negative impacts can be avoided, particularly through the adoption of a community-based perspective.

The Challenges of Integrated Management

Given the range of environmental, economic, political and social objectives of IM, it is not surprising that governments, including that of Canada, have been slow to develop policy that fully reflects the aspirations of IM, particularly with regard to participatory governance. Several difficult hurdles must be overcome. Single ecosystems usually fall under the jurisdiction of multiple authorities, and "the purposes for which authorities are statutorily permitted to act and their legal ability to cooperate with each other are sometimes restricted in ways that impede" (Gibson 2003: 128). (For further references, see Van Dyke 1999; Klinger 2004; Kearney et al. 2007; Wiber and Bull 2009; Weiss Reid 2004.) From the government perspective, IM has tended to be defined more narrowly (as in the left hand side of Figure 1), perhaps without highlighting the participatory collaboration and opportunities for co-learning that we argue will be key to overcoming IM barriers (compare with the right hand side of Figure 1).

"a comprehensive way of planning and managing human activities so that they do not conflict with one another and so all factors are considered for the conservation and sustainable use of marine resources and shared use of ocean spaces…" (DFO 2005).	"a continuous and dynamic process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources" (GESAMP 1996, in Bastien-Daigle et al. 2008).

Figure 1. Comparing definitions of integrated management

To build institutions that can accomplish multiple levels of integration in natural resource planning will require linking existing government agencies both vertically and horizontally, and this government "joining up" has received some attention (see DEFRA 2008). However, government linkages alone cannot accomplish effective IM. Keen and Mahanty (2006), among others, suggest that IM must also involve open discussion of the values and objectives promoted in planning exercises for any given geographic area, as well as open sharing of relevant information—thereby providing the opportunity for wider knowledge and skill based sets to be used in decision making.

The potential for collaborative local–level/government involvement in coastal IM is illustrated by the positive experiences found among several Environment Canada Atlantic Coastal Action Program (ACAP) sites, community-based projects focusing on environmental quality. Even in such cases, concerns arise: in a recent survey that included several of these projects, Bastien-Daigle and colleagues discovered that ACAP project staff and government bureaucrats seemed focused on quite different outcomes—the former on enabling environmental remediation and community empowerment, the latter on reducing conflict (Bastien-Daigle et al. 2008: 104).

While institutional progress is often slow, there are local success stories in the form of positive actions taken by communities in promoting IM. Through the Coastal CURA partnership, we have seen a diverse range of such actions, from production of a film that captures community voices, describing and demonstrating how different stakeholders can work together in and around Saint John Harbour, New Brunswick, to a clam harvester re-seeding project in Nova Scotia, which proved clams were able to return to depleted areas, with human help, to the work of the Mi'kmaq of Prince Edward Island to document traditional resource use and to starting the process for defining a common vision for all community members around Malpeque Bay.

The Coastal CURA (Community-University Research Alliance)

For the past several years, a unique alliance of four First Nation communities, two fishermen's associations, two universities, and several coastal resource centres has been examining processes of integrated management on the coast, and building local capacity for engaging in these processes. These collaborative community-university activities have been supported by the Coastal CURA project, which is studying and sharing lessons on community involvement in coastal IM in a variety of locations across the three Maritime provinces. Some of these initiatives are government-driven while others are grassroots, with the latter typically relying on community volunteers and receiving limited government support. The diverse initiatives in which our community partners are involved include ecosystem-based management plans (Malpeque Bay, PEI), watershed remediation (Bear River, NS), shellfish habitat restoration and restocking (Annapolis Basin, NS), harbour management (Saint John Harbour, NB), groundfish management (Fundy Fixed Gear Council, NS), aquaculture site planning (southwest New Brunswick), and larger area management plans (Southwest New Brunswick Marine Resources Planning Initiative). The Coastal CURA has examined these real-world community experiences with IM, we present one illustrative example below. Collectively, the experiences we have examined describe the nature of local initiatives, the challenges arising from interactions between community and government, and the grassroots success stories that highlight the different ways communities are working toward a common goal, but with alternative routes toward achieving IM.

Case Study: Mi'kmaq Confederacy of PEI – Plan for IM in Malpeque Bay

Several Coastal CURA case studies, based on local experience, demonstrate the linkages, or lack thereof, between efforts to address local problems by civil society, on the one hand, and policy development and implementation within governments, on the other. From this range of experiences have arisen unique grassroots perspectives from people who have worked to build community-centred IM institutions. We have documented a growing sense of urgency in communities as declines in vital resource stocks and increasing environmental degradation impact on livelihoods. IM institutions and responses must develop more quickly and be built on a foundation of community support if IM is to make a real difference to sustainability. Given space limitations, we present only one case study to highlight a local initiative and to illustrate concerns over the growing disconnect between community and government (Figure 2).

As the Coastal CURA team has reflected on this and other case studies, several key issues emerged as crucial to moving IM forward. First, it became obvious that reducing conflict and ensuring environmental sustainability could not come at the expense of local level benefits or the loss of social equity among users of public resources (see also Cicin-Sain and Knecht 1998: 129). Second, community partners feel that to avoid inequitable outcomes, IM must be a collaborative process where actors negotiate public policies based on multiple criteria and participatory decision-making for a given coastal or marine ecological area (Turner 2000). Increasingly, the Coastal CURA team saw this process as involving the Canadian public in discussions of value systems and objectives that any planning exercises would then promote (Keen and Mahanty 2006: 502).

Community Perspectives on Integrated Management

Our research to date on Maritimes coastal experiences has led us to a set of four major insights to rectify shortfalls, from a community perspective, in how IM is implemented:

A Focus on Community Participation as an Essential Element of IM

A participatory approach to IM clearly requires careful consideration of who should be involved, how they should be involved, and how to support involvement. It is desirable to begin with broad community participation. For example, government should encourage involvement of communities in identifying candidate marine protected areas. At the same time, government documents need to recognize the difference between types of stakeholders: for example, the term "stakeholder" often does not come across well from a community perspective and consideration should be given to use of "community" and "First Nation" instead for many planning purposes.

Incorporating Community Values into IM

Communities want long-range planning for alleviation of poverty, priority for local needs, and recognition of their rights to access local resources (e.g., the hope that youth from the community will have a realistic chance of entering the fishery). This implies close attention to "ecosystem/food-web" connections between vital components of the ecosystem and community livelihoods. Furthermore, within communities, the total life cycle should be considered in protecting livelihoods, so that people old and young have options in terms of phasing in or out.

Problem: Malpeque Bay has been the focus for food harvesting, transportation, recreation and economic development for PEI First Nations for thousands of years. Limited access or total inaccessibility to traditional fishing places, and restricted mobility due to the creation of the Indian reserve system, has resulted in the loss of fishing resources for many First Nation communities in PEI. The region's oyster fishery is strongly dependent on Malpeque Bay for production of spat (juvenile oysters) that supplies many of the Island's aquaculture operations. Tourism operators, aquaculturists, fishers and other users of the marine and coastal environment around the Bay impact the environment and compete for space. Increased and varied use of the region has resulted in conflicts between different resource users. The development of offshore mussel aquaculture that will depend on spat production from within Malpeque Bay and calls for increased aquaculture activity in the Bay will impact on First Nations food, social and ceremonial rights.

Regulatory Powers: Department of Fisheries and Oceans, Environment Canada, Transport Canada, provincial Department of Aquaculture, Fisheries and Rural Development, Provincial Department of Environment, Indian and Northern Affairs Canada, Canadian Food Inspection Agency

Local IM Institutions: MCPEI is a not-for-profit Tribal Council and Provincial Territorial Organization (PTO) governed by a Board of Directors consisting of the Band Councils from Lennox Island and Abegweit First Nations. In response to the growing awareness of ecological links between the various resource sectors and First Nation's responsibilities for effective management of resource harvesting activities, the MCPEI Board of Directors created the Integrated Resource Management Directorate (IRM). This Directorate provides technical advice and assistance to the First Nations, They will direct the progression of the development of an integrated management plan for Malpeque Bay. They have begun a process of identifying resources and stakeholders in the Bay. They have a GIS section that has collected resource use data in the surrounding area for use in this project.

Community Actions: Historical resource reflection of the Mi'kmaq of Prince Edward Island—interviews and documentation of traditional Mi'kmaq resource use—were used to start the process for defining a common vision for all community members, First Nations, and other stakeholders. A film was developed to capture this message and to bring it to a larger audience.

Challenges and Concerns: Each group, be they government, NGOs, communities, non-native fishers, individuals, or visitors has their own specific idea of what constitutes proper use of Malpeque Bay. Each user seems to be able to only reflect on the issues that pertain to their use, and are not able to look at an integrated approach that would cover all aspects of sustainable use of the Bay. Each government department hides behind their mandate and effectively compartmentalizes themselves for protection. An integrated approach to coastal management requires a leadership partner to assimilate and encourage participation by all stakeholders. The leadership partner must be able to share a vision and engage positive steps towards successful attainment of the goal of IM.

Figure 2. Case study on Mi'kmaq Confederacy of PEI and plan for IM in Malpeque Bay

Providing the Legal Space and Local Necessities for Effective IM Institutions

As a fundamental prerequisite, legal space must be made for integrated management; sometimes this will require changing existing legislation, while sometimes it will require enabling legislation. Certain attributes and processes of IM planning institutions also need emphasis. Such institutions should:

- create space for deliberative debate in planning, to help overcome community 'push back' when planning is imposed from above without considering their local needs and values;
- take a long range perspective on inclusivity (e.g., the recognition and authorization of local and First Nation rights), and focus on creating a level playing field for participants so that economic or political clout does not have a disproportionate voice;
- aim for healthy linkages between community and ecosystems, and include a mechanism to have someone who speaks for the ecosystem, identifying potential risks and risk elements, carrying capacity issues and cumulative effects;
- incorporate effective mechanisms for incorporating place-based knowledge into the planning process (as this can often trigger useful local projects) and for sharing information to facilitate "co-learning" (e.g., through public metadatabases and forms of university/community collaboration);
- consider that in some cases, a key ingredient is an "entrepreneur for change" who is given the resources to bridge administrative silos and conflicting uses locally.

Reflecting Multiple Scales in IM Governance

It is important to consider multiple spatial scales in IM. While there may be a tendency to take on large areas (such as large ocean management areas), these may tend to seem too large and lacking in focus when seen from a local scale. Focusing instead (or in addition) on specific localities and specific problems (as the ACAPs do) can improve the efficiency of IM initiatives. Examples include dealing with land-based pollution that affects streams and beaches in the Annapolis Basin, or better planning for Saint John harbour. The "scaling up" of smaller, more focused initiatives, and IM institutions, to the regional and national level should be encouraged, potentially through suitable councils or other deliberative bodies. The resulting cross-scale linkages need to work effectively, since communities are keen to see the resolution of jurisdictional quagmires.

Conclusion

While the Canadian government has made global and national commitments to IM, the Auditor General has found that implementation to date has not produced the desired results (Canada 2005). The Coastal CURA team of researchers has identified several barriers or limiting factors to community participation in IM (described in this paper; see also Kearney et al. 2007). Among the underlying issues is the fact that government and community seem to be operating on different temporal scales (government IM is slow while community needs are immediate), often on different geographic scales (large, administrative space versus local place-based), and with different purposes (coordinate intra/governmental processes, manage conflict versus addressing local ecological and social inequity, ensure access to resources, etc). Other challenges include lack of brokers between community-level and government-level processes, or in other words, troubles in 'scaling up' to government and 'scaling down' to community. Finally the concept of community itself is an issue; if community is seen (wrongly) as something outdated and inefficient, it can be an uneasy fit within modern planning initiatives.

IM is inherently value driven. Since values are not universal, any values underlying IM should first be made explicit, articulated and then debated. This is the core argument of deliberative democracy. We need to build (or support) the institutional settings for IM where this deliberation and debate can happen. To ensure that communities are at the center of this renewal and implementation of IM, we propose that IM incorporate the four key insights needed to support community involvement in integrated management:

- A focus on community participation as an essential element of IM
- Incorporating community values into IM

- Providing the legal space and local necessities for effective IM institutions
- Reflecting multiple scales in IM governance

These considerations support the key message of this paper, a call to achieve the broad potential of the IM concept, particularly the potential for inclusivity and the active involvement of communities. It is clear from our research that there are feasible IM mechanisms which can involve communities, which have their own valid conceptions of IM and indeed undertake successful IM-oriented projects at a local scale. The Coastal CURA, in continuing its work to support community involvement in IM, will be undertaking participatory research, capacity building and knowledge transfer, film making, community participation techniques, community GIS, comparative case studies and the development of indicators. In the course of this work, we look forward to engaging, as individuals and as a team, with government departments and others, across agencies and communities, and across horizontal and vertical boundaries.

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CALLING FOR INTEGRATED MANAGEMENT OF SAINT JOHN HARBOUR

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Coastal CURA

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Abstract

The Canadian port city of Saint John, New Brunswick, has many management challenges, including expanding petrochemical development, international shipping, tidal power, and tourism, agricultural and forestry run-off, pulp and paper mills, oil refineries, freighter and cruise ship terminals, harbour dredging and dredge dumping, and raw municipal sewage outflows. In the midst of this remains an important inshore fishery. Mitigating environmental impacts and juggling the multiple uses of the harbour requires effective integrated management institutions. Jurisdictional overlaps and several federal, provincial and municipal agencies produce fragmentary management efforts. While the 1997 *Oceans Act* promised integrated management and a stronger role for stakeholders, many feel that over ten years have passed without any progress. This paper discusses the concerns of one such group, the Fundy North Fishermen's Association, which has been central to the formation of a number of *ad hoc* committees to address specific management harbour issues, including: dredging, post 9-11 wharf restrictions, liquid natural gas terminal development, and expanding harbour traffic. They have undertaken planning and research, participating in environmental impact assessments, developing monitoring protocols, and evaluating tugboat and shipping damage to fishing gear and subsequently to lobster stocks. Fundy North has experienced first hand the frustrations created by the existing consultation process, in which there are unclear channels of responsibility and authority. Analysis by the Coastal CURA team suggests that strong government leadership is needed to establish an integrated planning board that will facilitate harbour planning and operations.

Introduction

International seaports present one of the most difficult challenges facing integrated coastal management (ICM) today. Significant environmental, social and political challenges are intrinsic to seaports, given their industrial nature, and situated as they are at the mouth of important watershed systems (Dawkins and Colebatch 2006). Exponential growth in seaport infrastructure and activities, taken together with coastal gentrification, has everywhere challenged the capacity of local managers to produce sustainable, green, participatory, and well-integrated management plans that can respond to global environmental challenges (Thom and Harvey 2000). Recent anti-terrorism regulation has only added to the complexity of their task (Stasinopoulos 2003, Goulielmos and Anastasakos 2005). And yet, a survey of seaport governance literature demonstrates that management capacity has not kept pace with this unprecedented growth of management challenges (Brooks 2004; Sherman 2002; Thom and Harvey 2000; Van Gils and Klijn 2007; Wakeman and Themelis 2001). One interesting lacuna is the role that fisheries play in a number of important international harbours around the world; in the little literature that does exist on integrated management of international harbours, the integration of fisheries into management plans is noticeably absent. It would appear that in terms of seaport integrated management "best practice," there is opportunity for global leadership for those who move to address international harbour management issues now.

Integrated coastal management has become the primary mechanism for addressing those critical environmental, economic and social challenges that face coastal communities and resource users (Cicin-Sain and Knecht 1998). Since the 1992 Rio Declaration flagged ICM as vital to sustainable development and to environmental protection, a great deal of research around the globe has demonstrated that wide public participation is the key to success (Tobey and Volk 2002: 290). However, as Gibson (2003) has pointed out, no European Union state has yet enacted legislation to enforce integrated management, much less created institutional arrangements for wide public participation. In the Canadian context, ICM is mandated under the *Oceans Act* (Government of Canada, 1996, Chapter 31), which authorizes the Department of Fisheries and Oceans (DFO) to work "in collaboration" with other persons and bodies, including local stakeholders. Despite DFO leadership, ICM has been slow to develop in Canada (see Guenette and Alder 2007; Kearney et al. 2007). There is a need then to develop capacity at all levels to be involved in integrated management institutions.

The Coastal CURA (www.coastalcura.ca) is a five-year project funded by the Social Sciences and Humanities Research Council of Canada to build the knowledge and capacity across the Maritimes, needed to support community initiatives and community involvement in ICM. The Coastal CURA supports the ecological, social and economic well-being of coastal communities, through cooperative research and capacity building on coastal and ocean management, and on community-oriented governance of coastal resources. The Coastal CURA involves eight partners – two universities (Saint Mary's University and the University of New Brunswick) and six community partners (the Fundy Fixed Gear Council, Acadia First Nation, Bear River First Nation, the Fundy North Fishermen's Association, the Bay of Fundy Marine Resource Centre and the Mi'kmaq Confederacy of PEI, which includes Lennox Island First Nation and Abegweit First Nation). The Coastal CURA is undertaking a number of research initiatives relating to local-level use and management of fisheries, coasts and oceans. These include both site-specific studies and broader policy-level research.

One of the Coastal CURA partners, Fundy North Fishermen's Association, has members that fish in Saint John harbour, and the harbour has served as a case study into ongoing ICM efforts in the Canadian Maritimes. Saint John is one of the largest cities in the province of New Brunswick, with approximately 122,389 people residing in the Greater Saint John area. While it is an industrial city, with interests in oil, forestry, shipbuilding, media and transportation, Saint John has suffered an economic downturn for several decades (especially with the collapse of the shipbuilding industry) leading to population declines. Recent economic growth, particularly in the petrochemical industry, has begun to reverse this trend. The Irving companies are major employers in the region with businesses including eastern North America's first deepwater oil terminal, a pulp mill, a newsprint mill and a tissue paper plant. Canaport LNG, a partnership between Irving and Repsol YFP, is constructing a state-of-the-art liquid natural gas receiving and regasification terminal in the city, the first in Canada, which will deliver gas to both Canadian and US markets.

The Port of Saint John is situated at the mouth of the St. John River on the north shore of the Bay of Fundy and is ice-free year-round. The port handles a wide range of traffic, including liquid bulk, dry bulk, forest and petrochemical products, containers, general cargo, and cruise passengers. It handles an average of 27 million metric tonnes of cargo annually and is one of Canada's key ports. As an international seaport, it is an important part of the regional infrastructure, providing close to 3,000 direct and indirect jobs. It is essential to the province's petroleum, potash, forestry, and tourism industries and to its import and export trade. It is also essential to the livelihoods of a number of fishermen who fish the waters inside the harbour. Fishing has historically been practiced alongside industrial activities in the harbour, but recent expansion of petrochemical and construction shipping has seriously challenged this coexistence.

Since the mid-1950s, the regulation of international shipping has increasingly fallen under the control of international regulatory bodies. The International Maritime Organization (IMO) is the most important of these, and is a specialized agency of the United Nations, established under a convention adopted in Geneva in 1948. The IMO's main task has been to develop and maintain a comprehensive regulatory framework for shipping and it addresses safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. Among other matters, signatory nations agree to maritime safety conventions for international ports. This has brought international standards into harbour management, especially as relates to traffic lanes, and to the interaction of shipping and fishing vessels.

For example, Rule 10 of the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (hereafter COLREGs), notes that fishing vessels "shall not impede the passage of any vessel following a traffic lane" but are not banned from fishing. This is in line with Rule 9 which states that "a vessel engaged in fishing shall not impede the passage of any other vessel navigating within a narrow channel or fairway" (see http://www.imo.org/ accessed February 2009). The IMO also regulates which vessels can utilize inshore waters and a complex system of shipping lanes and signaling systems in international seaports.

When the 11 September 2001 terrorist attacks in the United States highlighted security issues, the United States called on the IMO to institute global shipping security measures (Sokolsky 2005: 36). In 2004, a diplomatic conference adopted a number of amendments to existing IMO regulations (1974 SOLAS), among them, requirements for the completion and approval of port facility security assessments and plans (for the full text of SOLAS see https://www.imo.org/, accessed February 2009).

In the past, Canada made representation to the IMO that its system for updating or creating conventions moved too slowly for technological changes in the shipping industry; the IMO responded by instituting a 'tacit acceptance procedure' that can move amendments of a technical nature through more quickly. More recently, a coalition of government, fishing, oil and tourism industries, environmental groups and marine scientists applied to the IMO to modify the Bay of Fundy Traffic Separation Scheme (shipping lanes) to protect endangered right whales feeding in the Bay (See http://www.rightwhale.ca/shippinglanes-routesnavigation_e.php, accessed February 2009). These changes were approved by the IMO and implemented by Transport Canada in 2003. While this regulatory change was effective, it was also time consuming and required the combined efforts of national and international agencies. As this article will demonstrate, the effort required may have set up a chill mechanism within Canadian bureaucracy.

Another level of bilateral regulation has been undertaken to promote North American security following the events of 9/11 (Sokolsky 2005). As Sokolsky notes, this has primarily taken the form of collaboration between Canada and the US on shipping and port security, and by the 2004 formation in Canada of the Marine Security Operation Centers (MSOCs) to promote interagency cooperation. In part, these bilateral cooperative efforts are in support of the IMO's International Ship and Port Facility Security (ISPS) Code, which also took effect in 2004. As Stasinopoulos (2003) has argued, while 9/11 revealed the "soft underbelly of globalization," subsequent US moves to enhance homeland security often reflected "US 'hegemonic' ambitions and unilateralism in maritime trade." Given Canada's economic reliance on trade relations with the US, port security has been criticized as speedily undertaken without due public consultation in order to satisfy our dominant trading partner. IMO security regulations have been similarly criticized (Goulielmos and Anastasakos 2005; see also Cowen and Bunce 2006).

Under the *Canada Marine Act* (1998), Canada began a major reorganization of its port system (Sherman 2002). A total of 353 of 549 harbour and port facilities across Canada were transferred (to provinces, private enterprises, or local interest groups), demolished, or decommissioned (ibid). Among the remaining ports, 18 independently-managed Canadian Port Authorities (CPAs) were established to operate particular ports on behalf of the Government of Canada. Together these accounted for over 60 percent of Canada's waterborne general cargo (Sherman 2002: 6). Other ports have subsequently applied for CPA status. CPAs are neither public nor fully private organizations (see Brooks 2004). They possess the power to engage in activities related to shipping, navigation and transportation of passengers and goods, may be given Crown land to operate and manage (but not to own), and may acquire and own land in their own name. However, Transport Canada (including Marine Security Regulatory Affairs) is responsible for ensuring that CPAs conduct their affairs in accordance with the provisions of the *Canada Marine Act*, the *Port Authorities Management Regulations* and the *Port Authorities Operations Regulations*, as well as the provisions set out in their Letters Patent. Letters Patent are issued by the federal government to grant port authorities the right to operate a particular port. In 1999, a Canada Port Authority was authorized for the port of Saint John. But national regulation of the Saint John harbour is also impacted by a number of other agencies, including Industry Canada, the Department of Fisheries and Oceans, provincial departments of tourism, agriculture and aquaculture, fisheries, transport, industry and environment, as well as municipal authorities.

Issues and Problems – The Fundy North Fishermen's Association and Petrochemical Expansion

As with other international ports, Saint John harbour might be said to be over-administered and under-governed (see Dawkins and Colebatch 2006). The larger Saint John Harbour area has long been a catchment basin for the most heavily industrialized area in the province, affected by anthropogenic influences ranging from agricultural and forestry run-off, pulp and paper mills, textile plants, the oil refinery, a brewery, freighter and cruise ship terminals, harbour dredging and dredge dumping, as well as raw municipal sewage outflows (in excess of 6 million litres per day – see Vickers 2006). Natural science research has helped to understand these anthropogenic impacts (see Zitko 1997; Hargrave et al. 1997), but mitigating them requires better understanding of and management tools for social and economic behaviour and decision making (see Berkes et al. 1998).

While some environmental challenges have been addressed to a limited extent through the existing environmental impact assessment (EIA) processes and through federal and provincial initiatives in integrated management, progress has been disappointing for many stakeholders. Integrated management promised a much stronger role for them in the planning process (Bastien-Daigle et al. 2008), but in fact, many stakeholders feel that their involvement is tokenism, and both sustainable development and the precautionary approach remain ideals rather than practical outcomes of the process (see Kearney et al. 2007). In addition, public consultation has not always produced good local understanding of or local support for new initiatives, creating divisiveness rather than consensus (see CBC Online News 2007).

The capture fishery has played a significant role in the local economy since before European contact, and remains an important economic generator for most coastal communities. As a result, Fundy North Fishermen's Association is one stakeholder group that has been involved in public consultation for many of the new developments in the region. For example, as many of their members fish in the greater Saint John harbour, they are interveners in the environmental impact assessment for the Eider Rock Oil Refinery project, particularly with respect to the potential impact of the project on the inshore fishing industry and local ecology. They have worked for several years with DFO and Environment Canada to assess the impact on migrating lobsters of harbour dredging and of the dredge dump site off Black Point. In 2008, work began to develop a management plan and monitoring protocol for the dumpsite in addition to the establishment of a formal committee to address the issue. In the post-9/11 security environment, the Saint John Harbour Authority unilaterally denied fishermen access to the wharf facilities in the port city, and Fundy North has been working with harbour authorities to develop alternatives. As part of the HADD (Habitat Alteration, Disruption or Destruction) program as compensation for damage that occurred with the construction of the Canaport LNG terminal, they undertook a ghost trap survey to find and assess the lobster mortality rates in traps lost as a result of tugboat and shipping damage to fishing gear.

In all of these activities, the Fundy North membership has experienced first hand the frustrations created by the existing stakeholder consultation process. While a great deal of academic research is contributing knowledge vital to resolving marine and coastal environmental issues, often there is a disconnect between coastal and marine planning and the knowledge arena. Part of this disconnection problem lies in the workings of the planning institutions – into which stakeholders and the public are invited, but in which little attention has been paid to knowledge transfer. As a result, stakeholders often come to the table determined to protect their own economic interests, and with little knowledge or understanding of broader issues. A single holdout stakeholder can scuttle innovations and responsible management. This has proven disastrous to environmental stewardship and to good management.

In 2007, Fundy North supervised a Coastal CURA Masters student who developed a film to illustrate the planning problems in Saint John Harbour (Bood 2007).

Industrial development in the harbour has created spatial conflicts, with increased tanker traffic and other activities, especially as a result of the expansion of the petrochemical industry. The larger Saint John Harbour itself is facing new and increasing planning pressures linked to global issues (see Vandermeulen 1996), including a growing tourist presence that includes everything from cruise ships to pleasure craft, all occurring within a new restricted security environment (see Cowen and Bunce 2006).

In order to address expanding management problems, several ad hoc committees have been formed in the past few years, including: the Harbour Traffic Committee, the Dredge Dump Working Group, the Saint John Wharf Committee, and the Canaport LNG Community Liaison Committee (Fundy North Fishermen's Association serves on all of these). However, planning and management remains ineffectual with no overarching or coordinating authority. As committees have no real authority, there are often long periods between meetings when momentum is lost, and no government agencies have taken responsibility for carrying ideas into action. Transport Canada, for example, has argued that it would be difficult to improve marine traffic lanes to avoid fouling fishing gear, as the IMO presents a significant hurdle to adapting shipping lanes. There are currently no initiatives to improve spatial planning of the sort common in other international ports (see for example, van Gils and Klijn 2007) and despite marine spatial planning initiatives elsewhere (see Maes 2008). This is leading to significant environmental consequences—as was demonstrated this summer with the ghost trap survey undertaken as part of the Canaport HADD program.

In order to address these and other environmental challenges in southwest New Brunswick, we believe that evidence-based ocean and coastal policy must make better and more informed use of all available knowledge. And new thinking must be brought to bear on the institutions that will be required for effective integrated management.

But to date, no regulator has agreed to take responsibility for resolving these problems.

Lessons Learned: ICM and the Harbour

Several recommendations have come from local users as to management solutions in Saint John Harbour. Fundy North Fishermen's Association has suggested one government agency must take the lead in establishing an integrated planning board that will facilitate harbour planning and operations. They themselves have taken the initiative to resolve issues on a case-by-case basis with ad hoc committees. However, the ICM literature also suggests that new management institutions and policy initiatives be guided both by the local specificities in Saint John harbour and by best practices from elsewhere (Allan and Curtis 2005; Stojanovic et al. 2004). Stojanovic et al. (2004: 290) in particular have suggested that nine factors contribute to successful ICM, including management that is participatory, long term, focused, incremental, adaptive, comprehensive, precautionary, co-operative, and contingent. What this means in practice, however, is unclear.

A recent article on harbour management innovations in Sydney harbour, Australia, may provide some answers (Dawkins and Colebatch 2004). Institutions are said to rest on three mutually interactive supports: a shared framework of meaning, underlying values, and an organizational focus. In terms of Sydney harbour, Dawkins and Colebatch demonstrate that agencies and stakeholders had diverse values, although shared values did exist. While different actors agreed on the need for joint action in the interests of the harbour, they operated under different meanings of this need, and some were more interested in cooperating than others (particularly officials as opposed to the users). What was needed in this case was government leadership in the constitution and maintenance of the network, followed by "managerial craftsmanship" to support framing, activation, mobilization, and synthesizing of a harbour management approach.

The innovation of a harbour manager in Sydney created one policy entrepreneur who was dedicated to overcoming silo bureaucratic structures and lack of communication between agencies. But it must be added that this required the right conditions. In the case of Sydney's harbour master, no new levels of power or institutionalization were put in place. Indeed, Dawkins and Colebatch report that the harbour manager in Sydney saw no need for special powers, as he was afraid that these would have stepped on bureaucratic toes, saddled him with routine functions, encouraged agencies to limit interaction with him to the specified activities under his control, and kept the focus off the big picture. Instead, he focused on changing perceptions and relationships – in the Coastal CURA we have called this sort of initiative "co-learning." Over three years, his office used the small resources under their control to identify needs and opportunities, develop tools, strengthen partnerships, foster collaboration, develop new ways of working, and provide models for innovation (others have called this approach "interactive governance" – Bavinck et al. 2005). In the Sydney harbour case, this innovation was so successful, that when the state government allowed the position to lapse after three years, the process of collective management that had developed was formally recognized, and core agencies collaborated together to keep these operations going. As Dawkins and Colebatch (2004) note, policy in this scenario is less and less a product of a central authority, and more and more made in a process involving a plurality of both public and private organizations, and an outcome of continuing interaction between different sorts of organizations.

Conclusion

Canada prides itself on developing a leadership position in marine and coastal planning (see Ricketts and Harrison 2007), implementing large ocean management areas (LOMAs) and marine protected areas, and experimenting with the institutions that will be required for sustainable utilization of coastal and ocean resources (as with the Eastern Scotian Shelf Integrated Management Initiative or ESSIM, see Walmsley et al. 2007). However, much remains to be done, as the situation in southwest New Brunswick attests. While a great deal of academic research is contributing knowledge vital to understanding marine and coastal environmental issues, often coastal and marine policy and the knowledge arena are disconnected. Part of this disconnection problem lies in the workings of the planning institutions—into which stakeholders and the public are invited, but in which little attention has been paid to knowledge transfer or to co-learning. It should be no surprise then that stakeholders often come to the planning table solely to protect their narrow economic interests, and with little knowledge or understanding of broader issues, including environmental issues. The existing committees in Saint John harbour have helped break down these barriers to understanding, but as people who have the authority to make changes are not present at the meetings, politics rather than sound planning is determining coastal and ocean management. Perhaps information gets condensed as it is sent further up the chains of command so that mechanisms for knowledge sharing are not creating the right policy changes. Meanwhile, science is predicting the collapse of our shared marine ecosystem (Worm et al. 2006). Best practice from other settings, taken together with the advice from ICM literature can do much to address these problems, but only if a lead agency or actor is enabled to address the core problems of lack of coordination in innovative ways.

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REVIEWING CLIMATE CHANGE IMPACTS ON COASTAL HABITATS, MARINE INVASIVE SPECIES, AND WATER QUALITY IN THE GULF OF MAINE

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Introduction

In its 2007–2012 Action Plan, the Gulf of Maine Council on the Marine Environment (GoMC) identified understanding the impacts of climate change on various aspects of the Gulf of Maine environment as priorities for action. The GoMC's Climate Change Network recently completed three papers addressing the impacts of climate change on coastal habitats, marine invasive species, and water quality in the Gulf of Maine. The findings of these papers are summarized here. All three papers (Horton and McKenzie 2009 a, b, and c) can be obtained from the GoMC's publications Web page (http://www.gulfofmaine.org/council/ publications/).

The purpose of the three documents is to identify what research has been carried out in relation to climate change and its effects on the Gulf of Maine. Specifically, they focus on:

- habitats and climate change, including information on geology, topography, and watersheds;
- invasive species, habitats, oceanography, and the indicators of climate change; and
- streamflow measurements, sediment contamination, effects of precipitation changes on watercourse erosion rates, and the consequences to water quality in freshwater and marine environments.

The focus is to bring together the available information in publications and maps and to begin to identify where gaps may exist. Recommendations for further work are subsequently suggested.

Climate Change and the Gulf of Maine

Much of the Gulf of Maine as we know it today was carved by repeated movement of ice sheets advancing and retreating. This has left a unique and beautiful underwater landscape as the glaciers melted and the sea level rose. This geologic history combined with the earlier development of the Appalachians has also created a large watershed and a variety of coastal habitats. As some aspects of the climate appear to be changing at a more rapid rate than previously known, scientists are becoming aware of the need to consider the possible effects of climate change on these habitats and species within.

Wake et al. (2006) examined recent climate change in the Gulf of Maine and adjacent regions by looking at historical data for a number of indicators. These mostly terrestrial indicators included timing and magnitude of meteorological, hydrological, and phenological events over the last 100 years and generally indicated a trend toward a warmer, wetter climate for the region. Both sea level rise and sea surface temperature, the two marine-specific indicators chosen, showed upward trends.

Future climate change for the region can be summarized from the work of the Intergovernmental Panel on Climate Change (IPCC 2007) (Table 1). Again, the trend is toward a generally warmer, wetter environment.

Variable	*Direction of change*	*Amount of change*
air temperature	↑	2°C to 3°C
sea surface temperature	↑	1.5°C to 2.6°C
precipitation	↑ (particularly fall and winter)	
storms, coastal erosion	↑	
sea-level	↑	0.4 m to 0.5 m

Table 1. Changes to climate and sea level by the year 2100 for the Gulf of Maine Region (after IPCC 2007)

Coastal Habitats

The first of the three papers is titled 'Identifying Coastal Habitats at Risk from Climate Change Impacts in the Gulf of Maine' (Horton and McKenzie 2009a). This background report found that isostatic rebound is occurring in New Brunswick, Maine, New Hampshire, and Massachusetts but that much of Nova Scotia is still subsiding. This may influence the development and destruction of habitats on the coastal margins as coasts are particularly vulnerable to changes in climate. Sensitivity maps were used from Canadian and American sources for coastal regions. Wetlands are also listed as vulnerable and Ramsar conventions are identified for both sides of the border.

The coastal habitats are broken down into seven categories structured on the *Habitat Primer* (Tyrrell 2005) found on the GoMC website. Each category is described and possible effects of climate change are identified based on studies within the Gulf wherever possible. Included is a quick reference table of habitat types versus the main impacts of climate change: temperature, precipitation, storms, and sea level rise. Cause and effect are colour coded for easy distinction.

Generally it was found that both air and sea surface temperature affect coastal habitats and that increases will lead to loss of habitat and changes in species composition. Precipitation increases may lead to increased sedimentation and turbidity, therefore affecting photosynthesis and hence food webs dependent on key aquatic species. Storms have one of the greatest negative impacts with increased severity of storms destabilizing substrate and dislodging species. The concerns also raised are the possible increases in frequency, which could disrupt the ecosystems' ability to recover between events. Concluding is sea level rise, which may lead to flooding and, where human habitation has encroached, coastal squeeze or loss of valuable habitats such as salt marshes.

Marine Invasive Species

The second paper, titled 'Identifying the Possible Effects of Climate Change on Marine Invasive Species - a Background Report' (Horton and McKenzie 2009b), focuses on the synergistic effect of climate change impacts with the increasing threat of non-indigenous species. Included in this report are descriptions of the terrestrial, freshwater, and marine environments with an emphasis on the marine habitats and oceanography. Invasive species are defined and an appendix of the traits of these species is included. The main vectors are also identified. It was found that one of the greatest methods of species relocation is from ballast water and that steps are being taken to minimize the risks by government departments in both countries. However, government Web sites in neither Canada nor the United States have shown any work combining research on invasive species and climate change.

Water Quality

The third paper, 'Identifying the Possible Effects of Extreme Precipitation and Other Climate Change Impacts on Streamflow and Water Quality in the Gulf of Maine' (Horton and McKenzie 2009c), focuses primarily on the climate change effects on terrestrial and freshwater systems, particularly the watershed and how they impact on the marine environment. Extreme precipitation events increase discharge and can lead to scouring, flooding, sediment build-up, and a decrease in water quality. Another aspect of changes in precipitation in regards to streamflow is the lack of water for periods of time. It is projected that there may be changes to the quantity and state of water falling in each season. There have already been phenologic changes documented in the terrestrial environments that may be linked to earlier seasonal changes such as ice in/out dates. This could lead to problems with too much or too little water availability for ecosystems. Sedimentation, the consequence of this extreme pattern, is a major consideration for the coastal ecosystems. Not much work has been carried out in the GoM itself but studies in other areas can be extrapolated for use in this region. In the GoM region the possible increase in rain-on-snow events may be the most damaging to the environment and sensitive ecosystems such as wetlands.

Conclusion

In all the reports gaps were identified and further work suggested. The major gaps were categorized as:

- categorization of authority and responsibility;
- definition confusion;
- scientific study: fragmentation of information and research polarization;
- map varieties;
- multitude of organizations and protection orders;
- lack of legislation;
- modelling, software choices, and different model assumptions;
- lack of focus on the Gulf of Maine region;
- regional boundaries, disjointed results, and lack of standardization;
- grey literature and accessibility; and
- out of date material.

Often the gaps are universal and not subject specific. For example access to information, confusion over responsibility of government or non government organizations, and a general lack of focus on issues surrounding the Gulf region, to name a few. There is very good work being conducted by scientists but availability and awareness of that work is not always obvious.

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MEDIATION APPROACH TO THE INTEGRATED MANAGEMENT OF THE FISHERIES

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Abstract

The Canadian government has identified both in the Oceans Action Plan and the *Oceans Act*, and in their participation at the United Nations Conference on Environment and Development (UNCED) in 1992, their willingness to participate in integrated management. However, due to the finite nature of natural resources such as the fisheries, and the number of stakeholders who share their economic, environmental, political, cultural and social values (Daigle et al. 2006: 25), there will always be disputes concerning them. Disputes over natural resources are referred to as Environmental disputes, and often they arise as a result of the different views over what constitutes good policy for the environment (Boscow and Wheeler 1984), legislation, management and access to resources. Consultation in which fishers and government officials are involved in has proven to be both ineffective and inefficient. Alternative methods of dispute resolution processes such as mediation have the capacity to converge horizontal and vertical linkages in societies and therefore they can address all interests, concerns and levels of regulation. Therefore, it would be to the benefit of the government to create a forum with mediation as the theoretical approach when establishing plans for integrated management with stakeholders. Not only can mediation be used to resolve disputes, but also as a precautionary measure to mitigate them.

Introduction

Canada has the largest coastline in the world, which is approximately five million square kilometers and includes the Pacific, Atlantic and Arctic oceans (Boyd 2003: 196). Due to the finite nature of natural resources such as the fisheries, and the number of stakeholders who share their economic, environmental, political, cultural and social value (Daigle et al. 2006: 25), there will always be disputes. Disputes over natural resources are referred to as environmental disputes, and often they arise as a result of the different views over what constitutes good policy for the environment (Boscow and Wheeler 1984), legislation, management and access to resources. Environmental disputes are further characterized by inter-group conflicts, which occur as a result of "real differences between groups in terms of social power, access to resources, important life values, or other significant incompatibilities" (Fisher in Deutsch and Coleman 2000: 167).

An independent review, Improved Decision Making in the Pacific Salmon Fishery in British Columbia, conducted by the Institute for Dispute Resolution at the University of Victoria, clearly identified six issues within the consultation process which were causing conflict within the Pacific salmon fisheries (Owen et al. 2001: 9). Due to space limitations, only three will be discussed in the paper. Further insight into issues with consultations between the Department of Fisheries and Oceans and stakeholders is provided by Charles, Bull, Kearney and Milley (2007). The Atlantic Fisheries Review Policy makes the claim that disputes are impeding progress on other fisheries management issues (Fisheries and Oceans Canada 2004a). This is demonstrated the Case Study of the Fundy Fixed Gear Council who established community based management of the fishery in the Nova Scotian Side of the Bay of Fundy (Charles 2006; Charles, Bull, Kearney and Milley 2007).

If the Canadian government is truly committed to supporting and participating in the integrated management (IM) of the Oceans as they state in the Oceans Action Plan, Atlantic Fisheries Policy Review and in their participation at UNCED in 1992, then conflicts among stakeholders must be addressed and an alternative to consultation must be established. The elements which are conducive to IM are identified by Kearney, Berkes, Charles, Pinkerton and Wiber 2007 in their article, “The role of participatory governance and community-based management in integrated coastal and oceans management in Canada,” and by Lee (1993) who advances a similar theory. IM in the fisheries not only addresses the specific needs of communities which improves sustainability, but it can also increase both equity and efficiency in the fishery and community if effective mechanisms for resolving disputes are established (Charles, Bull, Kearney and Milley 2007). Due to the different types of legitimacy within societies and communities, the ability of the government to exert power over natural resources is limited (Lee 1993). Alternative methods of dispute resolution (ADR) such as mediation have the capacity to converge horizontal and vertical linkages in societies and therefore they can address all interests, concerns and levels of regulation. If the government is seeking both short-term and long-term resolution and consensus on policies for the management of the oceans, it would be in their best interest to engage in precautionary and reactionary measures of ADR such as mediation with stakeholders who are dependent on the resource.

I will begin this paper by generally discussing what conflicts are and the reason that they arise within environmental sectors such as the fisheries. Secondly, I will address issues of conflict in Canadian fisheries using case studies from the Pacific and the Atlantic fisheries. A significant amount of the content on the Atlantic fisheries and IM in this paper was borrowed from work done by members of Coastal CURA. The case studies will illustrate that the current approaches being taken to managing the resource are causing conflict and are not conducive to plans for IM. Finally, in response to the failure of the current approach to managing the fisheries, I will conclude by suggesting a different framework that could be used. The framework is based on the theoretical values of ADR and mediation.

Environmental Conflicts

Elizabeth Swanson (1995), in Environmental Conflict and Alternative Dispute Resolution, defines disputes as “a controversy or conflict, not merely a contrast between rights and interests recognized by the law” (p. ix). Conflicts and disputes therefore are perceived incompatibilities between interdependent people (Folger, Poole and Stutman 2005: 4). Folger, Poole and Stutman (2005) further explain that the most important feature about conflict is the interaction between the parties because disputes are created and continue due to the behaviors of the parties involved and the reactions to one another (p. 4). Furthermore, conflicts become even more complex as a result of the unique points of view and experiences that disputants bring to the table. Environmental disputes are particularly fascinating because of the finite nature of natural resources and the number of stakeholders who share in their economic, environmental, political, cultural, and social value (Daigle et al. 2006: 25).

Boscow and Wheeler (1984) provide insight into the sources for environmental disputes. They argue that conflicts arise between stakeholders who are dependent on a natural resource such as the fisheries, as a result of their inconsistent views as to what constitutes good policy, management, legislation and access to the resource. These intergroup conflicts therefore “are not simply a matter of misperception or misunderstanding; instead they are based on real differences between groups in terms of social power, access to resources, important life values, or other significant incompatibilities” (Fisher in Deutsch and Coleman 2000: 176). Incompatibilities however, are not by themselves grounds for conflict because parties can have differences or disagreements but live in a harmonious co-existence. It is when these incompatibilities prompt disputing parties to interfere in each others’ desires, goals, personal comforts or communication preferences, and one party attempts to control another party in order to deal with the incompatibility resulting in antagonistic emotion, that conflict arises (Folger, Poole and Stutman 2005: 5). Furthermore, conflicts become exacerbated when disputing parties only have partial information about data that form the basis for policies and other management schemes. As a result, parties will often form an inaccurate idea of how policies and management schemes will affect them. However, even if parties do observe the same data and information, often they will have entirely different conclusions about it based on their particular knowledge, experience or stake in the outcome. Fisher explains that often the real sources of conflict are further aggravated because of the subjective process that parties employ to "view and interpret the world and in how groups function in the face of differences and perceived threat" (in Deutsch and Coleman 2000: 167). Consequently, "even if there is no disagreement about the facts, there may still be legitimate differences of priorities, values and attitudes toward risk" (Boscow and Wheeler 1984: 10) in the environment. These elements which characterize environmental conflict are illustrated in the case of the Pacific salmon fishery of British Columbia.

In May 2001, the Institute for Dispute Resolution at the University of Victoria in British Columbia released *An Independent Review of Improved Decision Making in the Pacific Salmon Fishery.* Fisheries and Oceans Canada (DFO) initiated the review. The purpose of it was to "improve decision-making processes based on principles of administrative fairness, such as transparency, consulting those affected and providing reasons for decisions" because "it is critical to the future of the Pacific Salmon Fishery" (Owen et al. 2001: 3). It concluded that the most prominent issue causing conflict in the Pacific salmon fishery was the ineffective and poor consultation process between the DFO and other stakeholders (Owen et al. 2001: 8).

Charles, Bull, Kearney and Milley (2007) offer insight into the inadequacies of consultation practices by providing a brief history about why the DFO resorted to consultation with stakeholders. The begin by explaining that it became evident to DFO that the management procedure implemented in the second half of the twentieth century was inadequate. Illegal fishing and overharvesting resulted when fishers were excluded from management decisions as a result of the "polarized view of the world" in which government regulators were believed to be "protectors of the resource" and fishers were seen as "selfish exploiters." As a consequence of their exclusion, fishers were not accepting of the regulations and purposely acted against them (Charles, Bull, Kearney and Milley 2007: 279). Eventually it was discovered that the polarized view was dysfunctional and therefore, the DFO decided to participate and promote consultation with stakeholders. Consultations were a process where "government discussed management measures with the industry prior to implementation. However, attending consultations did not equate to decision-making power and, as a result, the government imposed regulations did not receive broad acceptance" (Charles, Bull, Kearney and Milley 2007: 279). The issues with consultation processes identified in the 2007 paper by Charles et al. are also the basis for the problems illustrated in the document created by Institute for Dispute Resolution about the Pacific salmon fishery. This paper will discuss in some detail, three of the six problems with consultations in the Pacific salmon fishery of British Columbia.

The fundamentals of the consultation process consist of "protocols, policies and standards of practice association with consultation and decision making" (Owen et al. 2001: 8). The first issue is that there is a clear lack of trust among parties, which can be partially attributed to the "lack of consultation protocols and standards of practice. It is also a reflection of the lack of commitment to common principles of management and participation" (Owen et al. 2001: 8). Some participants feel as though some stakeholders have more privileges than others and therefore they have more access to decision makers; the privileged have developed relationships with DFO who meet their needs at the expense of others. The underprivileged believe as a result, that their views are often dismissed without serious consideration. Furthermore, many people in the DFO feel unfairly targeted by participants. Consequently, there has been a deterioration in relationships amongst stakeholders causing tension, anxiety and conflict (Owen et al. 2001: 8). The "clear lack of consistency in approaches to consultation, and the lack of clear and specific standards for effective consultation" (Owen et al. 2001: 9) have also contributed to difficulties amongst stakeholders. Furthermore, reliable information regarding ongoing consultation processes was difficult to access and stakeholders received conflicting information and messages from individuals in DFO. A similar case in point is that which has occurred in the clam lease case in Digby and Annapolis Basin, Nova Scotia. A third reason cited in the document for problems with consultations is that stakeholders felt frustrated by DFO in their "apparent failure to act on the advice they have provided in the past" (Owen et al. 2001: 12). It is evident in these examples that stakeholders' had become disenchanted and aggravated with consultation processes, therefore creating an atmosphere for disputes to flourish in the management of fisheries and oceans. A policy review from the Atlantic fisheries in Canada cites conflicts between stakeholders as having negative effects on the ability to manage the resource as well.

The *Atlantic Fisheries Policy Review* (AFPR) (Department of Fisheries and Oceans 2004a) from the *Policy Framework on the Management of Fisheries on Canada's Atlantic Coast* (Department of Fisheries and Oceans 2004b), released in 2004, also specify that disputes and difficulty in decisions over management are impediments to any sort of progress in the IM of the natural resource. The paper states that the traditional approach taken by DFO is too paternalistic, and those who share a stake in the resource are not given the opportunity to share their knowledge. Furthermore, the last comprehensive review of management policies was completed twenty years ago and therefore it is argued that the policies lack relevance and significance (Fisheries and Oceans Canada 2004a).

The paternalist approach being taken by DFO and the inability of stakeholders to share their knowledge in an effort to establish an IM plan led to the creation of the Fundy Fixed Gear Council (FFGC), a groundfish community management board (Charles 2006). The FFGC was established in 1996 in the Bay of Fundy on the Nova Scotian side (Bull 1998 in Charles, Bull, Kearney and Milley 2007: 287) as a result of a series of protests and strategy meetings by fishers. Protests developed after DFO imposed output controls on the groundfishery, a management measure which inshore fishers believed was in direct contrast to the system effort and biological controls which promoted resource conservation and social equity. Furthermore, the DFO made the decision not to limit "the output of individual fishing enterprises per fishing trip" (Charles, Bull, Kearney and Milley 2007: 281) and as a result fishers feared that the larger boats would be able to fish during harsh winters and catch the entire quota before the smaller boats ever had the opportunity to even begin fishing. In 1995, efforts were made by fishers to create a system of distributing fish quotas allocated to them through trip limits and discussed their vision of the fisheries at a workshop. The goals established were to be achieved through community-based management and a request was made to the government to sub-allocate the total Scotia-Fundy fixed gear allocation of cod haddock, and pollock into "a number of discrete community quotas."

The management system that the fishers had established was "soon threatened by the real or perceived threat that the federal government, in collaboration with a group of license-holders comprising of the largest boats in the fleet, would scuttle the efforts by imposing a system of individual transferable quotas (ITQs)" (Charles, Bull, Kearney and Milley 2007: 282). Protests ensued, and a moratorium was put on ITQ's for a year for the fixed gear groundfish. Furthermore, an agreement was made to allocate fixed gear groundfish quotas by area, rather than by fishing sectors and community management boards would determine the allocation. Thus, the FFGC was born when the Digby-Annapolis fishers saw an opportunity to create community-based management. The FFGC not only is successful in sharing quotas amongst its members, but they have also established a "system to resolve allocation conflicts, they maintain livelihoods through an equitable allocation of fishing opportunities and handle compliance through its own self-managed Infractions Committee" (Charles 2006: 6). Compliance and inclusion is secured as fishers must sign a civil contract with the FFCG and belong to one of the two associations in order to participate in the fishery. Furthermore, the two fishers associations in the area, the Bay of Fundy Inshore Fisherman's Association and the Maritimes Fishermen's Union, Local 9, have equal representation and decision-making powers. It is as a result of conflict over what constitutes good policy in the fisheries that the FFGC was established. Although it is one positive consequences of the dispute, there is still a fundamental problem with the approach that the government took to begin with; it was not integrative in strategy.

Kearney, Berkes, Charles, Pinkerton and Wiber (2007) in their article "The role of participatory governance and community-based management in integrated coastal and oceans management in Canada" suggest methods of consensus building and cooperative management schemes. It can be argued that the methods are based on theories of mediation. The elements which they provide are required if the government is genuinely interested in participating in the IM of the fisheries. They begin by explaining that one of the most fundamental challenges of coastal communities lies in the fact that resources that they are dependent on such as the fisheries, are subject to a mix of jurisdictions and furthermore, First Nations must deal not only with these government structures but treaty realities or a lack there of (p. 81). The authors suggest that now is a critical time for coastal communities and the various government levels to make efforts to balance economic, social and environmental needs. The basis for the government's initiatives for IM were predicated on evidence that systematic input from stakeholders who are directly dependant on resources was required in order to manage multiple values and outcomes and to ensure ecological sustainability and economic development. In order to do this and to increase participation by stakeholders, "community must be understood not just as a part of the 'social' component of sustainable development but as a reality that integrates all social, economic and other attributes, at a particular organizational level" (Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 81). The authors then outline nine elements that are required for community participation in IM to be successful. Only four of the nine will be discussed because they are most relevant, however, all nine are based on values and theories of ADR and mediation.

The first component the authors outline is that paradigms must be shifted by DFO sharing power with stakeholders and stakeholders sharing power among themselves. In doing so, competition will cease and more can be achieved through cooperation (Pinkerton 1996 in Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 88). Ensuring sufficiency of information is also significant in creating an atmosphere where consensus building can take place. The authors suggest that "real progress is not likely to be made until there is a more widespread acceptance of new ways of approaching science, which includes skills, practices, and networks as legitimate forms of knowledge in addition to mental representations and theories" (Holm 2003 in Pinkerton 1996 in Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 89). Therefore knowledge cannot come solely from one source such as government information gathering sessions just because they are perceived to have more social power. In order to obtain fully informed scientific harvesting decisions, knowledge of Ocean and Coastal users must be included The government cannot overlook it just because other stakeholders knowledge might be 'tacit or dissimilar in cognitive culture'. Internal community stratification must also be addressed so that local elites do not maintain special power in community based management, otherwise they might not share the benefits of the resource equally (Agrawal and Gibson 1999 in Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 89) and existing conflicts and equality will become even more entrenched in the community. Power imbalances amongst stakeholders must first be neutralized and this can be achieved in three ways. An "institutional design for participatory decision making" can include a number of different methods of controlling the use of excessive authority such as giving the power to community members to fire local officials. Local elites can be counterbalanced by creating strong relationships between advocacy groups, unions and community organizations. Thirdly, legislation can be established which "makes domination much more expensive than cooperation and may not only neutralize power imbalances but convert it into a productive force" (Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 89). Cross-scale linkages must also be established in order to build cooperation and establish consensus amongst stakeholders. Horizontal cross scale interaction refers to crossing geographic space or across sectors and vertical refers to crossing levels of organization. If these linkages are achieved, an opportunity is created to bring management closer to stakeholders and communities who are most affected by decisions (Young 2002 in Kearney, Berkes, Charles, Pinkerton and Wiber 2007: 89). Furthermore, it can be argued that if other stakeholders are taking on responsibilities, it lessens the load of the governments who then can focus on other issues which might need immediate attention.

Lee (1993) argues similar ideologies to those advanced by Kearney, Berkes, Charles, Pinkerton and Wiber (2007). However, Lee proposes that the approach should be identified as Adaptive Management. He explains that although in theory governments ultimately have the decision-making authority, in practice, their powers are limited due to legal pluralism (p. 88). Legal pluralism is based on different types of legitimacy such as international law, state law, religious law, customary law, and forms of self-regulation (Max-Planck Institute 2009). As a result Lee (1993) contends that it would be in the best interest of the government to participate in

ADR processes (p. 88); it is indispensible for resolving disputes because ADR is able to cross all horizontal and vertical linkages and address all levels of regulation. Furthermore, this type of collaboration and collective dialogue contributes to system planning and can contribute to the health and welfare of the fisheries and oceans. System planning in natural resources "involves trying to think about the interactions among the hundreds of activities affecting the abundance and health of the Oceans…" (Lee 1993: 43), which is an IM based objective referred to in the *Atlantic Fisheries Policy Review.* When an atmosphere of consensus building is created through forums such as mediation, parties develop "power with others" which entails a certain degree of trust. This idea was developed by Mary Parker Follet in the 1920s. She proposed that even though power was usually conceived of as "power over others," it was also possible to develop the conception of having "power with others." She envisioned this type of power as jointly developed, coactive and non-coercive (Coleman in Deutsch and Coleman 2000: 111). During mediation, parties' positions and more importantly, their interests become understood and they learn to appreciate others. While positions shift, they change the character of conflict among them. Additionally, common interests are recognized and a proposal for action can be established based on their common interests. Creative solutions can create results based on objective criteria because decisions are developed from exploration, fairness and mutual interest. Therefore, any commitments made between the actors, whether short-term or long-term, are more likely to be upheld because all of the parties contributed and their relationships were preserved (Trace 1995).

Ultimately what is being suggested is that the government must shift its approach from one of paternalism to one where they are sharing power with stakeholders. If ocean and coastal users have an equal opportunity to contribute their knowledge and engage in meaningful dialogue with the government over management of natural resources, it would be much easier to establish consensus and long-term commitment. These are theories championed by ADR, and more specifically, mediation. Furthermore, a process can be developed in the direction of IM in which a forum is created based on a mediation approach where conflicts can be discussed, future disputes can be anticipated, and stakeholders have an equal voice in plans for IM.

The Benefits of Mediation: Working Towards IM

In 1992, at the Rio de Janeiro United Nations Conference on Environment and Development (UNCED), the Government of Canada signed and ratified the document legally binding them to the regulations stated the conference document, Agenda 21 (United Nations 1992). Agenda 21, Chapter 17, "Protection of the Oceans, All Kinds of Seas, Including Semi-Enclosed Seas, and Coastal Areas and the Protection, Rational Use and Development of their Living Resources" discusses and proposes strategies for IM. The document suggests that IM can provide stakeholders of the oceans with the opportunity to "provide for an integrated policy and decision-making process, including all involved sectors, to promote compatibility and a balance of uses" (United Nations 1992). IM is described in the *Atlantic Fisheries Policy Review* as:

> … an Ecosystem-based approach to management that aims to ensure sustainable development of coastal and marine resources. It is a planning process in which interested parties, stakeholders and regulators reach general agreement on the best mix conservation, sustainable resource use and economic development for coastal and marine areas. Goals include sustainable use and economic diversification (Fisheries and Oceans Canada 2004a: 43).

With the creation of the *Oceans Act* in 1996, the Canadian government has committed to "managing them [the Oceans] wisely" (Department of Justice Canada 1995: 3). Section 31, IM Plans of the *Oceans Act*, states:

> 31. The Minister, in collaboration with other ministers, boards and agencies of the Government of Canada, with provincial and territorial governments and with affected aboriginal organizations, coastal

communities and other persons and bodies, including those bodies established under land claims agreements, shall lead and facilitate the development and implementation of plans for the IM of all activities or measures in or affecting estuaries, coastal waters and marine waters that form part of Canada or in which Canada has sovereign rights under international law (Department of Justice 1996).

In 2004, the Government created Canada's Oceans Action Plan. The plan states that "our oceans are important and present an opportunity to make a greater contribution to our well-being and to benefit from the protection of critical marine environments" (Fisheries and Oceans Canada 2004b: 3). IM supports "working together among governments; bringing sectors and citizens together using more open and transparent management and advisory bodies; pursuing ecosystem-based approaches; to base decisions on strong scientific advice and apply conservation and protection measures in the environment…." (Fisheries and Oceans Canada 2004b: 9). The question is, how should IM processes proceed? Consultation processes have proven to be inadequate and unsuccessful. Because the definition of IM provided in the *Atlantic Fisheries Policy Review* and the theory of ADR are similar in purpose, it can be argued that mediation would be an appropriate theoretical approach to use in establishing processes for management of the fisheries and oceans.

Alternative Dispute Resolution

ADR processes such as mediation and negotiation began as a result of dialogue between academic lawyers and legal practitioners and their disenchantment with the adversarial system (Pirie 2000: 6). The fundamental elements of the "rights or entitlement based" approach which dominates the resolution process in the adversarial system, establishes a winner and a loser and resources are imagined as fixed or "zero sum." Furthermore, it entails value claiming and haggling (Morris 2002) and as a result, communication and relationships between disputants become tense and no effort is made to preserve them. Therefore, any agreeable relations that may have been in existence prior to litigation completely deteriorate during the process. Additionally, it is argued that litigation is more time consuming, complicated and costly than mediation (Jasper 2000) and the outcome is sometimes determined by which party has the "deepest pockets." The objectives of ADR are distinctly different from those of the adversarial system. Because neither the adversarial system nor consultations are appropriate for environmental conflicts, it can be argued that mediation is.

Consensual ADR refers to mediation, negotiation or facilitation processes where disputants themselves decide to participate in the procedure of collectively discovering a method for resolution (Morris 2002). It can be argued that mediation would be the most appropriate process to use between stakeholders in environmental disputes because it involves the use of a third party neutral. Parties, who are perceived to have power due to economic, political or cultural circumstances, are regarded as having the same knowledge as parties perceived to have less power.

Mediation is defined as "a method of settling disputes outside of a court setting; the imposition of a neutral third party to act as a link between parties; similar to arbitration and conciliation" (Gifis 1998: 295). Mediators that are selected are mutually agreed to by parties and therefore the mediator is neutral and independent. Independence implies that the "mediator will have no economic, emotional, psychological or authoritative affiliation with the parties involved in the conflict" (Barsky 2000: 123). Neutrality suggests that the mediator must have "no decision making authority and no stake in a specific type of outcome…and no pre-existing bias" (Barsky 2000: 123). Because no human being is without bias, mediators can conduct self-assessments for the biases and any biases that the mediator intends on bringing into the mediation process should be disclosed (Barsky 2000: 123). Co-mediation, the use of more than one mediator, would also be advantageous because often in disputes over natural resources such as the fisheries and oceans, there are many parties and difficult issues to address (Barsky 2000: 186). With more than one mediator, responsibilities are divided and shared and therefore it is easier for them to watch listen and "access the interaction in progress" (Picard 1998 in Barsky 2000: 186). Furthermore, co-mediators can offer one another both instrumental and moral support (Barsky 2000: 186). Mediators "must encourage parties to recognize the right of others to be involved in the process; the mediator must be a catalyst who stimulates discussion and who encourages parties to see problems from a variety of viewpoints" (Isenhart and Spangle 2000: 78) and to structure and guide sessions.

To date there is no conceptual framework that clearly distinguishes different environmental dispute processes (Bingham in Swanson 1995: 28). Additionally, there is no model of environmental dispute resolution (EDR) to use as a framework in mediation processes and therefore, disputants with the help of a mediator have the benefit of structuring their own mediation process to suite the unique factors in their environmental conflict (p. 278). Therefore, mediation can act to resolve disputes amongst stakeholders. However, the greater advantage may be that a forum can be established prior to creating management strategies and policies where sessions similar in structure and theory to mediation can be practiced as a precautionary measure. The Oceans Action Plan states that "there are serious and limiting factors that handicap our oceans economy" and one of these factors is that "few venues presently exist for multi-sectoral interests to interact effectively with each other and to sort out conflicting use issues" (Department of Fisheries and Oceans 2004c: 7). The interest based or cultural island models of dispute resolution for example, have the fundamental requirements to create an atmosphere where the foundations for interests and conflicting issues can be discussed.

Interests refer to a person or groups' needs, desires, concerns, hopes and fears (Pirie 2000: 65). The emphasis of interest based approach is on "the problem" not the people involved in the process and underlying interests of the parties are identified and examined (Fisher, Ury, and Patton 1991). If there are conflicting interests, the approach is integrative in process and problems are seen as having more than one potential solution. Resources should be understood as expandable and in order to achieve this, parties should attempt to create more potential solutions. Thus parties are said to be "value creating" and it becomes a "win-win" or "gain all approach" where parties attempt to accommodate as many interests as possible (Morris 2002).

The cultural island model is an approach where interests are discussed and examined through the four-step process of group formation, storytelling, confrontation and resolution (Halabi 1998 in Barsky 2000: 210). When hostility weakens, there becomes the opportunity for an equal relationship between parties. The dominant group becomes more willing to recognize the legitimate concerns and interests of the oppressed group. Consequently, healthy dialogue develops and a better understanding for the diversity of groups' interests emerges (Halabi 1998 in Barsky 2000: 210). Groups also develop a different sense of their role in the broader context of management, policy creation, implementation and ratification. Therefore, what is required is a radical change in the approach by the government to integrated management; one that resembles what has been described by Lee (1993) and Kearney, Berkes, Charles, Pinkerton and Wiber (2007) with the inclusion of mediation as a theoretical approach.

Conclusion

Canada has the longest coastline in the world, which includes three oceans. Because Canada has such as large stake in environmental assets, it is important that Canadians and various groups develop a process to resolve conflicts and collectively establish a plan for future management policies. The consultation strategies that the government has used in their plans for IM thus far have proven to be both insufficient and ineffective which was illustrated in the *Independent Review of Improved Decision Making in the Pacific Salmon Fishery*. Furthermore, *The Policy Framework on the Management of Fisheries on Canada's Atlantic Coast* argued that the approach taken in the management of the fisheries and oceans by DFO is too paternalistic, currently policies lack relevance and significance, and stakeholders are not given the opportunity to contribute their knowledge in plans for management. The Fundy Fixed Gear Council was established as a result of conflict over what constituted good policy in the fisheries of the region. Although the FFGC is a positive step forward, the initial approach taken by the government was not inclusive or cooperative. These documents have cited legitimate reasons for environmental conflict to arise, however, the Oceans Action Plan cites that currently very "few venues presently exist" where stakeholders from various backgrounds can discuss their interests and resolve conflicts (Department of Fisheries and Oceans 2004c). If the government is genuinely interested in participating in the IM of the Fisheries and Oceans as they state in the *Oceans Act*, Oceans Action Plan and in participating in UNCED in 1992, then they must address this issue. Lee (1993) and Kearney, Berkes, Charles, Pinkerton and Wiber (2007) have suggested that in order to manage multiple values and ensure ecological sustainability and economic development there must be an increase in participation by stakeholders affected by decisions. It can be argued that mediation is a good strategy for achieving this because it would be to the benefit of the government to create a forum with mediation as the theoretical approach when establishing plans for IM with stakeholders. Furthermore, mediation also allows groups to develop a different sense of their role in the broader context of management, policy creation, implementation and ratification in an atmosphere that is hospitable towards co-operation and collaboration. Because there is no conceptual framework that clearly distinguishes different environmental dispute processes or model to follow as a framework, parties can work together and structure their own mediation process to suite the unique factors in their environmental conflict. Mediation not only serves as a reactionary tool, but it can also be a tool for mitigation, thus supporting and promoting the health and welfare of fisheries and oceans.

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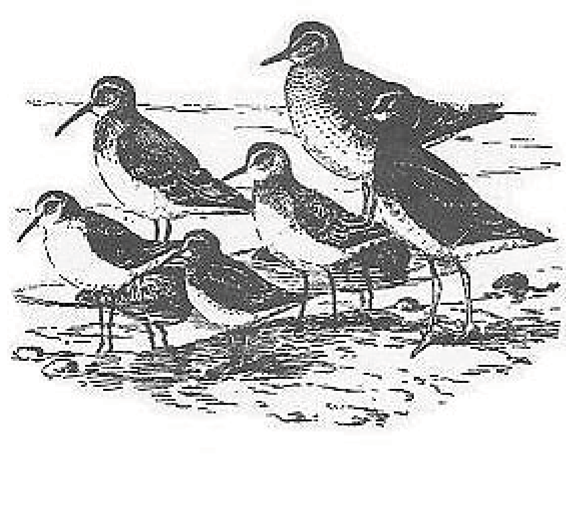
Session E

INTERTIDAL ECOLOGY

Chair: Diana Hamilton, Department of Biology, Mount Allison University, Sackville, New Brunswick, and Myriam Barbeau, University of New Brunswick, Fredericton, New Brunswick



FOOD HABITS AND FORAGING BEHAVIOUR OF SEMIPALMATED SANDPIPERS (*Calidris pusilla*) DURING MIGRATORY STOPOVER IN THE UPPER BAY OF FUNDY, NEW BRUNSWICK

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We investigated the feeding ecology of Semipalmated Sandpipers (SESA) during their fall migratory stopover in the upper Bay of Fundy in 2006 and 2007. We set out to test whether SESA diet at important stopover sites was restricted to the traditional prey, the amphipod *Corophium volutator*, or whether alternate prey were consumed. We also tested whether diet composition was consistent among the sexes and among birds roosting at different sites. Alternative foods include biofilm (a thin benthic layer of microalgae and associated mucopolysaccharides), polychaetes, and other meiofauna such as ostracods and copepods. Diet composition was assessed using stable isotope analysis of SESA blood plasma. To investigate links between SESA foraging behaviour and relative abundance of prey, we videotaped foraging birds and collected mudflat core samples for invertebrate prey in areas where birds were feeding. Using videotapes, we later observed different foraging behaviours and quantified proportion of time spent in each. Isotopic mixing models suggested a high intake of biofilm in 2006, but very little in 2007. However, behavioural observations indicate that SESA did not target biofilm as a food source; in 2006 a strong relationship was found between a novel foraging behaviour, "slurping", and abundance of ostracods. In 2007, slurping disappeared, but evidence of dietary segregation among roosting sites was observed. Dietary segregation among sexes was not substantial in 2006 but was more pronounced in 2007, though biological significance of these differences cannot be determined with certainty. Foraging behaviour and diet in this region appears more flexible than previously thought.

Second Prize - Undergraduate Paper

NOCTURNAL FORAGING BEHAVIOUR OF SEMIPALMATED SANDPIPERS (*Calidris pusilla*) AND HOW IT RELATES TO PREY AVAILABILITY

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Introduction

Intertidal mudflats in the upper Bay of Fundy serve as critical staging areas for migratory shorebirds, in particular Semipalmated Sandpipers (*Calidris pusilla*) (Hicklin 1987). Each summer, 1.1–2.2 million Semipalmated Sandpipers stopover on local flats (Mawhinney et al. 1993) and rebuild fat stores by feeding intensively on the amphipod, *Corophium volutator* (Hicklin 1987; Hicklin and Smith 1984).

Substantial research has been conducted diurnally; however, little is known about how birds forage at night; only two single-site studies have considered it in this region (Manseau and Ferron 1991; McCurdy *et al.* 1997). Feeding at night can compensate for insufficient diurnal energy intake or allow for the use of different prey items and/or feeding areas (Burton and Armitage 2005; Mouritsen 1994). As nocturnal foraging has been observed in other shorebird species in wintering, breeding and staging habitats (Mouritsen 1993; Burger and Gochfeld 1991; Robert and McNeil 1988; Warnock and Takekawa 1996), it may be a critical component of a successful shorebird migration.

To begin to investigate nocturnal foraging behaviour, prey selection and habitat use by Semipalmated Sandpipers in the Bay of Fundy, we conducted a comparative day-night study of sandpiper activities. We hypothesized that birds would switch from mainly visual feeding by day to tactile at night due to reduced visibility. We also predicted a relationship between foraging behaviour and food availability, as particular foraging modes may be better suited to capturing particular prey.

Methods

From 28 July to 14 August, 2008 we collected day and night video observations of sandpipers foraging on two mudflats in the upper Bay of Fundy: Grande Anse (45º48'N, 64º29'W), in Johnson's Mills, NB and Mary's Point (45˚73'N, 64˚65'W), near Hopewell, NB. Film was captured at low tide using a high definition camcorder attached to a tripod. Night video was collected using a night vision scope with 7x magnification and infrared illuminator attached to the camcorder. To accompany each video clip we took two vertically divided sediment samples, to estimate how much of the prey is physically available to the birds (Wallace and Hamilton, submitted) as well as two chlorophyll *a* samples [an index of diatom abundance (Underwood and Smith 1998)].

We later used video to calculated time budgets, determining the proportion of time in each clip spent in each behaviour. Three foraging behaviours were observed: slurping, pecking and probing. The resolution of the night video was insufficient to distinguish between pecking and probing, thus foraging behaviour was classified as either slurping or pecking/probing.

Within each layer of each sediment sample, we counted the total number of *C. volutator*, ostracods and polychaetes. Additionally, we measured each *C. volutator* from rostrum to telson and classified individuals as juveniles (<4 mm) or adults (>4 mm).

Using appropriate statistical analyses, we assessed whether the proportion of time spent pecking/probing varied across sites and time of day. We also determined whether food (total *C. volutator*, ostracods and polychaetes abundances (summed over the four layers)) varied across sites and time (fixed factors), and whether food availability affected foraging behaviour.

Results and Discussion

We obtained 22 day clips and 3 night clips from Grande Anse as well as 20 day clips and 6 night clips from Mary's Point. Three behaviours were observed: stereotypical pecking and probing (described in Baker and Baker, 1973) as well as slurping, a novel behaviour whereby the individual maintains contact between the bill and substrate (Ginn et al., unpubl. data).

We observed dramatic and site-specific differences from day to night with respect to foraging behaviour, habitat use, and food availability. At Mary's Point, individuals behaved similarly during the day and at night, pecking and probing along the water's edge relatively close to shore. We did not detect day-night differences in food availability; *C. volutator* and polychaetes were abundant and ostracods were absent. At Grande Anse, the birds behaved very differently at night. Individuals flocked tightly close to shore, did not follow the tide as during the day, and did not settle to feed until they were > 1 km from shore. They also engaged in slurping at night, rather than the pecking and probing that was observed during the day. *C. volutator* were abundant in diurnal feeding areas but essentially absent in nocturnal feeding areas; ostracods were equally available in both day and night foraging patches.

Individuals foraging at Grande Anse appeared to switch from visual foraging by day to tactile foraging at night. However, this was probably related to prey availability rather than a need to change foraging modes. Previous research detected a relationship between proportion of time spent slurping and ostracod abundance (Ginn et al. unpubl. data). This, combined with the fact that *C. volutator* were scarce in nocturnal foraging areas, suggest that birds at Grande Anse were consuming ostracods at night. However, *C. volutator* is likely still a preferred prey item, as slurping occurred only when amphipods were unavailable.

Presence of predators, combined with an available alternate food source far from shore at Grande Anse, may explain differences between the two sites in nocturnal habitat use. Semipalmated Sandpipers select foraging sites at least in part based on distance from cover (Sprague et al. 2008). At night, they may face a higher risk of predation due to reduced visibility, so foraging even further from shore may be advantageous. Owls are known prey on shorebirds in other areas (Page and Whitacre 1975) and were speculated to be prompting Red Knots to choose sites further from shore at night (Sitters et al. 2001). As there are several owl nests near Grande Anse, they may account for the peculiar behaviour observed at this site (P. Hicklin, pers. comm.).

At Mary's Point, individuals did not go further from shore at night; however, samples taken far from shore contained minimal *C. volutator* and no ostracods (MacDonald, unpublished data). Manseau and Ferron (1991) observed sandpipers foraging >1500 m from shore at Mary's Point at night, as opposed to close to shore diurnally. This suggests that sandpipers will choose to forage further from shore at night at Mary's Point if food is available.

Overall, our study has highlighted day-night differences in foraging behaviour, prey selection and habitat use at least at some sites. Further, we have illustrated the importance of including site-specific diurnal and nocturnal observations in future studies.

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First Prize - Graduate Paper

EFFECTS OF FORAGING SEMIPALMATED SANDPIPERS ON THE VERTICAL DISTRIBUTION OF THE AMPHIPOD *Corophium volutator*

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Each summer, migrating Semipalmated Sandpipers (*Calidris pussila*) stop at mudflats in the upper Bay of Fundy en route to wintering grounds in South America (Stoddard et al. 1983). They consume large quantities of the amphipod *Corophium volutator*, which can represent up to 90% of their diet (Hicklin and Smith 1984). *C. volutator* construct "U"-shaped burrows that extend 2–10 cm into the mud (Hicklin and Smith 1984). The extent to which *C. volutator* use these burrows to avoid predation is unknown. *C. volutator* are known to cease surface crawling after birds arrive a behaviour termed prey depression (e.g., Goss-Custard 1970; Yates et al. 2000). However, *C. volutator* may also retreat to greater depths in burrows when birds are present. Historical estimates of prey availability have been based on measures of absolute density. However, if *C. volutator* can evade capture by retreating beyond the reach of foraging sandpipers, density alone would not provide an accurate estimate of availability.

To quantify *C. volutator* burrowing activity in the presence and absence of sandpipers, we monitored the vertical distribution of amphipods in bird exclosures and adjacent control plots. Field work was conducted at Peck's Cove in the Bay of Fundy, New Brunswick, in summer 2007. Sediment samples from each study plot were periodically collected and immediately separated into four distinct layers using a modified Milbrink stratification sampler (Milbrink 1968; Hill and Elmgren 1987). Surface activity (crawling *C. volutator*) was noted prior to collecting each sample. We later assessed abundance and size distribution of *C. volutator* in each layer.

For each sampling period, the majority of individuals <6 mm in length were found in the uppermost layer. However adults (>6 mm), those most susceptible to predation (Peer et al. 1986), retreated deeper into burrows after sandpipers arrived, many beyond the reach of foraging sandpipers. There were significant declines in surface activity over the summer, and no crawlers were observed during the last sampling period, corresponding with the most intensive shorebird foraging. This tendency of adult *C. volutator* to inhabit deeper segments of mud in the presence of sandpipers may represent a predator avoidance mechanism that is more effective than simple cessation of crawling. Bill lengths of sandpipers foraging in the upper Bay of Fundy range from approximately 16 to 23 mm (Ginn 2009). Thus, it would be very difficult for foraging shorebirds to obtain prey burrowed deeper than 2 cm, and most sandpiper foraging does not involve probing that deeply. Therefore, by adjusting their depth in the mud even slightly, *C. volutator* could reduce their risk of being eaten (Hill and Elmgren 1987).

While prey depression was more obvious in control plots (where sandpipers could forage freely), adults in exclosures also responded to predators by retreating further into burrows. This suggests that *C. volutator* respond to broad predatory cues, not only direct predation.

Results of this work contribute to our understanding of prey depression, broadening the definition of this behaviour from simple cessation of crawling (Goss-Custard 1970) to a marked behavioural response of the prey. Our findings also highlight the need to distinguish between prey density and prey availability when examining potential for Semipalmated Sandpiper foraging success on mudflats in this region.

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First Prize - Undergraduate Paper

THE EFFECT OF *Ilyanassa obsoleta* ON THE VERTICAL DISTRIBUTION OF *Corophium volutator* IN MUDFLAT ECOSYSTEMS OF THE BAY OF FUNDY

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Introduction

The eastern mudsnail (*Ilyanassa obsoleta*) is common to mudflats of the upper Bay of Fundy. In their movement across the flats, mudsnails bulldoze the upper 1–2 mm of sediment and disturb fauna within the sediment (DeWitt and Levinton 1985). The amphipod *Corophium volutator* is the most abundant macroinvertebrate on many mudflats in this region. This species is integral to mudflat habitats, as it constitutes the main prey item for migrating Semipalmated Sandpipers (*Calidris pusilla*) which stage annually in the upper Bay of Fundy (Hicklin and Smith 1984). *C. volutator* occupies U-shaped burrows within the sediment, providing refuge from predators and reducing desiccation at low tide (Meadows and Reid 1966). However, these burrows may collapse due to mudsnail movement, resulting in interference competition. Mudsnails have also been observed preying upon *C. volutator* (M. Coffin, pers. comm.). In response to these negative interactions, *C. volutator* may exhibit avoidance behaviour, as they are known to do when in the presence of shorebirds (Wallace and Hamilton, submitted). By adjusting their vertical position within their burrows and shifting deeper into the sediment, *C. volutator* may avoid interacting with mudsnails. If avoidance behaviour does occur in response to mudsnails, *C. volutator* availability to shorebirds would be reduced. As a result, the mudsnail-*C. volutator* relationship may have a significant influence on Semipalmated Sandpiper ecology.

Methods

During summer 2008, we examined the abundance and vertical distribution of *C. volutator* in the presence of mudsnails at varying densities. Field work was conducted at two mudflats on Dorchester Cape, NB: Grande Anse and Peck's Cove. At each mudflat, eight sites 30–50 m apart were chosen. Four snail treatments were applied to each site: low snail density (50 snails/m^2), high snail density (125 snails/m^2), exclosure (0 snails/m^2), and control (ambient snail density). Each treatment consisted of a 1m x 1m netted cage which restricted snail movement and excluded shorebirds. The order of treatments within each site was randomized, and cages were placed in areas maintaining similar puddle cover.

Sampling occurred on three occasions: June 26–27, July 24–25, and August 22–23. During each sampling round, sediment cores which divided each core into four vertical layers were collected, thereby preserving the vertical distribution of *C. volutator*. The depths of each layer from the sediment surface were as follows: 0–0.5 cm, 0.5–1.5 cm, 1.5–3.0 cm, 3.0–5.0 cm. Each layer was sieved separately through a 250 µm sieve, and *C. volutator* within were measured and sexed.

To analyze these data, *C. volutator* were divided into two size classes, juveniles (0–4 mm) and adults (6≤ mm). A linear mixed model analysis was performed on each size class with site as the subject, and round, treatment and layer as repeated factors. Due to significant interactions, each size classes within each mudflat was analyzed separately.

Results and Discussion

Grande Anse

In general, juvenile *C. volutator* resided primarily in the first and second sediment layers. In June, there was no effect of mudsnails on *C. volutator* abundance or vertical distribution. This result was expected, as sampling occurred just prior to the erection of the snail treatments. In July, we observed a drastic decrease in the abundance of juveniles in response to mudsnails. Abundances were substantially lower in the high and low snail density treatments compared to the snail exclosure. In August, the abundance of juveniles equalized across all snail density treatments. At this point in the season a new cohort of *C. volutator* hatches, enters the water column, and disperses across the mudflats (Drolet and Barbeau 2009). This influx of juveniles into the system likely increased abundances throughout all snail treatments, thereby masking any effect of snails previously observed. There was no evidence of a change in juvenile vertical distribution throughout the study.

In contrast to juveniles, adult *C. volutator* (6≤mm) occupied primarily in the second and third sediment layers. In June, there was no effect of mudsnails on the abundance or vertical distribution of *C. volutator*, as expected. In July, there was a significant decrease in adult abundance in response to mudsnails. Abundances were lowest in the high snail treatments, and highest in the exclosure treatments. Adult *C. volutator* also adjusted their vertical distribution in response to snails. In the absence of mudsnails, *C. volutator* increased their use of the top sediment layer, while in the presence of low snail densities, *C. volutator* shifted deeper into the sediment. This suggests that adult *C. volutator* do respond behaviourally to the presence of mudsnails. In August, total adult abundance was extremely low in all snail density treatments as a result of normal seasonal mortality in the population (Wilson 1988; Barbeau et al. 2009; Peer 1984; Hamilton et al. 2006). As a result, we cannot draw concrete conclusions as to the response of adult *C. volutator* during the month of August.

Peck's Cove

At Peck's Cove, there was no observed effect of mudsnails on the abundance or vertical distribution of *C. volutator*. We attribute this lack of response in part to the sediment properties of this mudflat. The aerobic layer at Peck's Cove is very shallow compared to that of Grande Anse, and the sediment is significantly drier. As a result, mudsnail movement across the sediment at Peck's Cove may not have as negative an effect on *Corophium* burrows, as the sediment is more stable and less likely to collapse. Therefore, a behavioural response by *C. volutator* is not observed.

In conclusion, our hypothesis that *C. volutator* would shift deeper into the sediment in the presence of mudsnails was supported, but varied with both size class and mudflat. These results highlight the importance of considering site variability in ecological studies, and further our knowledge of interspecific interactions in the Bay of Fundy.

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EFFECT OF THE MUD SNAIL (*Ilyanassa obsoleta*) ON VITAL RATES AND BEHAVIOUR OF THE AMPHIPOD, *Corophium volutator*

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The two dominant invertebrates on mudflats in the upper Bay of Fundy, *Ilyanassa obsoleta* and *Corophium volutator*, are negatively correlated. This may be related to exploitation competition, interference competition and/or predation. We examined the effect of snail density (0, 5, 50 ind./m^2) on survival, growth and movement of juvenile and adult *C. volutator*, and on fecundity of adults in laboratory experiments (with simulated tides). Based on results analyzed to date, survival of juveniles decreased significantly with increasing snail density, whereas survival of adults was minimally affected. During behavioural observations, we discovered that snails did prey on *C. volutator*. The probability of a snail attacking an encountered amphipod was variable (partly dependent on the snail's hunger level); however, probability of capture after attack was consistently high (~85%). Snails did not appear to affect movement patterns, such as immigration into or emigration away from an area, when amphipods were given a choice of areas with and without snails. Other observations indicated that: (1) upon immersion, swimming frequency of amphipods was initially low but increased steadily until a plateau was reached 3–4 h into the high tide period, and (2) upon emersion, crawling frequency of amphipods was initially high, but declined steadily during the low tide period. In future studies, apparent effects of snails on swimming and crawling frequencies need to take into account mortality of amphipods. Mud snails have long been thought to feed primarily on detritus, carrion and biofilm. However, our results indicate that they are at least opportunistic predators.

EFFECTS OF NUTRIENT AVAILABILITY, SNAIL ABUNDANCE AND SHOREBIRD PREDATION ON AN INTERTIDAL MUDFLAT COMMUNITY

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Bay of Fundy intertidal mudflats are important staging areas for more than one million Semipalmated Sandpipers (*Calidris pusilla*), which feed primarily on the amphipod *Corophium volutator* to fuel their annual migration to South America. Diatoms are an essential food source for *C. volutator*, polychaetes, copepods and nematodes. Eastern mud snails (*Ilyanassa obsoleta*) migrate into intertidal zones in the spring where they compete for diatoms and interfere with other invertebrates. To investigate trophic interactions in this system, we conducted a manipulative experiment examining the individual and combined effects of Semipalmated Sandpiper predation, changes in primary production, and presence and abundance of mud snails on community structure. Fertilizer addition was used to stimulate primary production, while bird and mud snail exclosures and enclosures controlled predation. Semipalmated Sandpipers reduced densities of adult, but not juvenile *C. volutator*, while mud snails of low, medium and high densities had a negative effect on both, acting primarily as interference competitors. Although mud snails were more detrimental to juveniles, there appeared to be an additive effect of sandpipers and mud snails on adults. Fertilizer had a negative effect on *C. volutator*, likely due to aggregations of mud snails in fertilized sites. While nematodes and copepods were unaffected by Semipalmated Sandpipers, medium and high mud snail densities significantly reduced their abundance, likely due to interference competition and possibly consumption. Results indicate that community structure is controlled by both top-down and bottom-up factors. A community-ecological approach is required to fully understand interactions between *C. volutator* and migrating shorebirds.

WITHIN-MUDFLAT VARIATION IN DENSITY, DEMOGRAPHY AND MOVEMENT OF THE AMPHIPOD *Corophium volutator* ON THE MUDFLAT OF PECK'S COVE, UPPER BAY OF FUNDY

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Variation in life cycle of the amphipod *Corophium volutator* between mudflats has been well described, but within-mudflat variation in demography and movement remains largely unstudied. We performed a year-long survey of density, demographic variables and movement patterns of *C. volutator* on the intertidal mudflat of Peck's Cove in the upper Bay of Fundy, Canada, using hierarchical sampling, mark-recapture trials and stationary plankton nets. Distribution of *C. volutator* showed significant positive spatial autocorrelation at lags ranging from 0.5 to 200 m suggesting small and medium scale patchiness, and non-significant autocorrelation, indicating random distribution, at lags of 200 to 2000 m. As well, temporal patterns showed that early-summer increases in amphipod density were faster close to shore compared to far from shore. Proportion of adults, sex ratio, proportion of ovigerous females and proportion intersex did not show this temporal pattern in distance from shore, but rather were mostly location-time specific, corresponding to the small-scale variation detected in the autocorrelation analysis. Emigration, immigration and density of swimmers also showed small-scale spatial and temporal variation, although amphipods consistently swam along-shore (towards the south of the mudflat), likely reflecting tidal currents. Correlation between the different variables suggests that formation of large-scale patterns in distribution of *C. volutator* on a mudflat results from movement patterns rather than variation in demographic parameters.

EXAMINING ENCOUNTER RATES OF THE NUDIBRANCH, *Onchidoris bilamellata* (L.) IN RELATION TO MOSIMANN RANDOM MOTION AND SEARCH THEORY MODELS

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Abstract

Onchidoris bilamellata is a simultaneous hermaphrodite nudibranch found in low densities at Indian Point in Passamaquoddy Bay. It is hypothesized that encounter rates would be non-random during mid-breeding season when population density is highest. When breeding densities are low due to immaturity or senescence at the beginning and end of the breeding season, encounter rates are expected to be random. Encounter rates were found to be non-random during the middle of the breeding season, as well as on two out of three of the sampling dates at the beginning of the breeding season. Non-random encounter rates suggest mate-seeking techniques, such as trail following, are being employed.

Introduction

Simultaneous hermaphroditism, where an individual produces both gametes within a single breeding season, is less studied than sequential hermaphroditism, where individuals function as one sex and then another (Karlsson 2001; Bleakney 1996). The main advantage for the former reproductive strategy is that every conspecific encountered is a potential mate, as opposed to half in gonochorism where the sexes are separated (Shaw 1998). The main disadvantage of simultaneous hermaphroditism is the cost of energy needed to maintain the production of both gametes (Shaw 1998). Behavioural studies using simultaneous hermaphrodites have the potential to better our understanding of the evolution and maintenance of mating strategies (Karlsson 2001).

Ghiselin (1969) proposed three models: low density, size advantage and gene dispersal, to explain the evolution of hermaphroditism. The low density model is applicable to simultaneous hermaphrodites such as *O. bilamellata* which lives in a low density population (Ghiselin 1969). This model states that hermaphroditism evolved to increase the effective population size to counteract a population's low numbers (Ghiselin 1969). This would increase each individual's reproductive fitness in relation to gonochorism in a low density population (Ghiselin 1969).

Animals can afford to be choosy (non-random encounter) in high density populations, but this is not true in a low density population since another mate may not come along, and so encounters would be random (Argument 1996). Comparing expected encounter rates calculated by a model that assumes random motion to actual observations could reveal if random mating is occurring. Two random motion models were used to determine the expected rate of encounters between *Onchidoris bilamellata* conspecifics. Using two models allows for comparison and confirmation of the findings.

The first model proposed by Mosimann (1958) is expressed by the equation:

$$\Theta = 1.2732rvn,$$

where r = detecting range,
v = velocity, and
n = density.

The animals detecting range (r) is half the body length plus half the width between rhinophores since the most common encounter is that of the head of one animal touching the side of another. The probability of an encounter can be increased according to Mosimann's model by broadening the detecting range through mechanisms such as chemical signals and increasing velocity or population density.

The second model being examined, search theory model, was proposed by Koopman (1956 in Cox 1983). Search theory is an exponential model seen below:

$$p = 1 - e^{-wL/A}, (2)$$

where w = width,
L = length of search path (nearest neighbour distance), and
A = area searched.

The probability of an encounter can be increased through this model by increasing the body width, and therefore any morphological feature which does so may be greatly favoured by natural selection (Cox 1993).

This study is based on Shouldice (2000) who examined encounter rates of the nudibranch *Flabellina salmonacea* using Mosimann's (1958) random motion model. Shouldice (2000) found that the encounter rate was significantly higher then would be expected according to Mosimann's (1958) model, indicating that there was physiological or morphological mate seeking being employed, such as mucus trail following (Davies and Blackwell 2007), or pheromone use (Angeloni et al. 1999).

The second finding which has led to this study was made by Argument (1996) who found that *Dendronotus frondosus* mates randomly according to Mosimann's model (1958) during the beginning (May) and end (July) of their breeding season when population densities were low, and non-randomly during the middle (June) of their breeding season when population density was at its peak.

The animal used in this study is the nudibranch *Onchidoris bilamellata* (L.), which is in a low density population on Indian Point of Passamaquoddy Bay (Shouldice 2000). Members of this species are 15–30mm long, appearing dull white with patches of brown pigment (Bleakney 1996). Their gills surround the anal papilla and tubercles, many of which are supported by calcareous spicules (Bleakney 1996). *O. bilamellata* is a primarily intertidal nudibranch in the boreo-arctic North Atlantic (Barbeau et al. 2004). Little research has been done on this species (Haase and Karlsson 2000).

O. bilamellata feeds exclusively on barnacles, mainly *Semibalanus balanoides*, which are readily available on the intertidal (Bleakney 1996). Sea slugs have lost their shells and opercula over evolutionary time, and are susceptible to desiccation (Todd 1979). Therefore, they require the shade and dampness under the rocks lower on the intertidal, and are unable to match the broad distribution of their prey, but rather have a clumped distribution (Todd 1979).

The annual life cycle of *O. bilamellata* is matched to the life cycle of their prey (Barbeau et al. 2004). The adults spawn in the cold waters from December to April when they are about 30 mm long. They attach egg masses of 100,000 within a white gelatinous ribbon to the substratum in concentric circles (Barbeau et al. 2004; Bleakney 1996; Claverie and Kamenos 2008; Todd 1979). After spawning, adults undergo autolysis (self digestion), converting their organs into more sperm and eggs, which drastically reduces their weight and results in post-spawning mortality by May (Barbeau et al. 2004; Bleakney and Saunders 1978; Todd 1979). The larvae hatch after developing in the egg for 4–6 weeks, after which they are planktonic for about 2.5–3 months from May to July (Barbeau et al. 2004; Bleakney 1996; Todd 1979). During this time, they are prey to young fish and crustaceans; therefore, large numbers of offspring are produced to ensure survival (Bleakney 1996). The life span of one individual is from 9 to 10 months, consisting of 6 months of spawning, dying out in May, and being replaced 2–3 months later in August and September by juveniles (Todd 1979; Bleakney 1996).

The aim of this study is to examine encounter rates in relation to the Mosimann (1958) and search theory

(Cox 1983) random motion models throughout the breeding season to determine if *Onchidoris bilamellata* is encountering conspecifics randomly, and if the rates are dependent upon population density. It is hypothesized that when an animal has many choices in a higher density population during peak spawning, the animal will be choosy or mate non-randomly. Conversely, it is expected that when the effective population density is low during the beginning of the breeding period due to immaturity, and the end of the breeding period due to senescence, the animal cannot afford to be choosy and so will mate randomly.

Materials And Methods

Specimens were collected at Indian Point in St. Andrews, New Brunswick on October 18th, November 11th, November 21st, 2008 and February 14th, 2009. During the 2008 collection dates, the fieldwork was as follows. Individuals were found by turning over rocks, and once a slug was found a 1x1m quadrat was placed such that the individual was in the center. The remaining rocks within the quadrat were then turned over, and nearest neighbour distances to all slugs found in the quadrat were recorded with a tape measure. It was also noted whether or not the individuals were found to be in an encounter (i.e. touching, which was defined as a nearest neighbour distance of 1 mm.). The quadrat was then flipped end-over-end toward the water twice, and the same searching, measurements, and notes were taken. If there was no neighbour found within the quadrats, then the nearest neighbour distance was defined as twice the longest nearest neighbour distance found (2.3×10^4 mm) to mimic infinity. This process was repeated until the tide invaded the beach.

On February 14th 2009, field sampling was done by 10 people in an attempt to increase the number of sea slugs found. A 100 m transect was laid about 5 meters above and parallel to the water line. Five groups of two people sampled 5 meters along the transect line, and as many meters toward the water line as was possible. Instead of nearest neighbour distances being measured directly, each slugs position was recorded based on a column/row system where the meter mark of the transect line was the column number, and the meter mark toward the water line was the row number. Each quadrat had centimeter markings on the side, which were used to measure a specimen's x, y coordinate. These measurements were then plotted and nearest neighbour distances were calculated (Figure 1).

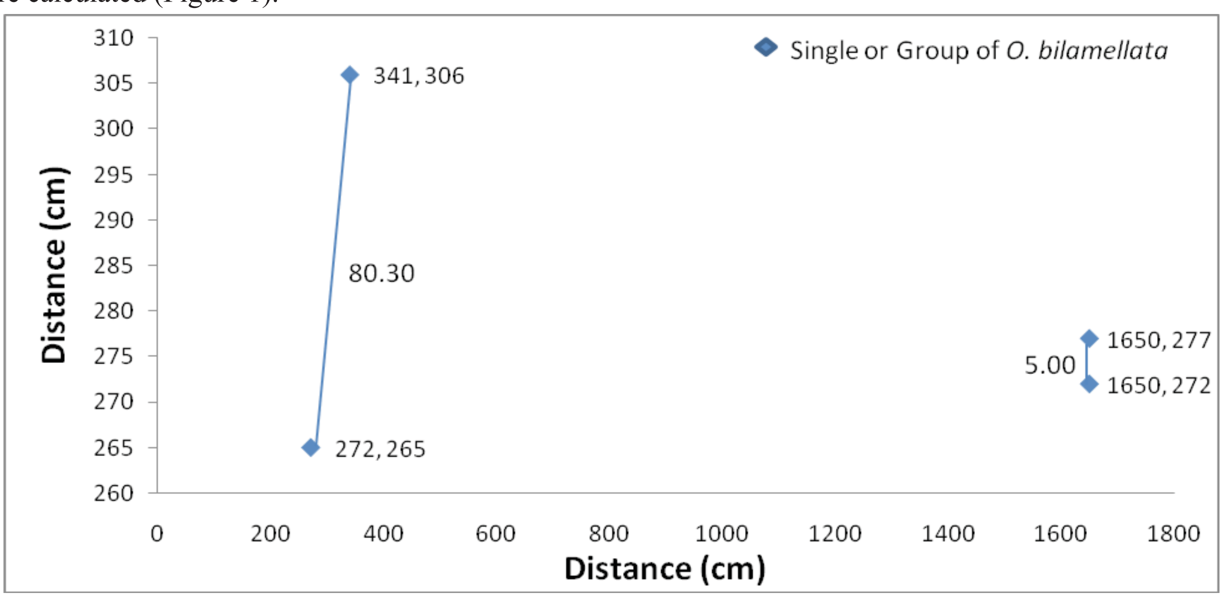

Figure 1. Location of *Onchidoris bilamellata* individuals alone or in an encounter with respect to a 100 m transect at Indian Point, St. Andrews on 14 February 2009

Animals were placed individually in sealed bags with water from the field and a label, then placed in a cooler and transported to the Mount Allison University Cold Room in Sackville, New Brunswick. Individuals were transferred to a small, perforated container with its label and a small rock with their preferred prey, *Semibalanus balanoides*. These containers were placed in an aerated tank filled with 8˚C saltwater.

The nudibranchs were acclimatized for at least 24 hours, after which they were removed from the Cold Room and taken to the Invertebrate Behaviour Lab. An individual was placed in a petri dish with sea water, which was then placed on top of millimeter graph paper. Once movement was steady, the length, width, and width between rhinophores were measured. Velocity was also measured by averaging three timings of how long it took a sea slug to move 5 mm. The nudibranchs were then patted dry with paper towel, and weighed using a Mettler AE 50 analytical scale. One specimen died before measurements could be taken.

Observed and expected encounter rates were compared to determine if the nudibranchs were encountering each other randomly according to either Mosimann's (1958) or search theory model (Cox 1983). Observed encounter rates were determined by noting how many individuals were in an encounter when collected in the field. Expected encounter rates were determined by inserting field and lab measurements into Mosimann's (1958) ($\Theta = 1.2732rvn$) and search theory models (Cox 1983) ($p = 1 - e^{-wL/A}$).

The relationship between velocity and size was examined using a model I linear regression after principle components analysis was done on the two independent size variables of length and mass. This was done to determine if speed was dependent on size, and therefore if velocity could be taken as a constant. Changes in length and mass throughout the breeding season were examined using linear regressions.

The hypothesis tested was that *Onchidoris bilamellata* encounter each other randomly according to both Mosimann (1958) and search theory (Cox 1983) models during the beginning (December) and end (April) of the breeding season, while non-random encounters will be observed during the middle of the breeding season (January). This main hypothesis was tested by comparing observed and expected encounter rates of *Onchidoris bilamellata* under both Mosimann's (1958) and search theory (Cox, 1983) models by using the goodness of fit G-test (Zar 1996). This test was used because the difference between observed and expected numbers was greater than the expected numbers, and because the expected values were lower than recommended for the chi-squared test (Zar 1996). On November 11th, there were no observed encounters and so the G-test could not be used since it involves taking the natural log of the observed:expected ratio. In this instance, the chi-squared test was used. This is thought to be appropriate since during all other days the two tests resulted in the same outcome despite the low expected encounter rates.

The results of Mosimann's random motion model (1958) and search theory model (Cox 1983) were compared through a paired samples t-test. All statistics were calculated using SPSS 16.0.

Results

Population density was expected to be low at the beginning of the breeding season (October–November), and high at the middle (February). Densities found were highest at the beginning of the breeding season with 27 individuals found within 24 quadrats on October 18th 2008, and 14 individuals found on both November 11th and 21st 2008 within 33 and 24 quadrats searched, respectively. The lowest density was found during the middle of the breeding season with 8 individuals found within 84 quadrats on February 14th 2009 (Figure 2). Similarly, growth was expected to increase as the sea slugs grew to maximum size (length and mass) during the breeding season. Observed trends followed these expectations, though this was not found to be significant (Figures 3 and 4).

The relationship between size and velocity was examined using a linear regression on *O. bilamellata* individual's average speed and chosen size index variables – length and mass. This was performed to determine if velocity is dependent on size, and therefore if speed could be considered a constant. Principle components analysis was done on the two independent size variables. Log transformations were done to these variables to

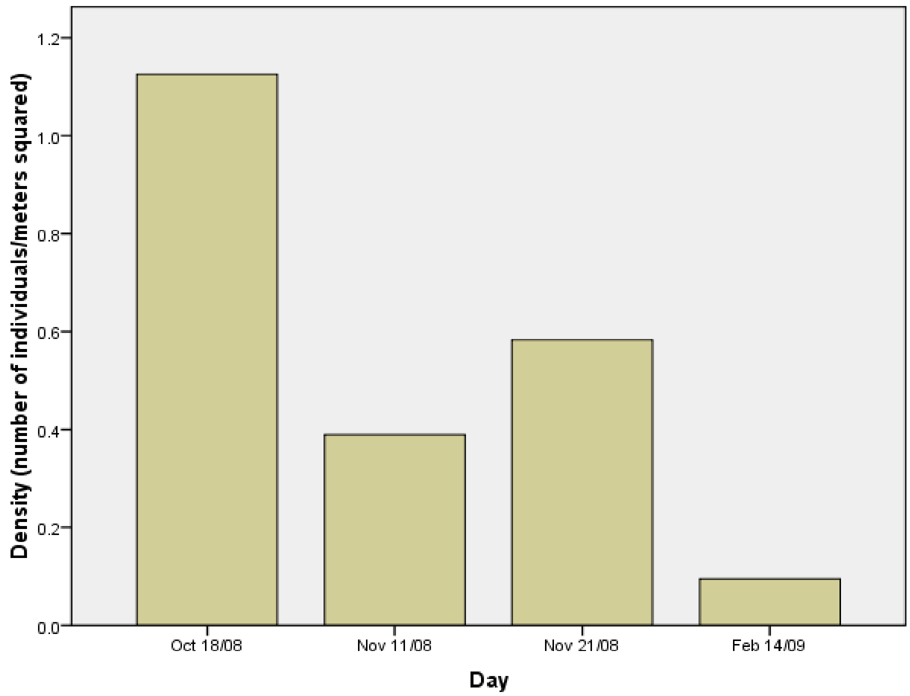

Figure 2. Changes in *Onchidoris bilamellata* population densities over a breeding season

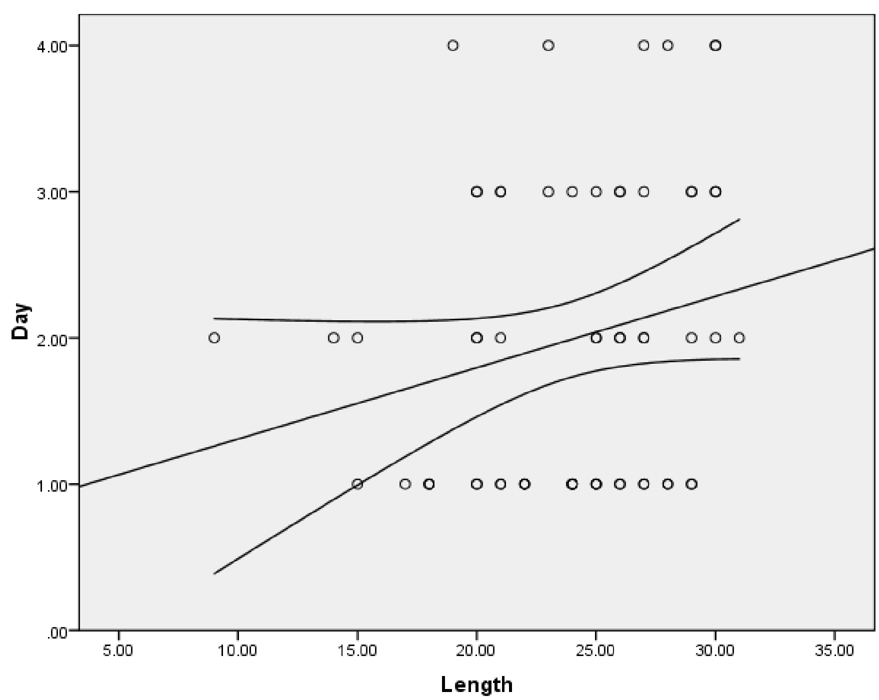

Figure 3. Linear regression of total length (mm) of *Onchidoris bilamellata* on four sampling days (1-Oct 18/08, 2-Nov 11/08, 3-Nov 21/08, 4-Feb 14/09)

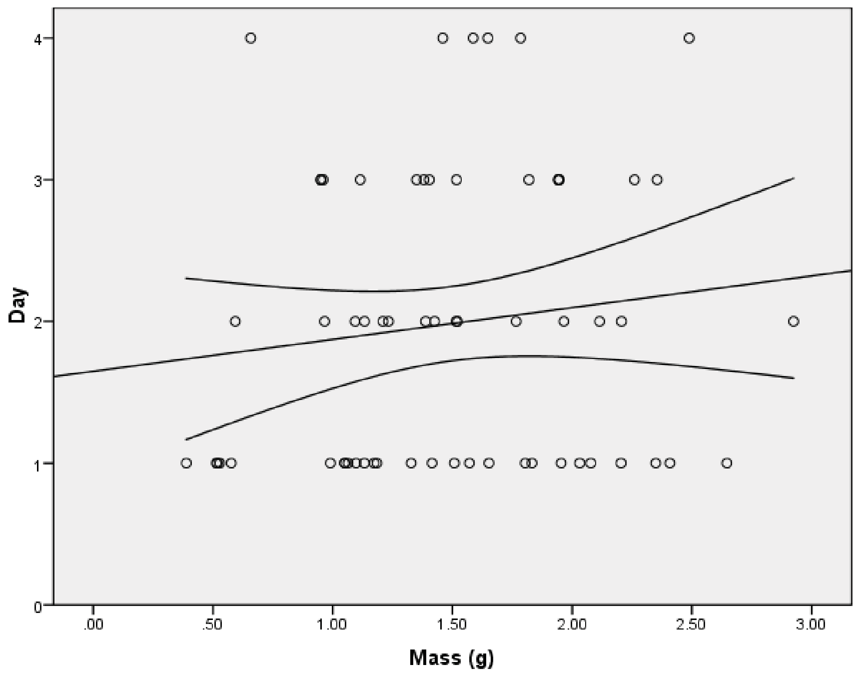

Figure 4. Linear regression of total mass (g) of *Onchidoris bilamellata* on four sampling days (1-Oct 18/08, 2-Nov 11/08, 3-Nov 21/08, 4-Feb 14/09)

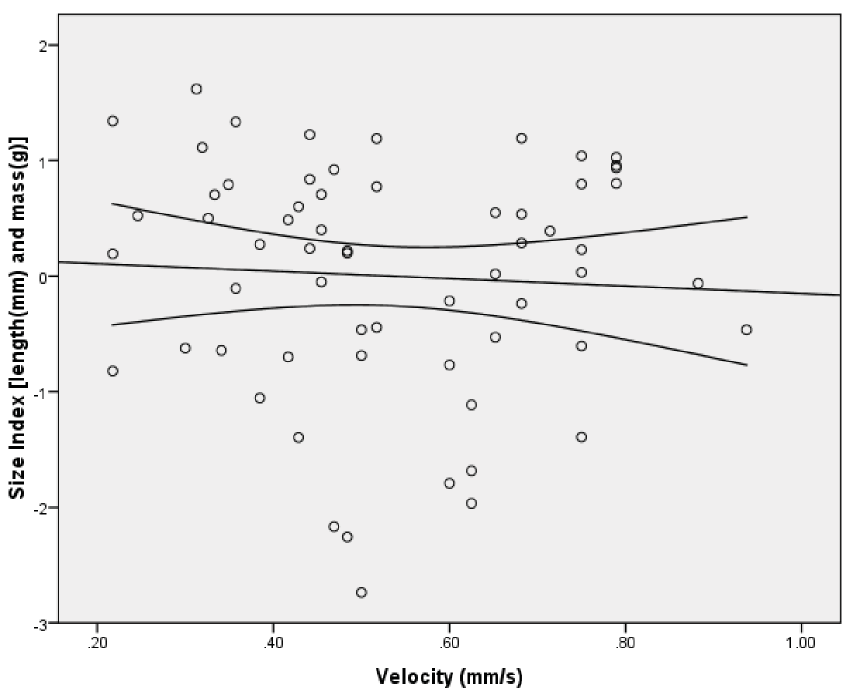

Figure 5. Linear regression of velocity and size (principal component of length and mass)

better meet assumptions (normality, homogeneity of variance). One component was extracted representing a size index, which was then compared with velocity using a model I linear regression (Figure 5). It was found that velocity could not be predicted by size. Therefore, velocity was taken as a constant (0.53 mm/s).

The main hypothesis of this study was tested with a likelihood ratio test for goodness-of-fit (G test), excluding the November 11th data for which a chi-squared test was done since the G test was not possible. Each day was tested separately under both Mosimann (Table 1) and search theory (Table 2) models. Encounter rates observed on October 18th, 2008 were not compared to expected encounter rates until Search Theory model because there was a missing variable of width. Encounter rates were found to be non-random according to both models on October 18th, November 21st and February 14th, while they were found to be random on November 11th.

The results of the two models were compared by a paired samples t-test. It was determined that the two models are not significantly different (p=0.295). This predicts that as the expected encounter rates increase under one model, the second model will have increased expected rates as well.

Discussion

Mate seeking is important for all living organisms, especially in populations of low density. Ghiselin's (1969) low density model suggests that simultaneous hermaphroditism may have evolved when a population was of low density in order to double the number of possible mates. Even with the doubled effective population size, many animals have evolved ways to facilitate finding a mate in order to propagate their species (Davies and Blackwell 2007). This study asks two questions: (1) Does the low density population of *Onchidoris bilamellata* in Passamaquoddy Bay encounter mates randomly, or are they employing mate seeking techniques? (2) Does the strategy change throughout the breeding season as population density changes?

Day	Observed	Expected	G test statistic	D.F.	Critical statistic, p=0.05	p-value
Oct. 18/08	5	$2.96x10^{-4}$	113.12	8	15.51	<0.005
Nov.11/08*	0	$5.88x10^{-5}$	0.00006	11	19.68	>0.995
Nov.21/08	2	$1.6x10^{-4}$	46.43	9	16.92	<0.005
Feb.14/09	6	$7.9x10^{-6}$	164.34	2	5.99	<0.005

Table 1. Expected vs. observed encounter rates of *Onchidoris bilamellata* as calculated by Mosimann's random motion model (1958) during four sampling days corresponding to population density changes due to the breeding season

Day	Observed	Expected	G test statistic	D.F.	Critical statistic,p=0.05	p-value
Nov.11/08*	0	0.13	0.12756	11	19.68	>0.995
Nov.21/08	2	0.03	60.49	9	16.92	<0.005
Feb.14/09	6	$1.8x10^{-4}$	218.41	2	5.99	<0.005

Table 2. Expected vs. observed encounter rates of *Onchidoris bilamellata* as calculated by search theory model (Cox, 1983) during four sampling days corresponding to population density changes due to the breeding season

The first question is answered under two random motion models. According to Mosimann's (1958) model, *O. bilamellata* was found to encounter mates non-randomly on three out of the four sampling dates (Table 1). This implied that mate seeking techniques are being used, which is where future studies can focus. The same results were found under search theory (Cox 1983) model (Table 2). The two models were compared, and it was found that they were not significantly different. This means that these two random motion models, based on different variables of the same nudibranchs, reached the same conclusion about how often they should encounter one another. This confirms the findings and allows further studies to use only one model and therefore cut down on variables needed.

The second question requires a look at changes in population density. The first sampling set (18 October 2009) was taken after settling, when the young *O. bilamellata* were growing to maximum size in preparation for spawning (Bleakney 1996). At this time the population was expected have a low density, though this is when the highest density of 1.125 individuals/m^2 was found (Figure 2). This may be due to the fact that total density was taken without sexual maturity being taken into account; with this taken into account, the effective population density may have been much lower.

The second and third sampling dates (11 and 21 November 2008) occurred further into the growing season when individuals grew to spawning sizes (Bleakney 1996). The densities during this growth period decreased to 0.389 individuals/m^2 on November 11th, with a slight increase to 0.583 individuals/m^2 on November 21st (Figure 2). These low densities are in stark contrast to what Shaw found at Indian Point in 1998, where 86 *O. bilamellata* individuals were found in each square meter. This suggests that there may be annual fluctuations in population density, or an environmental factor is driving their decline.

The fourth sampling date (14 February 2009) occurred after the peak spawning period when density was expected to be highest. It was here that the lowest density was found (0.095 individuals/m^2), which may be due to the change in sampling technique (Figure 2). Some volunteers were inexperienced in identifying *O. bilamellata*, which may have decreased density due to decreased consistency.

Therefore the second question, which hypothesizes that encounters will be random with low population density and non-random with high population density, had mixed results. Non-random encounters were paired with high population density, but only during the beginning of the breeding season when breeding densities were expected to be low. Conversely, non-random encounters were found during the middle of the breeding season when densities were expected to be high, but in fact were found to be low. In summary, the majority of the time encounter rates were found to be non-random, meaning that *Onchidoris bilamellata* is choosy throughout the beginning and middle of the breeding season. It is possible that these mate choices are based on such mate seeking techniques as trail following and pheromone signaling. Future studies should examine encounter rates at the end of the breeding season when adults are going through autolysis and the population density decreases.

Trail following is known to happen in snails and other slugs such as *Limax pseudoflavus*, which travels the trail of another individual's mucus as a prelude to courtship, but mucus trails can only be detected once touched, therefore trail following may not be as important as pheromone use (Cook 1992). Pheromones have been shown to be very important for marine animals such as the sea slug *Aplysia californica*, which uses them to it to attract mates (Cummins et al. 2007).

In conclusion, the population of *Onchidoris bilamellata* found at Indian Point in Passamaquoddy Bay was found to be of very low density in the winter of 2008/2009. Overall, the encounter rates were found to be non-random according to Mosimann and search theory random motion models throughout most of the breeding season.

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STATUS AND TRENDS OF EELGRASS IN EASTERN CANADA

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Although eelgrass (*Zostera marina*) has been widely recognized as an important component of coastal ecosystems in eastern Canada, regional surveys to monitor changes in eelgrass distribution and abundance do not yet exist. Important areas for eelgrass in eastern Canada include the outer Bay of Fundy, Atlantic coast of Nova Scotia, the island of Newfoundland, Gulf of St. Lawrence, St. Lawrence River estuary, and James Bay. An overview of current information is presented on status and trends of eelgrass and efforts to develop cost effective monitoring programs based on a recent Northeastern Eelgrass Workshop in Portland, Maine and a DFO - RAP Workshop in Moncton, New Brunswick. The trends, issues and monitoring programs for eelgrass differ dramatically throughout eastern Canada. Several areas in Nova Scotia and New Brunswick have documented declines in the extent and distribution of eelgrass related to invasive species and eutrophication. On the island of Newfoundland, eelgrass appears to be stable but the European Green Crab has recently arrived. Eelgrass appears to be stable or increasing in the Gulf of St. Lawrence and St. Lawrence River estuary in Quebec. In James Bay, Quebec, localized declines of eelgrass beds potentially due to hydro-electric development have been reported.

MERCURY FATE AND BIOGEOCHEMISTRY IN COASTAL WETLANDS ON THE MINAS BASIN, BAY OF FUNDY

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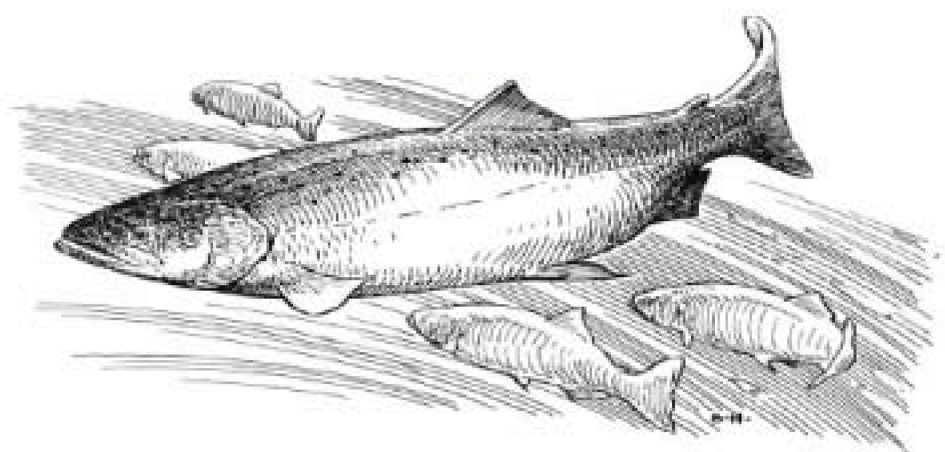
While much is known about mercury distribution and speciation dynamics in freshwater wetlands, very little is known about these processes in coastal wetlands and the capacity for bioaccumulation. To address these issues, sediment cores were collected from four coastal wetland sites (Wolfville, Hantsport, Kingsport, and Windsor) and one intertidal mudflat (Kingsport) on the Minas Basin, Nova Scotia, Canada. All samples were separated into mineral and vegetation and were analyzed for mercury speciation. The Minas Basin (on the Bay of Fundy) experiences among the highest tides in the world, with tidal amplitudes often in excess of 12–13 meters. In order to determine the effect of tide on mercury release from the coastal wetlands, mercury flux was measured at the Kingsport site over a period of 3 days using a Teflon flux chamber technique with Tekran gaseous mercury analysis. Total mercury concentrations in intertidal mudflat cores were low (0.45–35.77 ng g^{-1}) and minimal methyl mercury (MeHg) was present at depths < 6cm (mean = 2.7 pg g^{-1}; std. dev. = 1.0 pg g^{-1}). Coastal wetland sediments were also low in total mercury but ~90 times higher in methyl mercury when compared to unvegetated intertidal sediment. Windsor coastal wetland was notably higher in methyl mercury (ranging from 142–715 pg g^{-1} in Windsor and 14–269 pg g^{-1} at all other sites). A measured positive enrichment factor for total mercury (mean 1.5; std. dev. = 1.9; n= 68) and for MeHg (mean = 3.6; std. dev. = 4.8; n = 66) was observed between mineral sediment and below-ground biomass. Mercury volatilization was observed to be 3–4 times higher (0–7.5 ng/m2/h) at Kingsport coastal wetland than other reported flux measurements in Nova Scotia in areas of forest soil and glacial and granite till. While no direct relationship was observed between mercury flux and tidal height, ratios of flux to solar radiation does provide evidence that tidal inundation and gas release does facilitate mercury release from sediments during peak flux times.

Session F

FISH, FISHERIES AND AQUACULTURE

Chair: Trevor Avery, Department of Biology,
Acadia University, Wolfville, Nova Scotia



POPULATION CHARACTERISTICS, MOVEMENT AND ANGLING OF THE STRIPED BASS (*Morone saxatilis*) SUMMER AGGREGATION IN MINAS BASIN, NOVA SCOTIA

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Abstract

The status and composition of striped bass, *Morone saxatilis*, stocks within the Bay of Fundy is currently debated and ultimately not well understood. With native stocks presently designated by COSEWIC as threatened or reproductively extinct, combined with increasing recreational fishing pressure, and development of in-stream tidal power pilot projects to begin by 2009, the striped bass stocks of the Bay of Fundy may continue to be troubled. This study was designed to obtain baseline population data on length, weight, age, and stock origin from the summer bass aggregation in Minas Basin prior to turbine installation. In total 574 angled bass were measured, weighed, and scale and tissue samples taken between May–October 2008. Mean FL was 40.5 cm, with a corresponding weight–length relationship of Log(Wt) = 3.30Log(FL)-5.58. Aging results indicated that the mean age was 4.3 yrs, with 75% of bass being 2–4 yrs of age. Recaptures accounted for 23.2% of the 529 bass tagged, of which 92% were reported from the site of initial tagging, indicating a pattern of site fidelity throughout the summer season. Across all sampling locations, 7.08 anglers were present per tide, and overall rates of fishing effort were 0.34 fish/rod/hr, and 0.006 retainable size fish/rod/hr. Genetic analysis using mitochondrial DNA was performed on 60 striped bass tissue samples; 20 fish each from the Shubenacadie River, Five Islands, and Southern Bight of the Minas Basin near Wolfville. The analysis showed that 11% of the fish sampled were significantly different from the Shubenacadie captured bass and thus considered to be from other stocks, most likely US migrants. The highest level of differentiation from NS-spawned bass was observed in samples of bass collected from Five Islands, NS in May–June 2008. Mt-DNA analysis confirms that the assemblage in Minas Basin during the summer represents a mix of striped bass stocks.

Introduction

Striped bass, *Morone saxatilis*, is an anadromous species commonly found along the eastern seaboard of the United States and Canada where it has long been prized for both commercial and recreational fishing (Merriman 1941; Setzler et al. 1980; Boreman and Lewis 1987; Scott and Scott 1988; Rulifson and Dadswell 1995). The Bay of Fundy system was once home to three separate native spawning stocks of striped bass, two from the outer Bay of Fundy (Saint John River, NB and Annapolis River, NS) and one from the inner Bay of Fundy / Minas Basin, with spawning in the Shubenacadie River, NS (Rulifson and Dadswell 1995; Douglas et al. 2003; Rulifson et al. 2008). Of these three bass spawning rivers, only the Shubenacadie River is currently considered active. The others are deemed to be reproductively extinct (Douglas et al. 2004).

In addition to the local Shubenacadie population, Minas Basin is known to harbour contingents of migrant USA origin fish which contribute to a summer aggregate stock (Wirgin et al. 1993; Wirgin et al. 1995; Rulifson and Dadswell 1995; Rulifson et al. 2008). The extent to which migrant stocks contribute to this aggregation is generally unknown and is expected to vary from year to year depending upon southern stock densities and food availability. Larger female bass have been shown to migrate longer distances and in greater proportion than males. It is likely that most of the migrant bass which enter Minas Basin are female (Westin and Roger 1978; Setzler et al. 1980; Boreman and Lewis 1987).

The contribution made by US migrant bass to the Minas Basin aggregation convolutes the notion of local stock abundance, particularly within the recreational angling community. Due to possible reproductive failures in two of three native stocks and the apparent overall decline of striped bass within the Bay of Fundy system, steps have been taken to list the population as "threatened" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004).

Current interest in testing and development of alternative forms of energy production within Nova Scotia has prompted renewed attention toward harnessing tidal energy from the upper Bay of Fundy (Dadswell and Rulifson 1994; OEER 2008). A proposed pilot project for testing three in-stream tidal power turbines is expected to commence by 2010 within the Minas Passage, west of Black Rock, NS. An understanding of how striped bass move, feed, and behave within the tidal power test area will be critical for understanding any potential impact posed by installation of in-stream tidal power turbines. At present, the potential impacts arising from either direct or indirect contact of fish with in-stream tidal power turbines are unknown. There is also a lack of information on the intensity of recreational fishing pressure on striped bass within the Minas Basin.

The current COSEWIC status of striped bass, and its importance to recreational fishers in Minas Basin, has lead to concern regarding potential impacts of in-stream turbine testing on the fishery (OEER 2008). As much of the literature in respect to the Shubenacadie River striped bass stock relates to the freshwater portion of their life history, this project is focused on assessing the population of striped bass within the marine environment of the Minas Basin. The project was designed to provide information on critical population characteristics such as length, weight, age, and stock origin of bass captured within the Minas Basin. Tagging and fin clipping were performed to provide information on both the local and long-range movement patterns and stock definition.

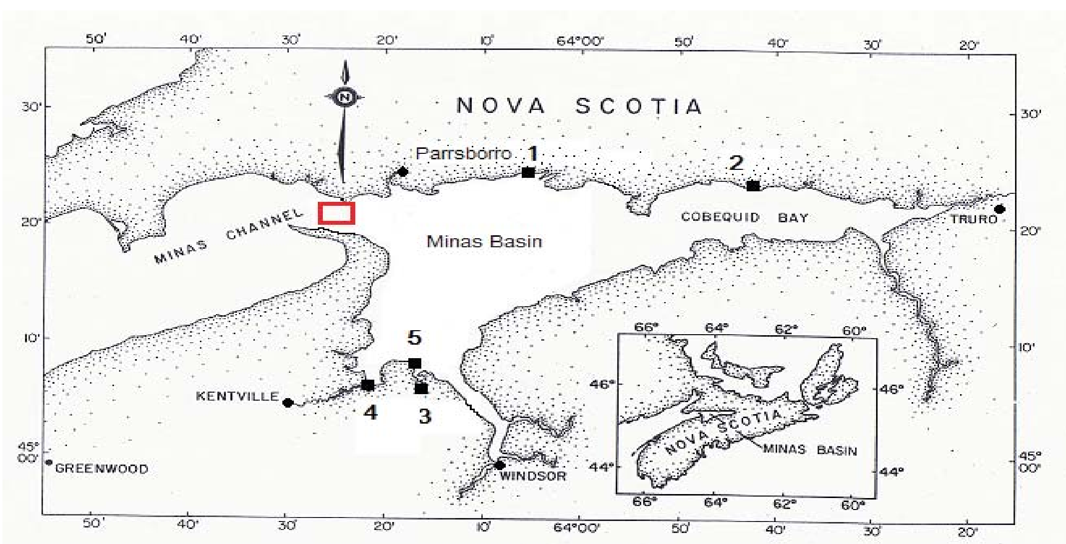

Figure 1. Minas Basin and Cobequid Bay of the inner Bay of Fundy, NS indicating primary sampling locations: 1) Five Islands, 2) Bass River, 3) Gaspereau River, 4) Cornwallis River, and 5) Grande Pré (The Guzzle). The rectangle indicates the proposed general location for the demonstration testing of in-stream tidal turbines.

Study Site Description and Field Methods

The Minas Basin and Cobequid Bay together comprise the inner Bay of Fundy (Figure 1), with Minas Basin being the larger, deeper, and cooler of the two water bodies (Greenburg 1984; Rulifson et al. 2008). This highly dynamic environment is characterized by extremely high tidal range (12–15 m), strong tidal currents (up to 10 kts), high suspended sediment loads (up to 1000 mg/L), and fully turbulent flow (Amos and Alfoldi 1979; Greenburg 1984; Rulifson et al. 2008). Sites from which striped bass were sampled and tagged were: Five Islands and Bass River on the North Shore, and Gaspereau River, Grand Pré (Guzzle), and the Cornwallis River within the Southern Bight (Figure 1).

Striped bass were captured by rod and reel angling during June–October 2008. Fishing effort generally lasted from 2 hours prior to high tide until 3 hours after high tide. Fishing was performed using hi-low style rigs featuring size 4/0–8/0 size circle hooks weighted with 4–6 oz doughnut sinkers, attached to 40 lb-test braided line on 9' surf rods. The predominant bait used was chunked or filleted mackerel, but other baits such as herring, shad, gaspereau, and squid were also used when in season.

Upon capture, striped bass were measured for fork and total length (FL and TL) to the nearest 0.1 cm, and weight to the nearest 0.1 kg. For aging purposes, a scale sample, 6–10 scales, was removed from below the first dorsal fin and above the lateral line and stored in paper envelopes. A fin clipping (1 cm^2) was taken from the pectoral fin, and placed in 95% ethanol for later mitochondrial-DNA analysis. Before being released, each fish was tagged with an individually numbered T-Bar style dart tag (Floy Tag, Seattle) inserted just below the first dorsal fin. Each tag contained return address information for Acadia University's Biology Department.

A single VR2 acoustic receiver (VEMCO, Halifax, NS) was deployed from shore during sampling activities in mid August–October to detect the presence of striped bass tagged during the downstream migration from the Shubenacadie River. Deployment consisted of wading into the water during a rising tide and throwing the receiver out into the water column. The receiver unit was weighted with a 1 kg lead bullet weight, and a small float was used to ensure the receiver sat upright in the current. The unit was tethered to shore using a 30 m rope spiked into the mud. The receiver was retrieved as the tide receded.

Population Data Analysis

Aging was conducted on scales collected during sampling. Three scales were selected for mounting from each sampled bass. Scales were then cleaned in water and mounted between two standard microscope slides. Using a dissection microscope, annular growth rings were counted and used for age determination. Each mount of scales was read by two individuals for age validation purposes.

Angling effort (rod hours) was recorded by tracking both the number of anglers and the number of rods being used by each angler during each tide sampled. Exploitation (μ) was calculated by using the equation (Ricker 1975):

$$\mu = R/M$$

where:
μ = exploitation rate.
R = number of tag returns.
M = number marked in the system.

Estimated total mortality (Z) was determined from the use of a Gulland Method plot which relates the natural log of abundance to year class (Ricker 1975). The sum-of-squares regression line was used to determine slope, which determined the value of Z.

Length and date information were used to calculate the growth increment (change in length between time of release and time of recapture) and time-at-liberty (time difference between date of release and date of recapture) for individual striped bass (mm/day).

Mitochondrial DNA Analysis

DNA (mt-DNA) analysis of striped bass fin clipping samples was used to characterize the origin of Minas Basin striped bass. A subsample of 60 striped bass was selected, of which 20 were collected from the Shubenacadie River, 20 from Five Islands, NS, and 20 from the Grand Pre, NS area. The Shubenacadie River bass sequences acted as a control and were assumed to be the only native population of striped bass in Minas Basin (Wirgin et al. 1995).

From each fin sample a small piece of the preserved pectoral fin was dissected and processed using a DNeasy kit to elute the genetic material. A segment of approximately 500 base pairs (bp) was amplified from the 5' region of the mitochondrial control region using primers utilized in past studies (Wirgin et al. 1993; 1995). The control region was targeted due to the known presence of high variability regions, coupled with regions of high conservation (Ruokonen 2000). This ensured that primers would recognize the region of the mitochondrial genome. Regions with a high rate of mutation provide differentiation among stocks.

The Polymerase Chain Reaction (PCR) conditions used to amplify this region consisted of heat treatment at 95°C for 5 min, 35 cycles of 95°C for 1 min, 56°C for 1 min and 72°C for 1 min, with a final extension at 72°C for 7 min. Once amplified, the PCR product was run on a 1% TAE agarose gel using electrophoresis. A 100-bp DNA ladder was used to reference the migration of bass DNA fragments within the agarose gel matrix. The ladder made it possible to estimate the size of the amplified genetic material, and to determine if it was the length of the targeted gene. Those bands which exhibited strongly under UV light were excised and further purified. The purified DNA samples were examined with a spectrometer to ensure adequate purity. A minimum of 5 ng/µl concentration of mt-DNA per sample was sent off for sequencing at the Genome Quebec Sequencing Facility at McGill University, Montreal.

Upon receiving sequence data, the program Bioedit was used to align forward and backward sequences of each sample (i.e., to create a consensus sequence). A representative sequence was searched against the GenBank database (i.e., a BAST search was conducted) to ensure that the sequence obtained was indeed striped bass control region sequence. All individual consensus sequences were then aligned using the program ClustalW. Sequences from the Five Islands and Grand Pré areas were then compared to individual bass from the Shubenacadie River using the program MEGA3. Any genetic polymorphisms among sampling localities were recorded. The individual samples from Five Islands and Wolfville region were compared to each other and any variation recorded.

The 'Neighbor-Joining' and 'Maximum parsimony' algorithms for clustering sequences, as implemented by the program Mega®, were used to reconstruct phylogenetic relationships among these sequences. Genetics distances were also calculated as a measure of the amount of molecular divergence among individual striped bass samples.

Results

Population Characteristics

In total, 574 striped bass were captured and sampled during the summer or 2008. Fork length (cm) and weight (Kg) measurements were used to determine the weight-length relationship: log(Wt) = 3.309 log(FL) - 5.58 (Figure 2). Mean FL (±SD) was 40.5±10.6 cm. A length frequency distribution was developed from FL measurements (Figure 3). From this, using the back calculated length at age equation Age(x) = ((FL) - 11.98)

/ 6.62 obtained from Rawley (2008), an approximate age frequency distribution was determined (Figure 4). A strong peak in frequency is apparent which centers around the age 2–4 year classes. Individuals within this age range accounted for 75% of all bass sampled. A second smaller peak, centered on the age 6–7 year class, was also observed. The total mortality (Z), obtained from a slope of a Gulland plot (Ricker 1975), was found to be 0.60 (Figure 4).

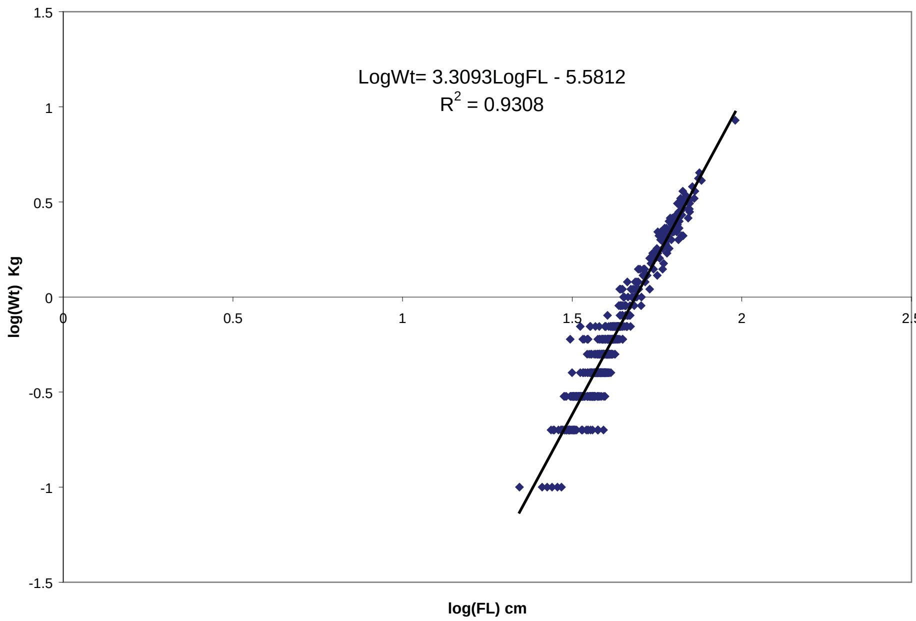

Figure 2. Log transformed weight-length relationship of striped bass sampled during summer 2008 in Minas Basin, NS. The LOG transformed weight-length equation: LOG(Wt) = 3.3093(LOG(FL))-5.5812 (R2 = 0.9308).

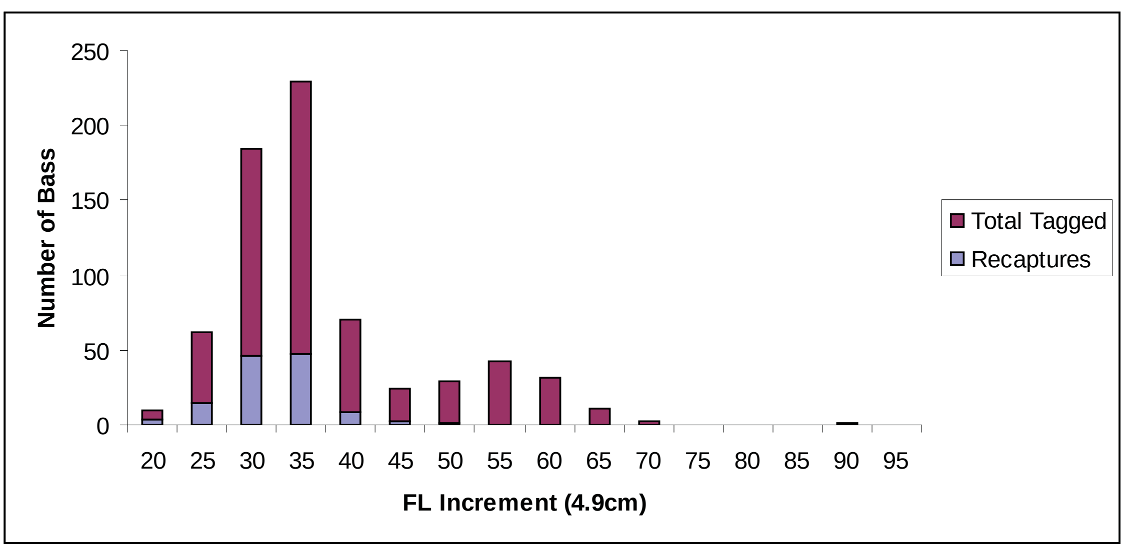

Figure 3. Length frequency distribution of striped bass sampled during summer 2008 in Minas Basin indicated in burgundy, with blue bars indicating the number of corresponding recaptures within each 4.9 cm increment

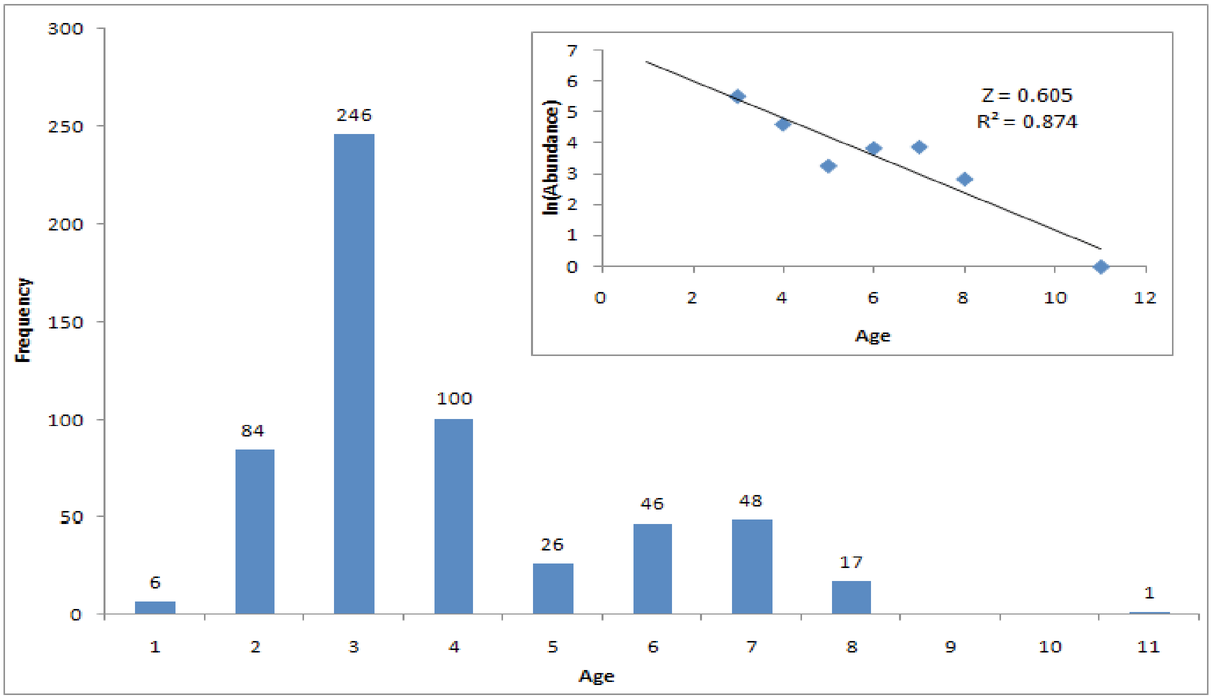

Figure 4. Age frequency distribution of striped bass sampled during summer 2008 in Minas Basin, determined from equation: Age = ((FL)-11.98)/6.62 (Rawley 2008). Offset is a plot of ln(Abundance) vs Age, used to obtain the rate of total mortality (Z).

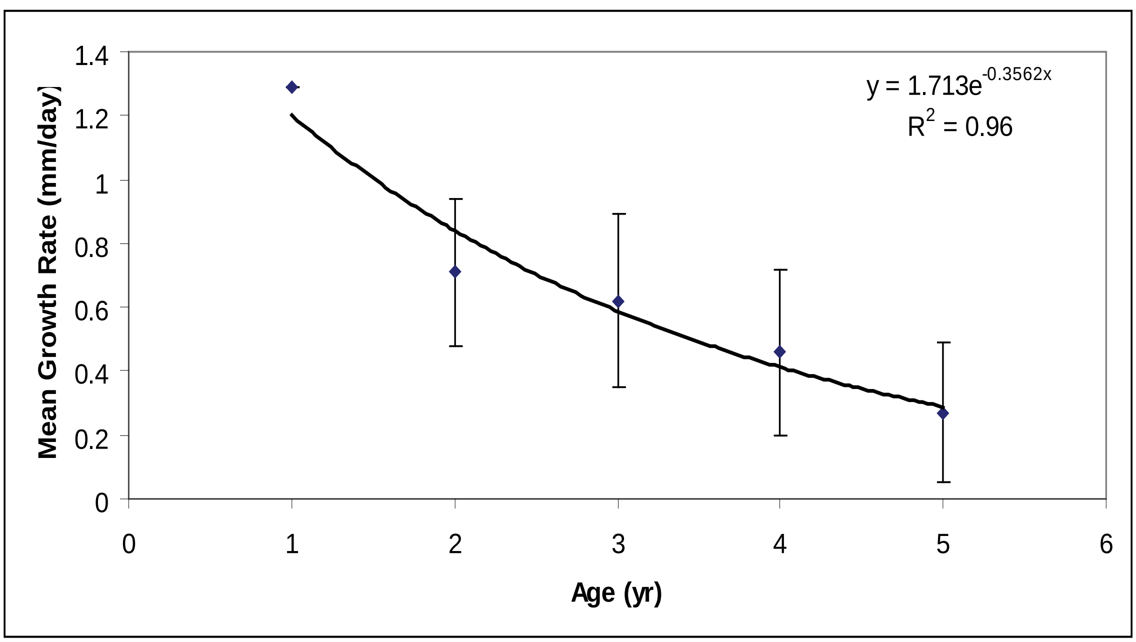

Figure 5. Age versus mean growth rates per year class (mm/day). The exponential regression equation: y = 1.713e-0.3562x, R2 = 0.96.

Growth Rates

Growth rates were calculated from those bass recaptured during continuing sampling. Only those bass that were measured using the same equipment, by the same individual, and recaptured more than 4 days after tagging, were included in growth rate determinations. The mean growth rate of all recaptured bass was 0.61±0.28 mm/day, with a mean fork length (±SD) of 36.5±4.6 cm at the time of recapture. Growth rates were further compared between year classes, where it was observed that mean growth rate declined with age (Figure 5). This relationship was represented by the exponential decay equation where Growth Rate (mm/day) = 1.713e-0.3562(Age).

Angling Effort and Catch Patterns

The numbers of anglers present at all sampling sites was tracked during sampling in order to determine rates of fishing effort and success. Angling activity and subsequent landings were recorded during collection over all sample locations. Effort per tide was found to vary greatly. The greatest numbers of anglers were observed when high tides occurred during weekends and late afternoon/early evening situations. A mean of 7.08 anglers were present per tide. In total 1732 rod/hours were recorded from June through October and within this time period a total of 603 landings (with corresponding effort data) were recorded by anglers (recaptures included). Of these, 11 bass were of legal retainable size (≥68cm TL). Catch per unit effort was 0.348 fish/rod hour, with 0.006 retainable size fish/rod hour. Recreational angler reports accounted for 100% of returned tags. The exploitation rate (μ), based on tag returns, was 0.25 (25%), with the bulk of tags being returned from locations within the Southern Bight of the Minas Basin.

Catch per unit effort data (Fish/Rod Hour) indicate trends in fishing success across the sampling period in which several peaking periods were observed (Figure 6). The data was plotted against lunar cycle stages which occurred during the sampling period, and appears to correlate well with moon stage. Peaks in landings occurred between the first quarter and full moon periods.

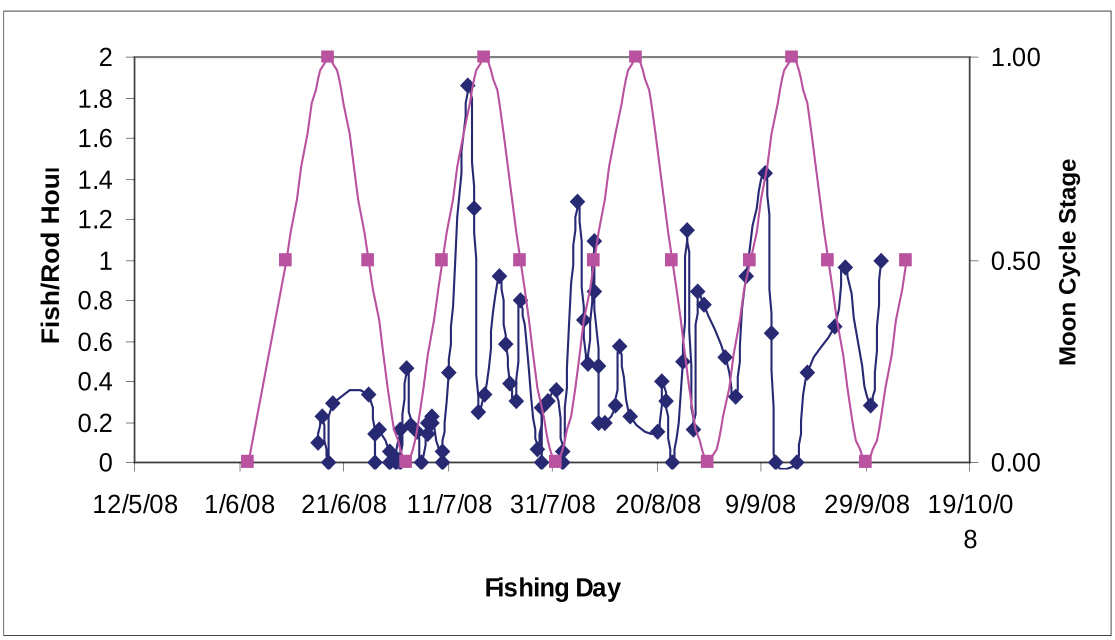

Figure 6. Catch per unit effort (Fish/Rod/Hour, blue line with triangles) shown in conjunction with the moon stage cycle (pink line with squares) throughout the course of summer sampling. New moon is 0.00, full moon 1.00.

Recaptures and Movement

For the period ending May 1, 2009, a total of 134 recaptures, representing 25% of tagged individuals, were reported. Recaptures were received from a small geographical area, with 86% of tags recaptured at the site of initial tagging, indicating a pattern of residency during the summer feeding season. On average, tagged fish were at large 27 days (n=134) prior to recapture. As of 2 October 2008, tagged fish were at large from 1–77 days.

Initial experimentation with a VEMCO VR2 acoustic hydrophone produced limited, yet interesting results. Upon uploading the stored data it was found that a single female bass (68.1 cm TL – of retainable size) had been observed in the Guzzle area on August 26, 2008. The detected bass had been tagged May 13, 2008 in the Shubenacadie River, near Enfield, NS (Rod Bradford, DFO – Dartmouth, NS, pers. comm. 8 January 2009). This work will be extended with a significant effort in acoustic tracking of striped bass during the summer of 2009.

Stock Discrimination

Results from mt-DNA analysis showed that it was possible to detect differences between the Shubenacadie River striped bass and other putative stocks. However, only 11% of the fish sampled were deemed to be from stocks other than those spawning in the Shubenacadie River. Within the Minas Basin, it was found that the highest level of differentiation existed in those striped bass samples taken at one site, Five Islands, NS. This site was sampled early in the year (May–June) and the fish exhibiting differentiation were found to be significantly smaller than others sampled at that site.

Discussion

Sampling was undertaken to gather preliminary data concerning population structure and movement of the striped bass summer assemblage in Minas Basin, NS. Weight–length comparisons indicate that those fish present within the Basin are in good condition as indicated by the condition factor (C=3.31), determined from the log transformed weight-length equation. The average fork length of angled bass (40.5 cm FL) was larger than the average 36.2 cm fork length for angled bass found by Rawley (2008) during 2007. This shift in the mean may simply be an indication of one year of growth within the sample population, or may be the result of sample size differences between the two studies. The presence of one particularly large bass during sampling in 2008 contributed largely to the difference in observed means.

Age frequency analysis indicated a large peak centered on the 2–4 year class which represented approximately 75% of striped bass sampled. This abundance of younger individuals may be indicative of a recruitment movement from the Shubenacadie River estuary nursery area into Minas Basin for feeding. As bass age, they are known to undergo longer range migrations from their home estuary, and upon reaching sexual maturity, bass will stray increasingly further to sea (Kohlenstein 1981; Rulifson and Dadswell 1995; Secor and Piccoli 1996). As migratory potential is considered to be both a function of maturity and overall size, the presence of these two peaks may also relate to the sexual maturity and therefore increased movement of males (3–4 years) and females (5–6 years). The abundance of bass within the 2–4 yr age class could also be an indication of success in recent management efforts including: elimination or restriction of striped bass as bycatch in commercial fisheries, and an increase in size limit for retention in the recreational fishery (Douglas et al. 2003). The exploitation of older adults by the commercial fisheries prior to 2004 or an out-migration to the Atlantic coast are two possible explanations why large bass were observed infrequently in this study.

The limited occurrence of larger fish may also be attributed to limitations placed on the angling effort by fishing from shore. Much of the deep water and channels where larger bass were expected to occur could not be reached through shore casting, and as such large bass which may have been present were not exposed to the bait and could not be caught. On the few instances where a boat was accessible for sampling it was possible to catch bass that were on average larger than those caught from shore.

Angling effort and success was found to vary widely during the study. Peaks in catch per unit effort appear to be closely related to the moon cycle. Peaks were observed just prior to the full moon. This could be related to the fact that Bay of Fundy tides reach their lowest range approximately 3 days before the full moon stage; this 3 day lag may be the reason why an offset from the full moon stage is observed. These data represent fishing effort across all locations sampled during the period and as such the pattern could be generalized throughout the sites sampled around Minas Basin. The increased catch per unit effort during these periods may be linked to the decreased range with which bass can feed over the tidal flats during high water events (i.e. they are more concentrated in the intertidal region and would come in contact with the bait more often).

Mean growth rates were determined for each age class and we found that growth rates decreased in an exponential fashion as fish aged. From the 57 bass used to determine growth rate, mean growth rate was found to be 0.62±0.28 mm/day. In a similar study, Rulifson et al. (2008) reported an average growth rate for bass recaptures during 1985–1986 as 0.37±0.12 mm/day (n=16). Although these two growth rates do not appear drastically different, it is important to consider that although the average FL of recapture was not reported by Rulifson et al. (2008), it was stated that recaptured bass were at minimum 1 year old (≥14.1 cm FL). The findings are counter intuitive in that the striped bass sampled by Rulifson et al. (2008), from the known nursery area of Minas Basin, were generally younger than the recaptured bass sampled during this study, which had a mean age of 3.5 years. It would be expected that younger bass exhibit a significantly faster rate of growth. It may be that the 1985–1986 bass study was biased by a few large bass. It is important to assess growth rates within and between stocks of striped bass as it allows for prediction of when bass of certain year classes will reach legal length limits. Such data is useful to studies on sexual maturation, fecundity, recruitment and migration.

Mitochondrial DNA results provided some interesting insight into the potential makeup of the Minas Basin summer bass aggregation. Prior to this study, the assumption was made that those samples collected from the Shubenacadie system during the spawning run were local origin bass. These 20 bass were of large size and were collected from the spawning grounds during 2008. Although mt-DNA testing did not provide complete information for determining the exact origin of all striped bass sampled, the percentage of non-local bass (11%) does align well with previous works which have estimated that migrant bass may comprise 6–20% of the total summer aggregation (Rulifson and Dadswell 1995; Rulifson et al. 2008). As an interesting comparison, it should be noted that to date no tag returns have been recorded from any other distant areas that would corroborate the presence of migratory bass; and further to this, only two tag returns have been reported from outside the Minas Basin.

A noteworthy limitation of the study is that sampling effort was not uniform across all locations. One sampling site (Grand Pré – Guzzle) received greater focus because bass were more abundant at this location. Although angling is considered to be an unbiased sampling technique, a bias that may have resulted in the capture of only a few large bass is the depth at which bait was presented. Due to the nature of many of the sites sampled, the large deep water channels, which are expected to hold larger bass, were generally inaccessible when casting from shore. When sampling occurred from small boats in deeper water, larger fish were obtained more readily.

Studies Planned for 2009/2010

Additional studies planned for 2009 include a project to test the capabilities of VEMCO acoustic receiver/transmitter technology for potential application in anticipated future fisheries monitoring projects. The capabilities of this equipment will be evaluated by assessing transmission efficiency in response to changes in water depth/tidal height, current speed and direction, wind speed, transmitter power output, and distance of the transmitter form the receiver. Establishing the range and frequency of detection within the megatidal Minas Passage will allow for more efficient and cost effective study designs. The project will serve as an important first step toward the future development and design of environmental monitoring strategies involving both fish and other mobile marine organisms.

In addition to the range test project, VEMCO acoustic receivers will be placed at strategic points along the shore of Minas Basin to provide information on movements of fish surgically implanted with acoustic transmitters. Local origin bass were tagged in May 2009 during their downstream migration from Shubenacadie Grand Lake and will join the bass from the population tagged during 2008. In order to properly assess and monitor the interaction of local fish species, particularly highly migratory striped bass, it will be important to gather information on their patterns of movement on both long- and short-term scales, and the depth at which they travel. Future modelling of striped bass movements in the upper Bay and in the test area will be useful in assessing the potential for fish-turbine interactions.

Assessment of population characteristics and overall abundance of the striped bass population should be continued. It is also important to examine other impacts upon striped bass, including mortality attributed to recreational angling pressure and catch and release practices. By enhancing knowledge in these two areas it will be possible to more accurately gauge the impact, if any, posed by installation and operation of in-stream tidal turbines.

Acknowledgements

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THE CHECKERED STATUS OF BAY OF FUNDY STRIPED BASS

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Striped bass, *Morone saxatilis*, formerly spawned in five Canadian rivers, the St. Lawrence (Québec) the Miramichi (New Brunswick), the Shubenacadie (Nova Scotia), the Annapolis (Nova Scotia) and the Saint John (New Brunswick). Currently, only two of these populations are known to produce new individuals annually, the Miramichi and the Shubenacadie. Within the Bay of Fundy, it is uncertain if spawning any longer occurs in the Saint John and Annapolis rivers, with the result that Bay of Fundy striped bass have recently been designated as threatened by the Committee on the Status of Endangered Wildlife in Canada, COSEWIC. This presentation provides a summary of activities aiming to resolve the present status of the Saint John, Shubenacadie, and Annapolis populations, to assess current abundance and habitat requirements of the Shubenacadie population, and to identify threats arising from human activities to either survival or recovery.

STRIPED BASS (*Morone saxatilis*) EGGS AND LARVAE IN THE STEWIACKE/ SHUBENACADIE RIVER ESTUARY 1997 TO 2008

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Plankton net tows conducted over the past 10 years close to the confluence of the Stewiacke and Shubenacadie rivers yielded insights into both the timing of spawning in May-June, and the recovery of the spawning population following a high recruitment year in 1999. In 2008, as part of the Alton Natural Gas project, more detailed sampling quantified the density of eggs and larvae in the water column with respect to tide and time of year. High density of freshly spawned eggs (>50 eggs/m^3 water filtered) was recorded May 30, June 1, 2, 5, 9 and 11th. The highest egg density recorded was 1562 eggs/m^3 on June 1 on the Stewiacke River (0.6 ppt salinity, 14.2 ^{o}C). Typically, egg density in the water column was low at high tide, and then increased progressively through the ebb tide. Eggs were present right through the ebb tide until the next tidal bore arrived. Larval stages were caught between June 5 and June 27. High densities of larvae occurred June 16 (154/m^3 water filtered) and again on June 20 and 24 (119–240/m^3 water filtered). The aim is to better understand how survival and growth of early life-history stages are affected by the complex interaction between tide, rainfall and temperature.

MINIMIZING VESSEL STRIKES TO ENDANGERED RIGHT WHALES: A CRASH COURSE IN CONSERVATION SCIENCE AND POLICY

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The North Atlantic right whale (*Eubalaena glacialis*) is considered one of the most endangered of all large whales: about 400 individuals remain. Species recovery is, in part, contingent on reducing vessel-strike mortality. Our science-based conservation program was policy driven and resulted in two implementations specifically designed to minimize the risk of lethal vessel-strikes of right whales without unduly compromising vessel navigation and safety. In Atlantic Canada, the Bay of Fundy Traffic Separation Scheme (TSS) was relocated in 2003 to reduce the risk of lethal vessel strikes by 90 percent where the original outbound lane of the TSS intersected with the Right Whale Conservation Area, and an Area To Be Avoided (ATBA) that was adopted for Roseway Basin in 2008 has demonstrated an 82 percent reduction in the risk of lethal vessel-strikes. The above rerouting of vessels for right whale conservation, as sanctioned by the International Maritime Organization, sets a precedent for national and international marine conservation policy by providing vessels with a direct action they can take to protected endangered whales; both regulated (TSS) and voluntary (ATBA). These works demonstrate that effective science-driven policy tools for conservation can be identified, made available, and implemented. Voluntary compliance with an IMO-adopted navigation policy in the second area, Roseway Basin, is now being monitored through the non-governmental Vessel Avoidance of Conservation Area Transit Experiment. Voluntary compliance by the shipping industry has stabilized at 71 percent and resulted in an 82 percent risk reduction, and is being proactively congratulated and encouraged through direct contact between scientists and vessel operators through the Marine Stewardship Recognition Program (MSRP).

GROUNDLINE PROFILES ON THE BAY OF FUNDY LOBSTER GEAR AS A THREAT TO NORTH ATLANTIC RIGHT WHALES

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Introduction

As a result of their coastal habitat along the east coast of North America (Kraus and Rolland 2007), an area that also receives large volumes of vessel traffic (Laist et al. 2001; Knowlton and Brown 2007) and contains extensive fishing activity (NOAA 2008), North Atlantic right whales (*Eubalaena glacialis*) have two major causes of mortality: strikes by vessels and entanglement in fishing gear (Kraus et al. 2005; Moore et al. 2007). With fewer than 400 individuals remaining (Kraus and Rolland 2007), the North Atlantic right whale is one of the most endangered large whales in the world and the only one whose recovery has been federally mandated in both Canada and the United States. Both countries are seeking to accomplish this by reducing the incidence of entanglements (National Marine Fisheries Service 2005, Brown et al. 2009).

Ropes in the water column are believed to present a risk to entangle whales (Johnson et al. 2005). Fixed-gear fisheries (i.e. those using pots, traps or gillnets) use ropes in several parts of their operation, but most notably as buoylines (connecting gear on the bottom to a surface buoy) and groundlines (connecting traps or nets together in a series; Johnson et al. 2005). The U.S. National Marine Fisheries Service (NMFS) considers groundlines to be a significant threat to entangle whales because they are normally made from floating rope and now require all fixed-gear fisheries in the United States to use sinking or neutrally buoyant ropes for their groundlines (ALWTRP 2007). To date, there have been no fisheries management efforts in Canada to modify the fishing industry in order to reduce the chance of entangling whales.

The objective of this research was to provide information about the elevations of Bay of Fundy lobster fishery groundlines above the bottom. We tested two central hypotheses about the elevations and assessed several factors that may influence these elevations. The first hypothesis was that groundline elevations would be greater than the approximate body-height of an adult right whale (3 m; Moore et al. 2005). An elevation known to pose a significant risk to entangle whales has never been established, so we chose this definition as a conservative estimate. The second hypothesis was that the elevations of groundlines would be no more than 0.6 m above a typical lobster trap (0.4 m), thus 1.0 m above the bottom. Four factors were also evaluated to determine their influence on groundline elevation: order of the groundlines on a trawl, water depth and the effect of tidal current velocity while the trawl was being set and after the trawl was set.

Methods

This research was done with assistance from fishermen on commercially active lobster gear being fished in two locations in the Bay of Fundy (Figure 1): at the mouth of St. Mary's Bay, Nova Scotia (March and May

2008) and off the west coast of Grand Manan, New Brunswick (July 2008). Depth data-logger sensors (Star-Oddi DST milli) were attached to some of the groundlines on trawls of lobster traps and on the traps at each end of the groundline. These latter sensors measured the depth of the bottom and the depths of the sensors on the groundlines were compared to this to determine their elevations above the bottom. Current velocities were calculated for each location and time using the latest version of the Fisheries and Oceans Canada Tidal Prediction Model (DFO 2009).

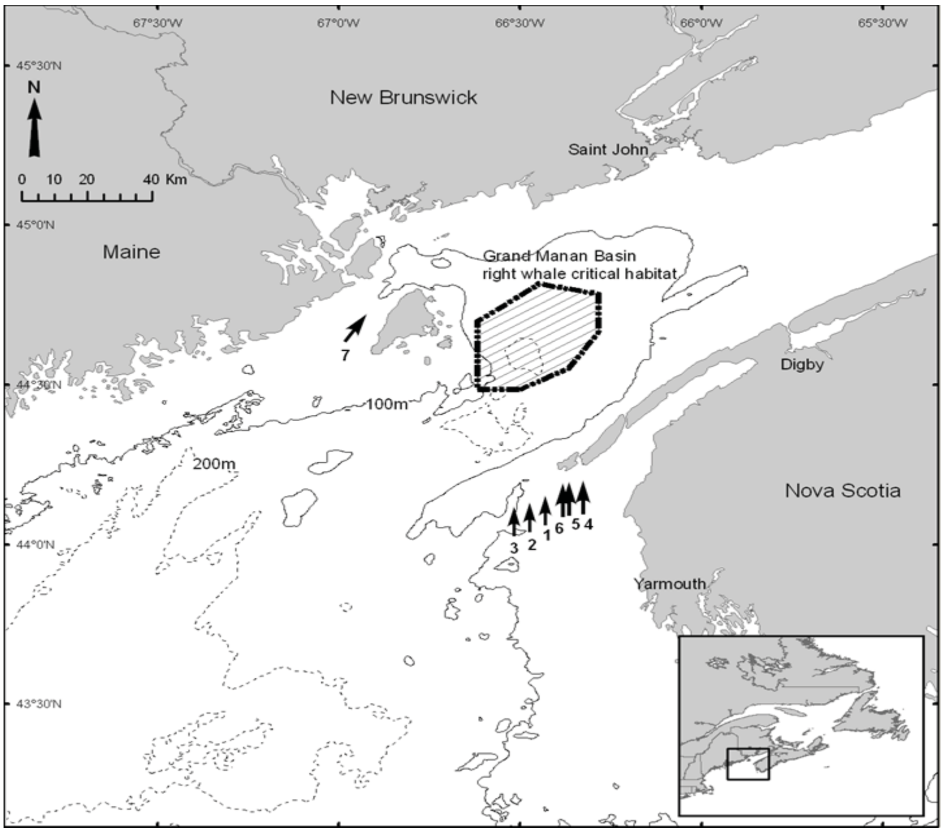

Figure 1. Map of the mouth of Bay of Fundy and southwestern coast of Nova Scotia indicating locations of trawls evaluated in the study in relation to the Grand Manan Basin North Atlantic right whale critical habitat as designated by the Canadian *Species at Risk Act* (SARA) (Brown et al. 2009)

Results

The elevations of 17 regular (floating) groundlines were recorded in the Bay of Fundy for at least 2 days each, at either 5- or 15-minute intervals (Figure 2). These groundlines were on seven different trawls set by two different fishermen at three different times of year. The mean elevation of the groundlines was 1.6 m (SD = 0.9, $n = 5968$) and 0.32 of these elevations were ≤ 1.0 m and 0.92 were < 3.0m. The maximum recorded elevation was 7.0 m. When the data from each of the groundlines were combined (as 17 independent tests using Fisher's combinatorial test; Fisher 1948), each of the central hypotheses were rejected ($P < 0.05$). Groundlines were not as low as was predicted if the groundlines were taut, but most were below the (conservative) elevation hypothesized to be a threat to entangle whales in the water column.

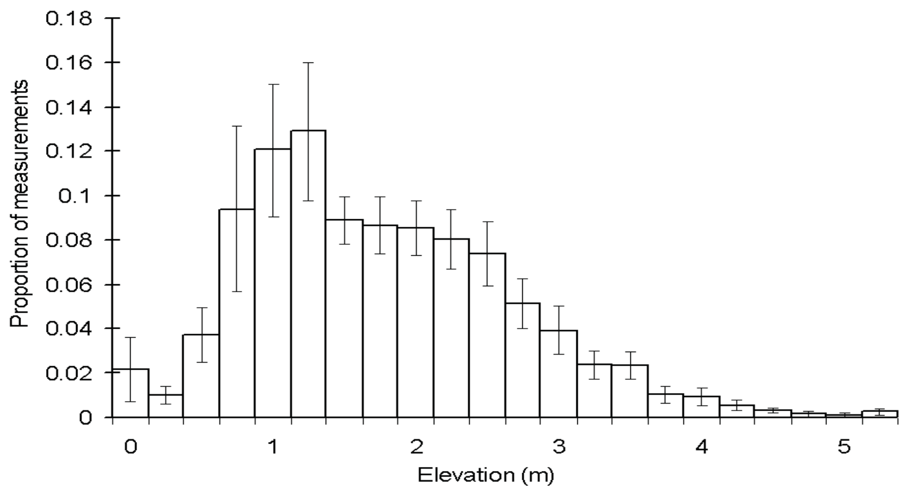

Figure 2. Frequency distribution of all groundline elevations measured at the vertex of each in 5- or 15-minute intervals for at least 2 days (see Methods). Bars indicated mean (± SE) proportion of observations for all groundlines (n = 17). Maximum elevation was 7.0 m. Proportion of observations ≤ 1.0 m = 0.32 and < 3.0 m = 0.92.

Of the four factors evaluated as potential influences on groundline elevations, only the order of the groundlines on a trawl had no effect. Trawls set in deeper water had lower groundline elevations and those set while tidal currents were fast had significantly lower groundline elevations than those set near slack tide. Once a trawl was set, however, the effect of current velocities on groundline elevation was dependent on the tautness of the groundline (Figure 3). The effect on taut groundlines was linear and directional, but the relationship between tidal velocity and elevation was less predictable for groundlines that had slack.

Discussion

This work has shown that lobster fishermen in the outer Bay of Fundy are capable of setting their trawls with low-elevation groundlines and that there are several factors within their control that influence these elevations. Within their constraints of time and costs, fishermen generally strive for low-elevation groundlines because this increases their fishing effort. Efforts to encourage trawls to be set this way would be favourable for fishermen and for reducing the probability of entangling North Atlantic right whales.

To date there has been little progress in determining the causes of the entanglement threat from fishing gear although management efforts in the United States have focused on groundlines. Will reducing the elevation of groundlines reduce the risk to right whales in the Bay of Fundy? Quite likely, yes, because this will result in less line in the water column. It is, however, worth considering that a large majority (0.92) of the elevations measured in this study were within one body-height of a right whale from the bottom (i.e. 3 m), so efforts to reduce groundline elevations further may not produce equitable reductions in the threat to the whales. An accurate evaluation of this requires knowing how close and how often right whales approach the sea floor. In the meantime, there are many other elements of fishing operations (e.g., buoylines) that must be evaluated as a means of reducing the threat of entangling right whales.

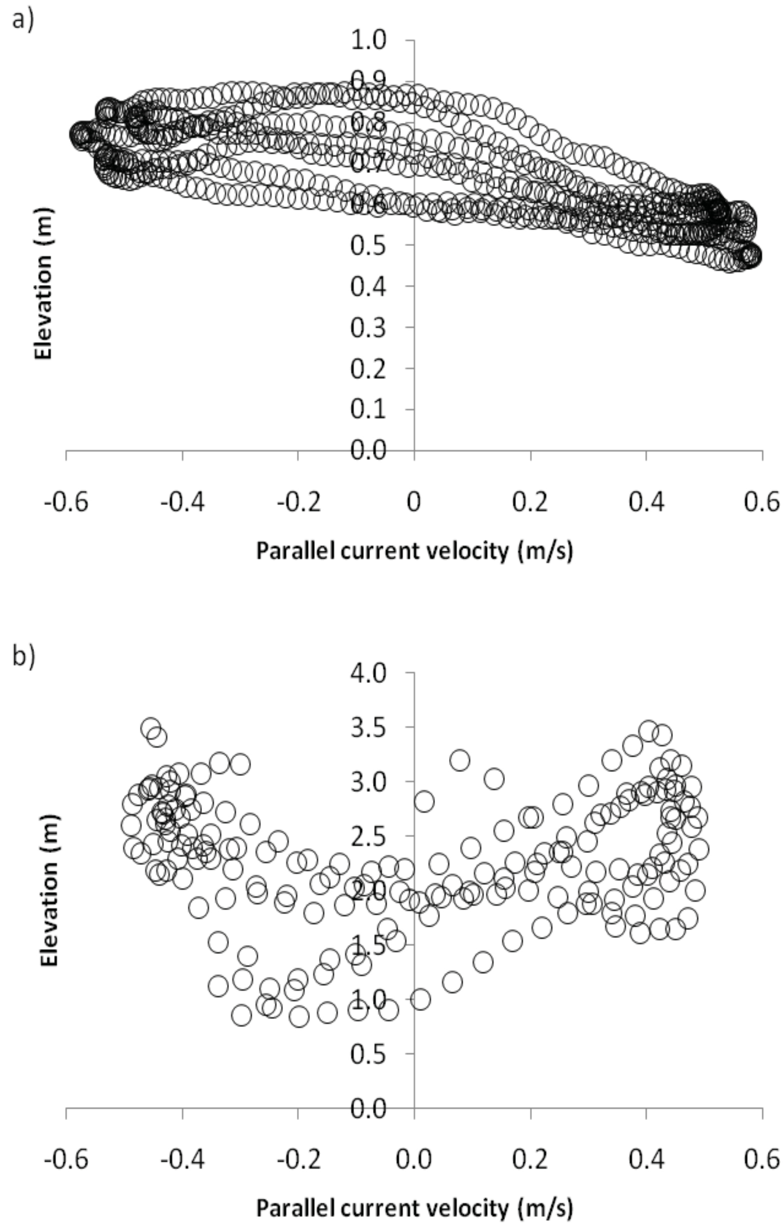

Figure 3. Relationship between elevation of a) a taut groundline and b) a slack groundline with the parallel forces of tidal currents relative to each groundline. For each groundline, elevations were averaged at 1.5 hour intervals. Results of multiple linear regressions for parallel tidal components shown here were: a) $F = 540$, $r^2 = 69.7$, $p < 0.001$; b) $F = 42.8$, $r^2 = 20.8$, $p < 0.001$.

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MACROZOOPLANKTON ECOLOGY OF THE LURCHER SHOAL AREA, 15 NM (28 KM) SOUTH OF BRIER ISLAND

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There is a 27 year time series of autumn icthyoplankton surveys of the Bay of Fundy and parts of the Gulf of Maine. We can look at this as an annual census of the main players in the macrozooplankton community. Copepods from eight stations in the Lurcher Shoal area have been identified and counted. These results are compared here with previously determined order of magnitude estimates of major invertebrate taxa; many of which are copepod predators, taken from the same survey samples. Temperature and salinity monthly averages from Station Prince 5 are also used to determine the timing of major physical changes in the water column.

Second Prize - Graduate Paper

CONTEMPORARY DIAGNOSIS OF AN INTRACELLULAR PARASITE OF COD: APPLICATION FOR INVESTIGATING THE LIFE HISTORY OF *Loma morhua*

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Farming Atlantic cod (*Gadus morhua*) in Canada is of particular interest because of consumer interest in the product and the market profit associated with cod. Emergence of the intracellular fungal parasite, *Loma morhua*, at cod aquaculture sites poses a significant threat to the developing industry. Moreover, the pathogen is of international concern and is expected to become a limiting factor for cod aquaculture in Iceland and Norway. *Loma morhua* infections are characterized by mortalities and reduced growth rates in juveniles and adults. To date, the life cycle of *L. morhua* has yet to be elucidated and epidemiological investigations have failed to identify route(s) of infections. A Polymerase Chain Reaction PCR-based method that takes advantage of the variable ITS region of rDNA has been developed for specific diagnosis of *L. morhua* in infected host tissue. Results from empirical assessment of this assay indicate that the specific rDNA primer sites are highly conserved among geographic isolates from Atlantic Canada, Iceland, and Denmark. The determination of presence/absence and quantification of level of infection will be facilitated by employing quantitative real-time PCR (qPCR). The qPCR diagnostic assay will represent an excellent tool for identifying route(s) of transmission and identifying organisms at cage sites that contribute to the epidemiology of infection. Moreover, the qPCR assay will be utilized to compare Atlantic cod families to assess resistance/susceptibility to *L. morhua* infection. The evaluation of family regarding resistance/susceptibility to infection will be used as a criterion for the selection of cod broodstock.

ESTABLISHING AQUACULTURE RESEARCH OBJECTIVES FOR SOUTHWESTERN NEW BRUNSWICK: BRINGING LOCAL FISHERIES AND SCIENTIFIC KNOWLEDGE TOGETHER

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Aquaculture is often viewed as an important contributor to the economy of New Brunswick coastal communities. Aquaculture operations can however, often compete with the capture fishery, traditional fishery, shipping, tourist amenities and other ocean industries for scarce marine space.

The province of New Brunswick has many aquaculture operations along the southwest coastline of the Bay of Fundy. Unfortunately, devastating fish losses resulting from disease in the mid-1990s greatly affected the entire industry. As a result new standards and practices for fish containment were adopted. Among the new practices was the rotation of fish cohorts between multiple aquaculture sites allowing all sites to remain fallow for one year after each harvest cycle. However, to meet this site rotation requirement operators with single site locations were required to apply for additional sites in an already over crowded bay.

In New Brunswick public policy dictates that the placement of new and additional finfish inshore aquaculture sites include public consultation. To meet the fall 2008 multiple site deadline, government representatives initiated dialogue with the Fundy North Fishermen's Association (FNFA) in early 2007. A not-for-profit fishermen's advocacy organization, the FNFA represents fishermen and coastal stakeholders along the Bay of Fundy from St. Martin's down to the U.S. border between NB and the state of Maine. Working directly with fishermen for new aquaculture site selection; this initiative served as a positive step towards bringing local fishers and scientific knowledge together. Further to the site selection process, in the fall of 2008 the province called for the development of a Fisheries-Aquaculture Working Group to establishe research goals that will combine the resource concerns of both the Traditional Fishers Coalition and the New Brunswick Salmon Growers Association of Southwestern New Brunswick.

Though these efforts show great promise, detailed examination of the processes to date present concerns paramount in public consultation that have not been met. Using deliberative democratic theory to examine specific consultation processes such as the provincial strategic environmental assessment for the introduction of tidal power, there are two important points that must be addressed. First, the creation of a political space for public deliberation and second, the provision of essential information to stakeholders wise decision making. To build appropriate institutions for integrated coastal and ocean management, these two concerns must be addressed particularly if spatial needs between aquaculture site allocations and the capture fisheries is to be achieved through combined traditional and scientific knowledge.

AQUACULTURE LEASES ON CLOSED BEACHES: A ROADBLOCK TO SUSTAINABLE SHELLFISH MANAGEMENT?

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Abstract

As part of a larger study of integrated management projects in the Canadian Maritimes (see www.coastalcura.ca), an assessment of habitat reconstruction and shellfish reseeding projects in the Annapolis Basin and St. Mary's Bay, Nova Scotia, area through the Annapolis Watershed Resource Committee was conducted. It demonstrated an important roadblock to integrated coastal management in the Canadian Maritimes. This case study examines how federal and provincial regulation in shellfish sanitation, in public health, in aquaculture leases and in depuration have come together to present a serious impediment to improved water quality and long-term habitat reconstruction. It also demonstrates that the public participation in integrated coastal management promised in the *Oceans Act* has been slow to develop in the face of other legislative agendas.

Introduction

A five-year community university research alliance is examining the barriers to integrated management (IM) in the Canadian Maritimes. It is funded by an innovative program of the Social Sciences and Humanities Research Council of Canada (SSHRC) that supports collaborative research involving community and university partnerships. The Coastal CURA (see www.coastalcura.ca) involves two universities, four First Nations, two fishermen's organizations, and several community organizations from the three Maritime provinces (New Brunswick, Nova Scotia and Prince Edward Island). This paper reports on some of the findings of that project, particularly as relates to one case study in clam management in the Digby area of Nova Scotia (see Figure 1). In 1996, the Canadian government passed the *Oceans Act*, which required the Department of Fisheries and Oceans (DFO) to lead in developing IM plans for Canada's oceans, in collaboration with other levels of government and with coastal communities. In 2002, Canada's Oceans Strategy promised institutional arrangements so that those dependent on coastal resources would be involved in designing, implementing and monitoring all coastal and ocean management plans.

IM has been described as "a continuous and dynamic process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal ecosystems and resources" (Bastien-Daigle et al. 2008: 97). Components that require "integration" include but are not limited to political and legal jurisdictions, ecosystem parameters, conflicting uses, social, cultural and economic needs, different knowledge systems, and controls on anthropogenic impacts (McFadden 2008). Bastien-Daigle et al. (2008) reviewed the progress of IM in the Maritime provinces, but their survey focused primarily on Atlantic Coastal Action Program (ACAP) staff and government bureaucrats and did not gather input from community people. This paper reports on the experiences of members of coastal communities. As the Coastal CURA team includes local community partners, we have rich detail on several key problems with IM as it is proceeding in Canada, as this paper will demonstrate.

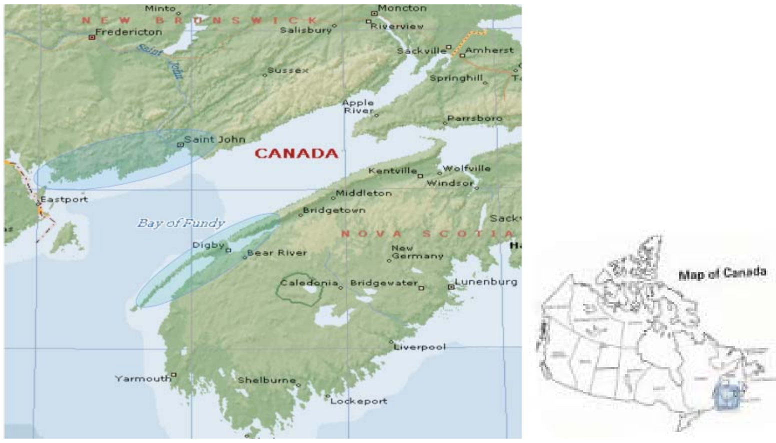

Figure 1. Bay of Fundy showing case study shellfish harvesting areas of Nova Scotia and New Brunswick

Issues in Shellfish Management

According to clam harvesters interviewed during the summer of 2008, harvesting soft shell (*Mya arenaria)* and quahog (*Mercenaria mercenaria)* clams has long been important for both aboriginal and non-aboriginal coastal communities in several ways: it is a component of household livelihoods and food security to which women and children can contribute; it sometimes serves as the entry and exit fishery for men at the beginning and end of their fishing careers; and it is an important fall back resource when other stocks decline. In more recent years, it has served as a refuge resource when members of coastal communities lose access to fishing rights (see also Pinkerton and John 2008). However, many coastal communities have found this important resource more and more difficult to access.

Land-based pollution and seasonal water quality problems can lead to concentration of toxins in shellfish, with a result that many productive beaches are closed for harvesting activities. Beaton (2008: 69), for example, reports that Nova Scotia shellfish closures have more than doubled over the past 15 years with an estimated annual economic loss of CAD8 million. Habitat destruction and overfishing have led to declining stocks on the remaining open beaches, and in Nova Scotia privatization by provincial regulators has further restricted harvesting options. Clam harvesters in Nova Scotia have protested the privatization policy, as it has proved a barrier to their cooperative attempts to redress pollution, habitat destruction and over-harvesting, for reasons that will be explained below.

There are several regulatory agencies involved in ensuring shellfish quality and safety in Canada. Environment Canada (EC) tests water quality and classifies shellfish growing areas; Department of Fisheries and Oceans (DFO) controls harvesting, transportation and cleaning of shellfish from classified areas and enforces closure regulations; the Canadian Food Inspection Agency (CFIA) regulates the handling, processing, marketing, import and export of shellfish. The *Fisheries Act*, *Management of Contaminated Fisheries Regulations*, the *Fish Inspection Act*, and *Fish Inspection Regulations* provide the framework for these powers. Bacteriological surveys (to measure fecal material) and shoreline surveys (to identify and quantify the pollution sources and to estimate their movement, dilution and dispersal in the environment) result in classifications that include: *approved,* where minimum counts of contaminants are found and harvesting and direct marketing is allowed; *closed*, where direct harvesting is prohibited due to chemical or bacteriological contamination, and *unclassified*, areas where the sanitary suitability for harvesting is undetermined and therefore not approved for harvesting at present. Classification of beaches is based on regular sampling but the methods and costs for frequent sampling have become an issue in both shellfish management and marketing. Exporting shellfish to U.S. markets, for example, has recently required tightened sanitary protocols. DFO records show that since 1995 beach closures have increased dramatically throughout the Canadian Maritimes (DFO 1996). Shellfish can be harvested from contaminated sources and marketed after they go through a depuration process, which involves placing them in purified sea water for periods exceeding 24 hours. As more shellfish beds become affected by land-based pollution, fewer clams can be sold without depuration. When harvesters sell clams to depuration facilities, however, they receive a lower price.

The result of this combination of factors is that key management activities include frequent water and meat testing to ensure beaches are opened and closed as appropriate; inspection of depuration facilities and regulation of buying and transport of shellfish to ensure product safety and quality; enforcement of harvesting regulations; and finally, habitat restoration and clean-up of pollution sources. While all of these regulatory activities are necessary and required for safe and reputable shellfish marketing, we will demonstrate that collectively, current shellfish management is a barrier to IM. In particular, pollution remediation and habitat restoration can be at cross purposes with privatization of Crown beaches.

Researching IM Institutions: The Annapolis Basin Watershed Committee Case Study

Complex watershed and ocean environmental issues are relevant to management of shellfish beds. St. Mary's Bay, Nova Scotia, for example, along with the Annapolis Basin and the Minas Basin, are part of a complex watershed system involving six rivers. Fifty years ago, the Annapolis Basin produced approximately 60% of the soft-shelled clam harvest in Nova Scotia. Resource decline has substantially reduced this harvest, arguably as a result of land-based pollution. Local clam harvester organizations have existed in the area for decades and their archives show that harvesters have lobbied government to address beach pollution, habitat destruction, and stock declines since the early 1980s. Clam harvester associations also sought government support for professional qualifications for harvesters in order to promote environmental awareness.

When the federal government responded to such local demands with its Atlantic Coastal Action Program (ACAP), the Clean Annapolis River Project (CARP) was formed. The CARP coordinator chairs the Annapolis Watershed Resource Committee (AWRC), a multi-stakeholder management board that focuses on the Annapolis Basin and includes representation from clam harvesters, clam processors, all levels of government, and the Bear River First Nation. The Bay of Fundy Marine Resource Centre (MRC) is a non-profit service organization that assists coastal communities on the Bay of Fundy in marine resource research and planning. It promotes IM in the Digby/Annapolis Basin area, and members of the MRC also serve on the AWRC.

As both the Bear River First Nation and the MRC are partners in the Coastal CURA, the AWRC was selected as one case study in the Coastal CURA project. The AWRC has focused on municipal sewage spills and siltation problems related to causeway construction. Unfortunately, unlike the ACAP on the New Brunswick side of the Bay (Eastern Charlotte Waterways, Inc), the AWRC does not have a water-testing laboratory that meets Environment Canada standards for shellfish quality testing. Subsequently, they have had to rely on Environment Canada. With the help of these ACAP organizations, however, clam harvesters have formed cooperatives, developed harvest management protocols and strategies for their membership, and experimented with habitat restoration and reseeding. The Coastal CURA team members have also worked with clam harvesters to promote IM through convening learning circles on clam management, cataloguing and digitizing the clam harvesting association records, and documenting the history of harvesting activities in the area.

Despite these attempts to build local IM capacity, shellfish management is significantly hampered in both provinces by the lack of effective coordination of both watersheds and adjacent coastal zones. Human and animal feces, agricultural land wash, leeching from dumpsites, siltation from hydroelectric developments, and other environmental issues all impact shellfish beds along the intertidal zone (Wells 2003). Despite the efforts by local organizations to organize an integrated response, to meet with municipal authorities on issues such as sewage disposal, and to coordinate with national and provincial administrators, they have received little government support from either the provinces or the federal government. Governments appear to prefer partnerships with large corporate actors, and as we will demonstrate, these are often based on accepting the environmental status quo. This preference is creating roadblocks to both sustainable development and IM.

Privatization in St. Mary's Bay

After the province and the federal government signed an MOU that enabled the province to manage aquaculture, the Nova Scotia Department of Fisheries and Aquaculture issued private aquaculture leases in 1997 to 1682 hectares of Crown land beaches in the St. Mary's Bay. The existing quahog stock on these beaches was subsequently harvested under new arrangements that negatively affected clam harvester incomes. In 2006, when harvesters learned that these annual leases were to be renewed for a ten-year period, they approached the AWRC and the MRC for assistance in preparing for public consultation that they assumed would be part of the lease renewals. The Coastal CURA followed up on the St. Mary's Bay situation as part of their assessment of IM in this area of Nova Scotia (see Wiber and Bull in press).

As no public consultation process was planned for the renewal process, members of MRC staff and of the Bear River First Nation arranged meetings with the municipality, the province and the federal regulators to make local concerns known. The MRC also organized several public meetings for community members, inviting federal and provincial regulators to respond. As part of the Coastal CURA project, these public sessions were recorded and transcripts were prepared. The Coastal CURA team did research on the history of the clam leases, on recent clam prices in local markets, and on the impact of clam harvesting on local communities. In the summer of 2008, a student member of the Coastal CURA team also collected comparative data by conducting twenty-five semi-structured interviews among clam and periwinkle harvesters and other onshore harvesters on the New Brunswick side of the Bay of Fundy where no privatization has yet taken place.

Privatization in St. Mary's Bay as led to deep conflict between the community and government regulators. Several aspects of the lease created local alarm. First, St. Mary's Bay contains the only commercially viable quahog clam stock in the larger Bay of Fundy, and after the lease, this stock fell under the exclusive control of the leaseholder. Second, an aquaculture lease would suggest that the leaseholder intended to cultivate farmed stock, whereas the St. Mary's Bay leaseholder has so far only harvested wild stock. Third, St. Mary's Bay had several contamination issues that had kept large portions of the bay classified as a closed beach. Fourth, the corporate leaseholder also owned the only depuration plant in the area, which means that while the leaseholder could process and sell clams from St. Mary's Bay, they had no incentive to work for habitat restoration and reopening the beach.

And finally, there had never been a public review of the site selection process as is required under provincial regulation. According to the provincial Web site, aquaculture leases can only be granted after public notice and public input in the licensing process, usually through the Regional Aquaculture Development Advisory Committee (RADAC) (see http://www.gov.ns.ca/fish/aquaculture/radac/ accessed November 2008). According to local informants, until the MRC organized some public meetings, no consultation was held to assess the initial lease application, nor the renewals.

Consequently, local stakeholders, including the municipality, the adjacent First Nations community of Bear River and the clam harvester associations, had many questions in 2007 when the St. Mary's Bay lease was to be extended for a further ten years. They were not surprised when provincial and federal regulators asserted in community meetings that enforcement and stock protection would be more effective under the lease arrangement. They were surprised, however, that when challenged to show the evidence for better management, the regulators refused to provide it, citing the need for corporate privacy.

This approach has done little to pacify clam harvesters who object to the fact that one company has been allowed to claim the public clam stocks as their private corporate holdings. In one public meeting, the clam harvesters listed several negative impacts from the privatization:

1. The allocation of all productive closed beaches to one corporate actor discourages investment in other depuration operations and effectively eliminates the other buyers – as one clam harvester put it "you are essentially forcing me to become an employee of this one private company";
2. The private right to depurate clams from closed beaches was a disincentive to habitat restoration and pollution clean up and undercut clam harvester management efforts – for example, harvesters felt that some closed areas should be left to produce brood stock for reseeding the overtaxed open beaches;
3. The terms of access to closed beaches controlled by the lease owner were objectionable to many harvesters – for example, they were required to dig 3000 pounds of soft shell clams in open beaches and to sell them to the lease holder, in order to get access to closed beaches. This questionable labor practice, taken together with offering higher prices for clams from open beaches, meant that the company was decimating open areas that the harvester association was trying to restock (Public Meeting Transcripts, Digby Municipal Chambers Office, January 30, 2007).

Most clam harvesters were even more alarmed to discover that the current St. Mary's Bay leaseholder had obtain a "first right of refusal" to lease all productive clam beaches that are closed. Regulators explained that this would provide some stability for the depuration plant, which had required a large capital investment. Finally, public health regulation was used to deflect criticism of infringement on First Nation access rights as regulators said that it could not be an infringement of aboriginal rights if harvesting is closed to the public anyway. In the end, the extended aquaculture site lease, the right of first refusal and the depuration plant has given this corporation an effective monopoly status in the clam industry in this region of Nova Scotia. We argue that this has created significant tension between private rights in closed beaches and the development of effective institutions for IM.

It also contributes to legitimacy problems for the regulator (see Pinkerton and John 2008). In the St. Mary's Bay area, tension has developed between harvesters and regulators on how and when beaches are classified or reclassified. Clam harvesters feel that the aquaculture leaseholder is in a significant conflict of interest, as keeping a beach closed extends the company's control over the clams on that beach. But even a public quasi-governmental group such as the AWRC has found it difficult to establish how often survey sampling is taking place, who is doing the sampling, and how the samples are being processed. Further, the relevant regulatory agencies have refused harvester requests for information about the survey process. Clam harvesters report that they have been told that the reason they are not given survey data for particular beaches is that they might try to use the data to press for a reopening of closed beaches.

This is in sharp contrast to the experience on the other side of the Bay of Fundy, where Eastern Charlotte Waterways, Inc. has been able to secure a certified laboratory to test water samples in order to establish whether beaches should be open or closed. New Brunswick clam harvesters reported that they were alarmed by the privatization experience in Nova Scotia. In order to deflect this possibility in New Brunswick, they worked closely with Eastern Charlotte Waterways, Inc. to form a cooperative. Harvesters pay a small fee to the cooperative to facilitate the cost of regular testing, and the response time on beach closures and openings is significantly shorter. The cooperative is not a marketing organization, but rather a mechanism for funding the necessary water and meat testing to ensure that the harvested clams are safe for human consumption. But the cooperative has also worked to further habitat restoration and stock rehabilitation.

Conclusion

The St. Mary's Bay clam management case raises several questions about the Canadian approach to developing effective IM institutions. While ACAPs have struggled to develop community involvement in IM, government privatization policy seems to be working in a contrary direction. Recently, representatives of DFO have argued that management strategies such as co-management or community based management are incompatible with legislative authority required of the minister. It seems contradictory, therefore, that so much management authority should be devolved to private corporate actors, including monitoring, enforcement and science. The government approach, however, may be explained using calculations of efficiency and cost-minimization (see Townsend, Shotton and Uchida 2008). Wyman (2002) has suggested that such considerations were at work in calculating the relative merits (and implied costs) of quota systems versus informal negotiations with key industry stakeholders. In the St. Mary's Bay case, the alternative to private leases would have been to deal with a large number of individual harvesters (or possibly harvester organizations) whose management capacity may be viewed with some skepticism. If that is the case, IM will not resemble the participatory decision-making suggested by the policy language, unless one defines participation very narrowly.

It is perhaps not surprising then that members of coastal communities have developed a bad taste for IM, as it appears to be just one more management strategy to incrementally deprive their communities of access to needed resources. As Bastien-Daigle et al. (2008) have noted, government and local ACAP personnel often have quite different objectives in mind when talking about integrated management; the former is seeking conflict resolution and the latter hopes to promote better environmental outcomes. Members of coastal communities, on the other hand, want equitable access rules and secure livelihoods. Unfortunately, in the Canadian context, no one seems to be speaking the same language when it comes to integrated management, sustainability, stakeholders and community. Despite the 1996 *Oceans Act* and the 2002 *Oceans Strategy*, institutional arrangements such as community-based management appear to mean one thing to the federal and provincial regulators and quite another to local communities. Canadian regulators have in fact encouraged further privatization, arguing that the corporate sector is the most important stakeholder of the community, and that community-based management is just another form of stakeholder consultation. It is important to recognize that questions of bureaucratic efficiency aside, the result may be a regulatory environment that discourages effective integrated management and sustainable resource utilization, with alarming consequences for our aquatic resources (Worm et al. 2006).

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CHANGES IN COMPOSITION OF ROCKWEED (*Ascophyllum nodosum*) BEDS DUE TO POSSIBLE RECENT INCREASE IN SEA TEMPERATURE IN EASTERN CANADA

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Ascophyllum nodosum (Rockweed) is the main economic resource of the seaweed industry in the Atlantic provinces of Canada. The annual harvest steadily increased since 1995, reaching an historic peak of 37,000 tonnes in 2008. Due to a high demand for fertilizers and animal feed supplements derived from rockweed, this trend seems likely to continue. The current management plan for the sustainable harvest of the *A. nodosum* resource is considered conservative. The resource has been managed with a precautionary approach since 1995 to protect the integrity of the habitat. Acadian Seaplants Limited (ASL) has been granted approximately 90% of the government-issued licenses to harvest *A. nodosum* resources in the Maritimes. Since 1995, ASL has proactively undertaken extensive annual surveys and research on biomass productivity of this renewable resource to establish acceptable annual exploitation rates.

Historically the rockweed beds of southwestern Nova Scotia have been almost 99% pure *A. nodosum,* with a minor component of *Fucus vesiculosus*. However, since 2004, a steady increase in *F. vesiculosus,* with a peak of 4.6% of the total biomass in 2008, was recorded. This coincided with one of the mildest winters on record for the Maritimes. This increase in temperature seemed to be also responsible for an unusual recruitment of the blue mussel *Mytilus edulis* in rockweed beds in some areas of southern New Brunswick in 2006, causing the detachment of up to 30% of the seaweed biomass in some harvesting sectors. Other phenomenon observed in southwestern Nova Scotia during 2003 and 2004 was extensive ice damage on rockweed beds produced by an early melting of the ice, with losses of up to 90% of the rockweed biomass in some areas.

Session G

WATERSHEDS

Chair: Andy Sharpe, Clean Annapolis River Project, Annapolis Royal, Nova Scotia

FROM THE HEADWATERS TO THE SEA, IMPLEMENTING A WATERSHED APPROACH IN SOUTHERN MAINE

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Coastal watersheds in southern Maine connect coastal and inland communities where diverse land-use practices and land conservation strategies create a complex mosaic of policies affecting water quality and quantity. This presentation shares lessons learned from a project designed to improve land-use decision making and overcome barriers to implementing a watershed approach. The watershed approach mirrors the principles and practices of community-based ecosystem management. This project integrated Collaborative Learning and land-use planning tools developed by the Ecosystem Based Management Network to connect the practice of ecosystem management to municipal land-use decision making. Desire to incorporate water quality and habitat protection into economic development strategies motivated the town of Sanford, Maine to examine existing resource conditions, and comprehensive plan priorities. In addition, Sanford's five watersheds drain to significant coastal areas including two National Estuarine Research Reserves, one National Wildlife Refuge and the area included in a National Estuary Partnership.

This project used the collaborative learning approach to guide stakeholder engagement and use of geospatial tools and CommunityViz technology to develop a conservation plan that considered the value of headwater streams, aquifers and riparian buffers for water quality and quantity protection. Watershed values were considered along with habitat, recreation and land productivity values. This presentation addresses challenges and successes associated with the application of land-use technology tools to improve decision making at the watershed scale, including stakeholder engagement, techniques to enhance public participation, developing priorities for watershed management, and linking land conservation goals with water quality protection goals.

OPTIONS FOR MANAGING NOVA SCOTIA'S WATER RESOURCES AT A WATERSHED-SCALE

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The province of Nova Scotia is currently standing on the edge of what could potentially be a very significant opportunity to make drastic changes to the way water is managed in the province and the ecological foundations on which we all depend for a healthy society, economy and environment. With the passing of the *Environmental Goals and Sustainable Prosperity Act* (EGSPA) in 2007, the province set itself on a brave course to improving the environment while ensuring a prosperous economy. Of the 21 concrete and time-sensitive environmental commitments in this act, four of them pertain to water, including improvements to drinking water treatment, upgrades to wastewater treatment facilities, a policy for no net loss of wetlands and a comprehensive water resource management strategy. The development of a comprehensive water resource management strategy is anticipated to be approved by cabinet by 2010 and it is this initiative that sparked the watershed management workshop in Wolfville, Nova Scotia, 26–27 March 2009 called "Wading In: Watershed Management in Nova Scotia."

During the course of this workshop, 45 participants from three levels of government, Aboriginal peoples, hydro electric generation, forestry, agriculture, non-governmental organizations, and other sectors attended presentations on water issues as seen by each sector. They were then guided through facilitated breakout sessions in order to come to a better understanding of what the barriers and opportunities for watershed management are in Nova Scotia and what will be required to help Nova Scotians achieve better water management.

There was consensus among the participants that integrated management of water is necessary to safeguard the future economic prosperity of Nova Scotia. Thoughtful and planned management of water resources will make Nova Scotia a better place to invest in and do business, and a better place to live, study and raise a family.

A number of key themes emerged from the workshop upon which there was consensus:

1. Watershed planning in Nova Scotia

Surface and ground water resources in Nova Scotia need to be managed in an integrated manner, based on the watershed scale. Watershed management should occur at a number of levels: (a) a provincial body responsible for coordinating watershed efforts in the province, (b) regional bodies responsible for watershed units (clustered watersheds i.e. Cape Breton, Valley, South Shore), and (c) local organizations working at the scale of individual catchments and river systems.

2. Delineation of the province into manageable watershed units

The province currently has approximately 45 to 50 watersheds—a number that is arguably too many for systematic management. There is a need to consolidate these catchments into larger, more manageable units. This consolidation could be based on geographic regions of the province (e.g., the Annapolis Valley) and the major river basins (e.g., the Mersey River), taking into account the scope of existing watershed groups. Within these management units, a nested catchment approach could be used to facilitate local action and engagement. This is a task that must be addressed in coordination with the design of the organizational structures to oversee watershed management in the province.

3. Provincial leadership – Joint responsibility

Under law and in practice, the province has primary responsibility for the management of Nova Scotia's water resources. The provincial government must assume a leadership role in the implementation of integrated watershed management, providing support and guidance on its structure and implementation. The province, with all segments of society, shares in the responsibility for the sound management of water resources. Aboriginal peoples, industries (e.g., agriculture, forestry), municipalities, and community watershed groups all have key roles to play.

Watershed groups are ready to support watershed management in the province, however leadership from the provincial government is needed to chart the overall direction and to provide the framework. Watershed groups have spent years building relationships with communities, businesses and individual citizens and know the needs, wants and values of the communities they work in.

4. Sustainable support through alternate funding models

Currently, funding mechanisms to support water management activities are sparse, fragmented and inconsistent, resulting in organizations dedicating considerable staff resources to grant writing. The irregular funding pattern results in high turnover rates among staff, precluding the retention of those with experience and expertise in Nova Scotia.

Integrated management of Nova Scotia's water resources will require dedicated, sustained resources for coordination. However, the province does not need to be the sole entity supporting watershed management. As the benefits of well-managed water resources will flow to all levels of government, industries and society as a whole, it is logical that support for this be shared. Numerous opportunities exist for alternative funding and cost-sharing mechanisms. Many of these are based on the notion that individuals, agencies and businesses that benefit from water quality and quantity should contribute to the maintenance and management of these water resources.

This paper represents a summary of the *Report of Workshop Outcomes* (May 2009), based on the contributions by following participants at the workshop:

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Amy Weston, NS Salmon Assoc./Adopt-A-Stream
Andrew Fedora, Federation of NS Woodlot Owners
Andy Sharpe, Clean Annapolis River Project
Angie Garnett, Cornwallis Headwaters Society
Anita Hamilton, Department of Fisheries and Oceans
Anna McCarron, Clean Nova Scotia
Barbara Veale, Grand River Conservation Authority
Barry Geddes, Halifax Water
Brad McCallum, Nova Scotia Federation of Agriculture
Bob Rutherford, Sackville Rivers Association
Brian McCulloch, NS Department of Agriculture
Brian Zurek, Dalhousie University
Britt Roscoe, Cape Breton Regional Municipality Water Utility
Cameron Deacoff, Halifax Regional Municipality
Cheryl Benjamin, NS Department of Environment

Dan Thompson, Nova Scotia Power Inc.
Dawn MacNeill, NS Department of Environment
Debbie Nielsen, Union of Nova Scotia Municipalities
Donald Parker, Federation of NS Woodlot Owners
Dr. Patricia Manuel, Dalhousie University
Dr. Sean Mitchell, St. Mary's River Association
Dr. Shannon Sterling
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Jennifer Graham, Ecology Action Centre
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Kathryn Parlee, Environment Canada
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Walter Regan, Sackville Rivers Association
Wayne Williams, ACAP Cape Breton
Dr. Ian Spooner, Acadia University
Dr. John Brazner, NS Department of Environment

The "Wading In: Watershed Management in Nova Scotia" workshop was organized by the following individuals:

Amy Weston (NS Salmon Association/Adopt-A-Stream)
Andy Sharpe (Clean Annapolis River Project)
Anna McCarron (Clean Nova Scotia)
Dawn MacNeill (NS Department of Environment)
Jocelyne Rankin (Ecology Action Centre)
Katherine Dugas (Clean Annapolis River Project)
Kathryn Parlee (Environment Canada)
Tamara Lorincz (NS Environmental Network)

The organizers gratefully acknowledge the support of the Nova Scotia Department of Environment and Rural Secretariat in making the workshop possible.

SOCIAL NETWORK ANALYSIS OF THE WATER MANAGEMENT REGIME IN THE ANNAPOLIS AND CORNWALLIS RIVER WATERSHEDS: A TOOL FOR COMPARATIVE ANALYSIS OF WATERSHED MANAGEMENT REGIMES

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Water is an increasingly valuable resource throughout the world. This is true even in water rich countries such as Canada, both because our own per capita consumption is on the rise and because water-poor countries demonstrate stronger interest over time in accessing water from abundant sources. At smaller scales, as the diversity and volume of uses continue to grow, we can anticipate increasing levels of competition both for the water itself and for the right to allocate and distribute it. The goal of this research was to quantify and illustrate the relationships among actors engaged in water management in the Annapolis and Cornwallis river basins in Nova Scotia. This exercise was undertaken to understand, broadly, water use in the region, and whether and how different consumers and providers align themselves politically in order to influence allocation patterns. Social network analysis is the measurement tool used to meet these research objectives. Representatives of public agencies (federal, provincial, municipal), non-profit organizations, and business and industry were interviewed in order to both complete a census of the actors in the watershed, and to measure the existing and strength of ties among them. The results of this research will be presented, and its implications for policy, planning, and management discussed.

THE KINGS COUNTY LAKE MONITORING PROGRAM, NOVA SCOTIA

Ben Sivak

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The Kings County Lake Monitoring Program is an example of an innovative approach by a municipal government to watershed management. Volunteers and municipal staff have collected lake water samples since 1997 and have compiled an extensive database on lake water quality. From May to October, dedicated volunteers set out once a month to collect water samples, record water temperatures, and take water transparency readings using a Secchi Disk. Water samples are sent to a laboratory for detailed analysis including total phosphorus and chlorophyll *a* data. A total of 11 lakes are monitored. The majority of these lakes are located in the Gaspereau River watershed that drains into the Bay of Fundy. The information collected is analyzed in order to observe trends and see if associated land use controls are working.

The lake monitoring program demonstrates the benefits of moving beyond scientific analysis to practical land use policies that impact where and how shorelines are developed. After twelve years of monitoring, however, Kings County's experiences illustrate both the lesson learned and challenges to maintaining the initiative in a municipal government context.

The most important aspect of the monitoring program is its inherent ability to inform municipal decision makers and planners on the state of lake water quality. Regular lake monitoring can be compared to regular visits to a doctor. It enables the municipality to identify and address problems before they become serious. Monitoring results also enables politicians and staff to readily respond to public concerns and perceived water quality issues.

In Kings County, the lake monitoring program is also important for informing lake residents about lake management. By enlisting volunteers, publishing an annual newsletter, and holding educational events, the monitoring initiative educates the lakes' residents about water quality science and encourages them to preserve the natural shoreline vegetation. In addition, annual reporting of lake monitoring results to municipal councillors and the public helps keep the monitoring program on the political radar and ensures it is funded year after year.

Ongoing challenges, however, with the lake monitoring program include issues with maintaining consistent laboratory testing and establishing a clear link to land use planning policies. An integral component of any monitoring program is the ability to compare results from year to year. But laboratory tests available to Kings County have changed for both total phosphorus and chlorophyll *a*, making it difficult to see if trends are due to changes in lab procedures or the environment.

Kings County uses a predictive lake water quality model to establish land use controls. The practicality, however, of using the model is questionable in the municipal context because municipal staff do not have the expertise to properly review, update or explain the model to the public. While a scientific steering committee provides advice, debates about the accuracy and validity of the model makes it difficult for planners to link model predictions to land use planning controls.

Limitations in establishing effective land use planning controls also pose continuing challenges. While the municipality has the jurisdiction control cottage development, it is the province that regulates forestry practices, a major contributor to water quality. In addition, the enforcement of bylaws that require cottage developers to preserve the natural shoreline are not as effective as they could be because the municipality lacks the resources to thoroughly enforce these land use controls.

Although challenges exist, Kings County experiences demonstrate that a lake monitoring program can be initiated and sustained by a municipal government. Lake monitoring has proven itself to be an effective way for the municipality to assess land use controls, as well as inform the public about lake water quality. The continuing challenges, however, illustrate that a lake monitoring program requires continual review as testing procedures change and the scientific understanding of monitored lakes improves. With continued public and political support, hopefully, the Kings County Lake Monitoring Program will continue to provide valuable water quality information for many years to come.

THE GREENCOVER PROJECT: RIPARIAN ZONE RESTORATION FOR IMPROVEMENT OF WATER QUALITY IN AN AGRICULTURAL LANDSCAPE

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This project is part of the Nova Scotia Eastern Habitat Joint Venture's Kings Agricultural Wetland and Biodiversity Conservation Initiative, and one of a number of recent initiatives being supported in part by Agriculture and Agri-Food Canada's Greencover Program to address water quality issues in agricultural landscapes. The project is located within the upper reaches of the Cornwallis River, which flows into the Minas Basin of the Bay of Fundy, and is being carried out by a multi-stakeholder group composed of farmers, local citizens, wildlife resource managers, and both federal and university research scientists, students and technicians. The primary objective of the project is to determine the effectiveness of a variety of beneficial management practices (BMPs) aimed at reducing the impact of agricultural activities on water quality. The project design and preliminary results of the first two years of the project will be presented.

INTEGRATING ENVIRONMENTALLY SUSTAINABLE GRASSLAND INTO THE ACADIAN LANDSCAPE

O. Thomas Bouman

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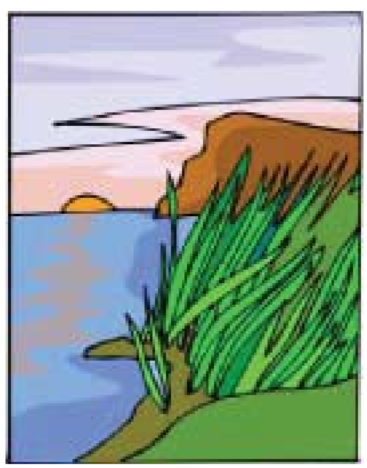
Grassland constitutes a form of agricultural land use with a long history in the Acadian landscape surrounding the Bay of Fundy. Management has been changing over time and the intensity of land use for hay production and livestock keeping can greatly influence the ecosystem function of grassland. The potential for grassland management to reduce the flow of nitrate into the aquatic environment has been explored in a plot experiment and in a field experiment near Truro since 2004. Results of these two experiments are discussed with a focus on the relation between management-induced plant diversity and soil nitrate leaching. The experiments have demonstrated the functional order of the diversity-function-relation in grassland. Implications for the environmental sustainability of grassland management and the integration of grassland into the Acadian landscape are discussed.

Session H

Other Industrial Activities

Chair: Marianne Janowicz, Bay of Fundy Ecosystem Partnership, Charlottetown, Prince Edward Island



UNDERSTANDING INFLUENCE: LESSONS FROM CANADA'S AND NOVA SCOTIA'S 1999 GEORGES BANK MORATORIUM DECISION

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This presentation provides a retrospective analysis of the four-year decision-making process leading to the 1999 ocean policy decision to extend the Canada-imposed moratorium on petroleum exploration and drilling on Georges Bank until 2012. It provides the background to the policy problem, describes the existing policy context, decision-making process, subsequent policy outcome, and potential opportunities for policy actors to exert influence over the decision-making process. The analysis focuses on the relationship and behaviour of policy actors involved in the process, based on their understanding of the principal areas of concern and preferred outcome, as influenced by their underlying core values and stated objectives. Stakeholders engaged in the current efforts to revisit the moratorium decision can benefit from this analysis, as the research findings suggest that policy actors with shared values can enhance their potential to influence the policy outcome by coalescing into subgroups of advocacy coalitions. The potential composition of such coalitions may prove surprising to some, with members possessing varying levels of authority, mandate or capabilities within the network.

POTENTIAL ADVERSE EFFECTS OF MINING NEAR THE BAY OF FUNDY

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Abstract

There is an increasing demand for extraction of mineral resources near the shores of the Bay of Fundy. The risk of adverse effects of mining on the Bay of Fundy is enhanced by a lack of coastal development and protection policy and inadequate attention paid to the long-term environmental impacts of the proposed developments in municipal, provincial, and federal regulations. Three examples of the proposed mining projects discussed in this article support the need for more strict environmental regulations to help sustain the well being of the Bay of Fundy and the residents along its shores. The first example is the proposed Whites Point Quarry for mining basalt. The project was not approved because of potential adverse effects on marine life and the well being of the community. The second example is the proposed extension of the Miller's Creek gypsum mine near the Minas Basin, which is undergoing an environmental assessment. This project will create cumulative and unmitigable impacts of pollution from the blast residue and drawdown of groundwater from mining. The third example is the proposed Alton Natural Gas Storage Project. The proposed project has failed to address both the environmental and the economic effects of dumping the saline water into the Shubenacadie estuary from the process of solution mining of the proposed salt caverns. We believe that development of mineral resources near the ocean is appropriate if it will bring value-added and environmentally neutral consequences to the area.

Introduction

The ever increasing and global demand for mineral resources poses a potential threat to the sustainability of the environment in areas like the Bay of Fundy. There is no coastal protection policy in place yet in Nova Scotia. The mission statement of the Nova Scotia Department of Natural Resources (MacDonald 2004), "To increase the amount of exploration and development of Nova Scotia's mineral resources through sound promotional activities," has no potential for addressing the adverse effects of mining near the extensive shorelines of Nova Scotia, including the permanent loss of groundwater and habitats for flora and fauna and the cumulative (long-term) pollution of groundwater and sea water (with impact on marine life). The three examples of mining projects near the Bay of Fundy illustrate the emergence of potential adverse effects and the need for addressing them through appropriate regulations.

Whites Point Quarry

Project Description

In June 2004, Bilcon of Nova Scotia, a subsidiary of Clayton Concrete of New Jersey, filed an application for a 120 hectare quarry and marine terminal at Whites Cove, Little River, in Digby County, Nova Scotia (Figure 1). The project would involve mining 2 million tons (1.8 billion kg) of basalt every year and shipping the aggregate to New Jersey, USA. The application triggered a joint Nova Scotia-federal review, which eventually involved the appointment of a Joint Review Panel. The Panel coordinated a scoping session, which was followed by the public hearings in Digby in June 2007. The panel recommended that the project not be approved (Joint Review Panel 2007). The provincial and federal governments accepted the Panel's recommendation and disallowed the project. Some selected aspects of the environmental impact of the proposed project, presented by the public, are provided below.

Figure 1. Location of the three example mining projects

Examples of Potential Adverse Effects

The blasting protocol, referred to in Appendix 9 of the environmental impact statement (EIS) of the project (Bilcon of NS 2006), is based on the use of ANFO (Ammonium Nitrate – Fuel Oil mixture) as the explosive for blasting the rock. However, the Department of Fisheries and Oceans (DFO) Guidelines (Wright and Hopky 1998) state that: "There is no regulation pursuant to the *Fisheries Act* that permits the deposit of by-products resulting from the use of ammonium nitrates-fuel oil mixtures." Obviously, the proposed project, as described in the EIS, is in conflict with the DFO Guidelines.

Approximately 2.6 million kg of ANFO would be used for quarrying over the 49-year production period (Mahtab 2007). Even a small percentage of this charge of ANFO will be a source of irreversible and unmitigable pollution to the local aquifer and the Bay of Fundy. The explosive residue will enter the surface water and groundwater (or the aquifer) through gravity flow of the runoff and the water used for washing the aggregate (see Figure 2). The potential contamination of the sea water near Whites Cove will spread through the Gulf of Maine over and beyond the 50-year span of the project. Pollution of the aquifer will also pose a devastating threat to the water resource of the local community.

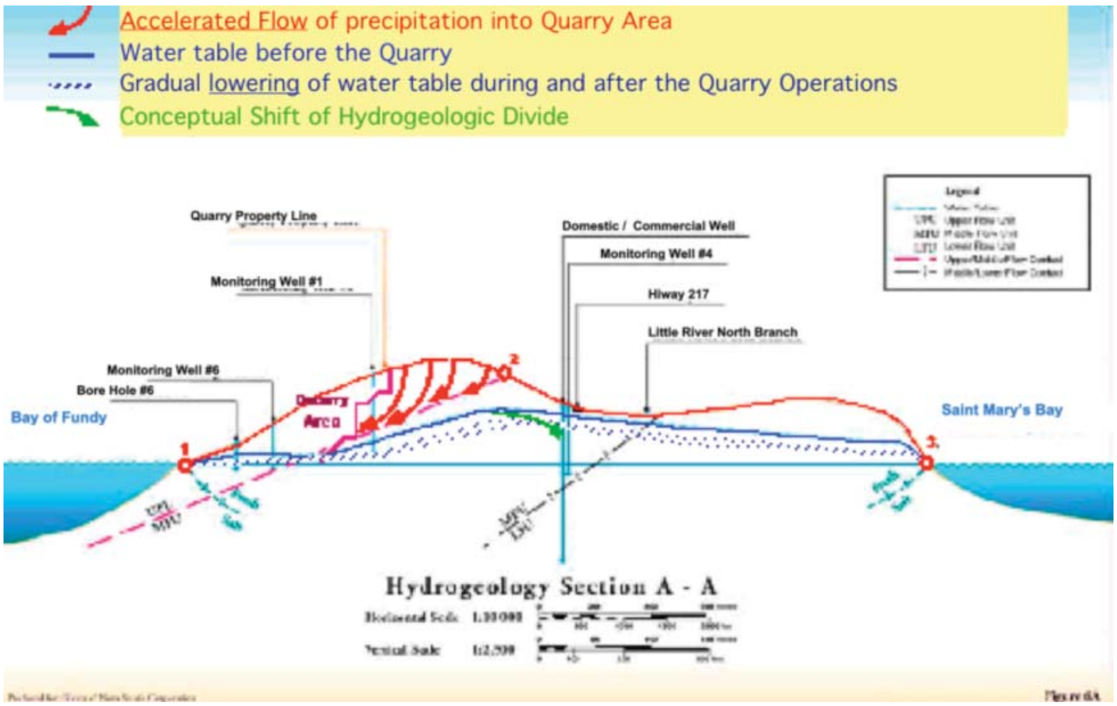

Figure 2. Cumulative effect of lowering the water table by the 49-year quarrying (at the proposed Whites Cove Project)

The bedrock on the quarry site consists of basalt flows designated as Upper, Middle, and Lower Flow Units (UFU, MFU, and LFU) as depicted in Figure 6A, Volume 1 (Bilcon of NS 2006). The UFU attains a maximum depth of 76 m on the site and is the main target for the quarry. As the quarry advances into the Bay of Fundy side of North Mountain, the water table behind the quarry wall will begin to decline as the water drains into the quarry through numerous fractures in the bedrock. The process of water table lowering would be slow, but would continue as the quarry face advances into the side of the mountain. Using Figure 2, a conceptual model of the cumulative effect of the 49-year quarrying operations, about 40% of the recharge area for the common aquifer will be removed by the quarrying operation of 49 years. With the reduced recharge, the level of the water table will continue to lower because of the drawdown from wells from both sides of the geologic divide.

Miller's Creek Gypsum Mine

Project Description

In February 2008, CGC Inc-Fundy Gypsum, a subsidiary of US Gypsum Corporation, filed an Environmental Assessment Registration Document (EARD) for a 50-year extension of its Miller's Creek Gypsum Mine on the Avon Peninsula near Windsor, Nova Scotia (Conestoga-Rovers & Associates 2008). The annual production of the proposed mine is two million tons, the same as for the proposed Whites Point Quarry. In March 2008 the Nova Scotia Environment Minister required the proponent to prepare a focus report to provide more information about impacts of the project on groundwater, surface water, wetlands, species at risk, and fish and fish habitat. In April 2009 the one-year deadline for the report was extended to October 2009. Submission of the focus report will trigger the second round of the provincial environmental assessment (EA). A decision as to whether a comprehensive study under the *Canadian Environmental Assessment Act* (CEAA) will be triggered is pending.

Potential Adverse Effects

Impact of the Mine on the Groundwater Resource

The EARD (Conestoga-Rovers & Associates 2008: Section 6.3: 92–93) states that the groundwater flow into the active mine area will be low because of the low hydraulic conductivity of the host bedrock. "It also indicates that the cone of depression from pit dewatering will not extend as far from pit boundaries." This statement is invalid and cannot be supported with a scientifically acceptable rationale. The following paragraphs aim to provide a more realistic view of the impact of the development of the mine on the water resource around the project site. The footprint of the project is 420 hectares, including 180 hectares of the surface area of the open pit (or quarry) that will be developed in stages over the life of the mine (Section 5.2 of EARD). The project area is generally higher than the surrounding lands. The direction of surface and groundwater flow from the project site is towards the Kennetcook, Avon, and St. Croix rivers in the north, west, and south directions, respectively. A cone of depression will form in the aquifer—around the pit—as the water level declines due to its drawdown into the pit. A low conductivity of the rock hosting the aquifer will slow the drawdown into the pit. However, there are two factors that will increase the drawdown: the hydraulic gradient and the time frame. With the sequential deepening of the pit, the hydraulic gradient will increase and the water will be drawn down faster and over longer distances. The drawdown will continue over the 35–50 year life of the mine. The expanding cone of depression (even after filling parts of the pit with broken rock during the planned reclamation) will continue to be the sump for the drained groundwater. The cumulative impact of the mine would likely result in spreading the cone of depression over an area which is several times the size of the excavated area. This situation will permanently disturb and deplete the groundwater resource of the watercourses and the community.

With respect to the permeability (or conductivity) of the bedrock, approximately half of the 48 drilled wells in the area indicated a higher permeability than the seven on-site monitoring wells. Two of the 48 wells reported yields of 100 gallons (378.5 liters) per minute (Nova Scotia Department of Environment and Labour 2008: 2). A high conductivity will intensify the drawdown of the groundwater resource. A high conductivity is further indicated by the hydrological characteristics of karst aquifers as discussed below.

Impact of Blasting on Water Quality

ANFO will be the predominant blasting agent. Approximately 0.15 kg of explosive will be used for blasting every tonne of rock. The average production per day will be approximately 14,000 tons, using over 2,000 kg of ANFO (EARD, Section 5.6.2.5: 35). The explosive residue will enter the surface and groundwater and finally drain into the three surrounding rivers and, eventually into the Minas Basin.

Dissemination of contamination (by ANFO residue) will be enhanced by the hydrological characteristics of the karst bedrock underlying the project area. Karst, produced by chemical weathering of the gypsum bedrock by rainwater, is characterized by a high connectivity between the surface and the subsurface (Figure 3). Subsurface conduits in karst aquifers can cause rapid lateral transport of water, leaving them particularly vulnerable to the introduction of harmful materials such as contaminants and sediments. Subsurface flows in karst systems can be hard to predict and can act independently of topographical drainage patterns. MacMillan (2008) developed a groundwater vulnerability map for the peninsula by weighing the impact of the removal of the protective vegetative cover, the infiltration conditions at the surface, and the subsurface karst network. In Figure 4, the yellow and red areas in the proposed project area indicate a very high vulnerability. The water resources on the peninsula are rendered highly vulnerable to contamination by the removal of protective vegetation and soil, suggesting a high degree of sensitivity to quarrying activities.

The blast-residue-polluted water collected in the sedimentation ponds cannot be restrained from entering the aquifer by gravity flow through the bottom of the pond. The average amount of ANFO used per day translates into over 500,000 kg per year and 15–25 million kg over the 35–50 year life of the project. The surface and groundwater polluted by the blast residue will affect the use of the water for agriculture and domestic purposes. It is unclear how the cumulative impacts of the ANFO-related pollution on the local aquifer, surrounding rivers, and Minas Basin could be mitigated.

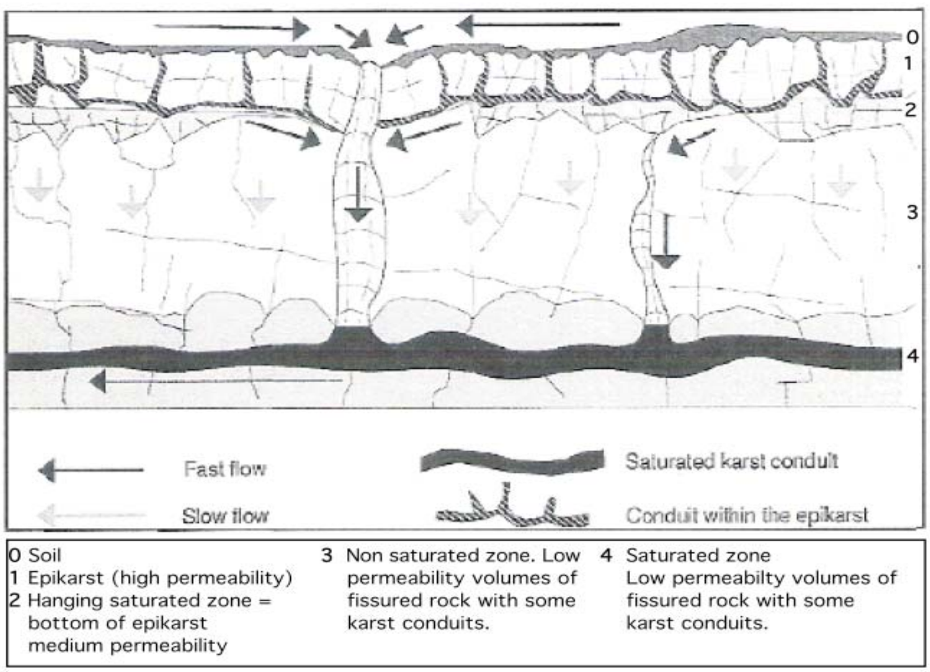

Figure 3. Conceptual model of a karst aquifer indicating lateral flow and water table recharge through the epikarst zone (Doerfliger et al. 1999)

Impact on Fish Habitat

Both freshwater and marine fish habitat will be adversely impacted. Stickleback (*Gasterosteus aculeatus*), speckled trout (*Salvelinus fortinalis)*, and American eel (*Anguilla rostrata*) are among the aquatic species that inhabit freshwater streams on the peninsula. Disturbance to the stream catchment areas will affect water temperature and in some cases reduce stream flow up to 50 percent (EARD, Table 6.2-3: 85). Water will be contaminated by both surface and subsurface flow as noted above. Thus freshwater fish habitat will be adversely affected by harmful alterations to both water quantity and water quality.

The surrounding rivers into which peninsula streams flow are historically important habitat for many marine species, including Inner Bay of Fundy (IBoF) Atlantic salmon (*Salmo salar*). The St. Croix and the Kennetcook are among those designated as endangered rivers for IBoF salmon by the Committee on the Status on Endangered Wildlife in Canada (COSEWIC). IBoF salmon species are listed as Endangered under the federal *Species at Risk Act* (SARA), which requires legal protection and mandatory recovery plans for scheduled species (Amiro et al. 2006).

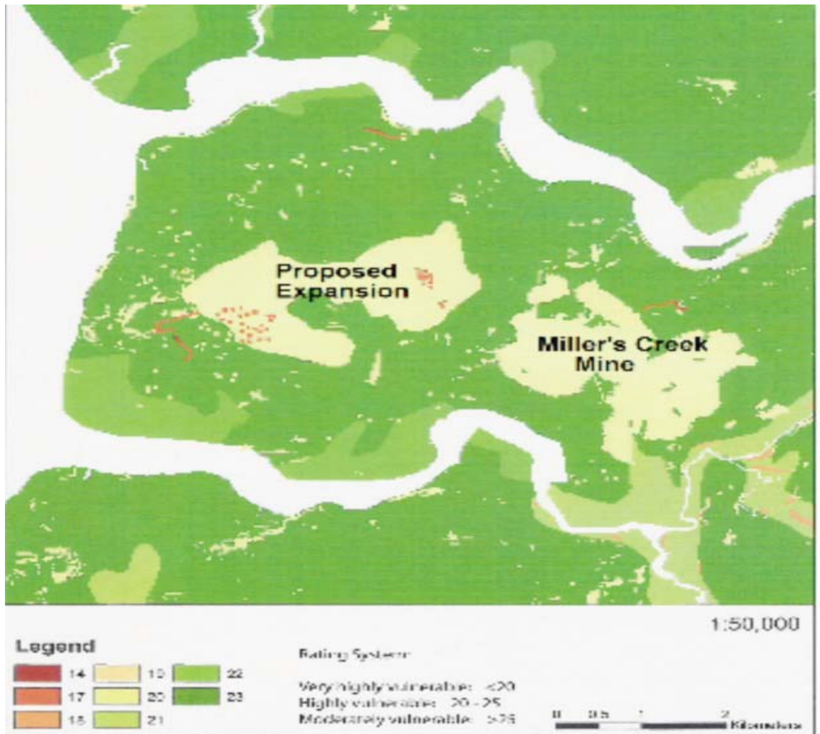

Figure 4. Vulnerability map under the quarry expansion conditions at Miller's Creek (MacMillan 2008)

As with the existing operation, gypsum would be transported from the marine terminal at Hantsport, Nova Scotia, by bulk carrier through the Bay of Fundy to the eastern seaboard. Bulk gypsum carriers have been implicated in the introduction of the oyster-killing parasite MSX to Little Narrows, Nova Scotia (Ecology Action Centre 2006: 18). The risk of ship collisions with several species of marine life, including the critically endangered North Atlantic right whale (*Eubalaena glacialis*), is another potential adverse effect over the 35–50 year life of the proposed mine.

Environmental Assessment

Under the Nova Scotia *Environment Act*, the Minister can require a full environmental assessment report (EAR), where there is public concern and potential for adverse environmental effects. It is yet to be determined whether an EAR will be required. In addition, a comprehensive study under CEAA will be triggered should DFO determine that an authorization to damage fish or fish habitat is required.

Alton Gas Storage Caverns

Project Description

Alton Natural Gas Storage, a company owned by Landis Energy Corp. and Fort Chicago Energy Partners, both of Calgary, was given an approval (on 18 December 2007) by the Nova Scotia Minister of Environment and Labour (NSDEL). The approval was for developing an underground gas storage facility described in the environmental registration document (Jacques Whitford 2007) in a series of salt caverns at depths of 700 m by means of solution mining (see Figure 5). The project will be located near Alton, NS, in the proximity of Shubenacadie estuary. As reported in the Business section of *The Chronicle Herald* of 12 March 2009, the project is on hold due to the "adverse market conditions in the capital market."

Water for solution mining will be taken from the Shubenacadie River estuary and carried to the facility via approximately 12 km of buried pipeline. The estuary water will also be drawn for use in a dilution pond, which would be used to dilute the brine, resulting from solution mining, prior to being discharged back into the estuary. Initially, four caverns will be formed over 18–24 months. Depending on the future market demand, the project may develop as many as 10–15 caverns at a later date.

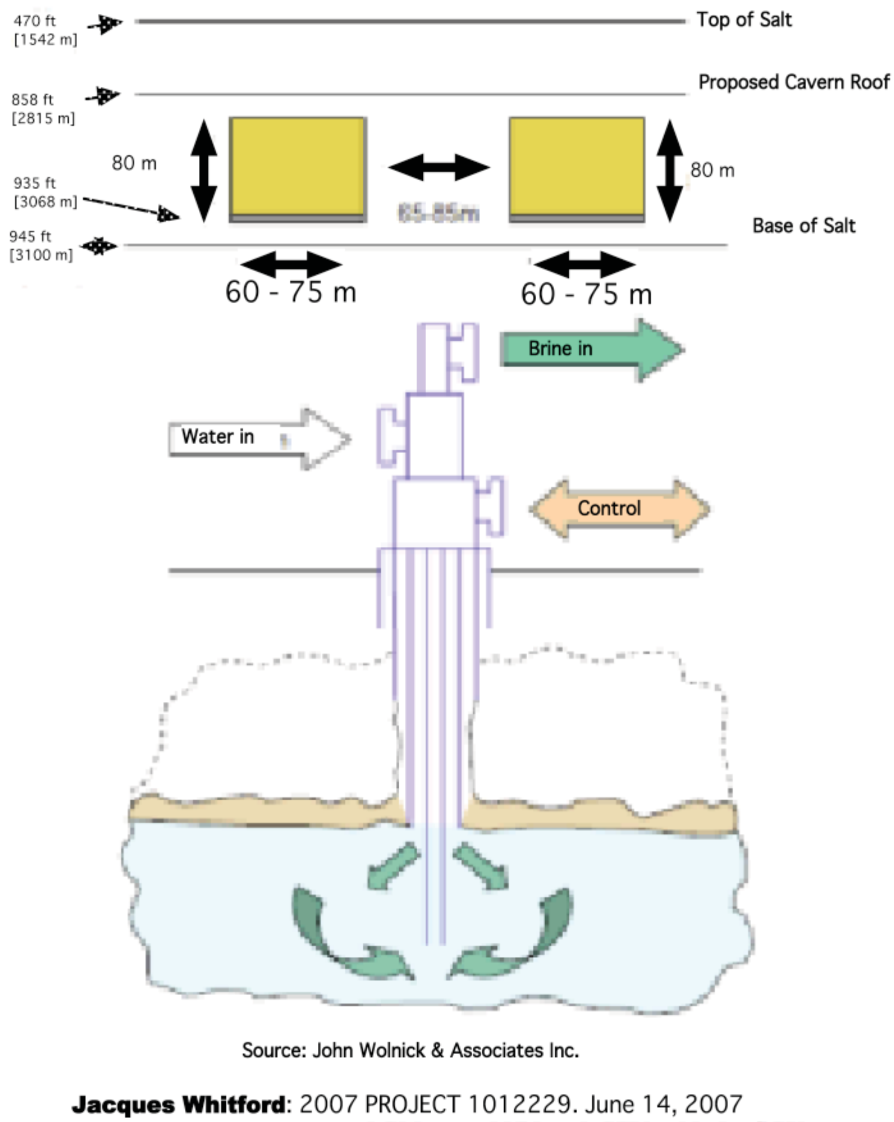

Figure 5. Proposed well configuration and simplified process flow diagram for a salt cavern

Adverse Environmental Effects and their Mitigation

The terms and conditions of the approval in the Minister's decision of 18 December 2009 include an extensive list of requirements. As explained below, it may not be possible to meet some of these requirements.

Requirement 2.1(b) of the approval states that the proponent needs to monitor the discharge-salinity levels on the estuary to ensure that there are no negative impacts to fish species. The proponent must make necessary modifications to the mitigation plans and/or operations to prevent unacceptable environmental effects. However, the planned monitoring and mitigation actions cannot ensure that there are "no negative impacts" because

1. the tidal disturbance does not allow it to obtain a credible salinity parameter, which is necessary for input to the numerical models that can be used for managing the salinity of the water in the estuary; and
2. the cumulative impact of the 10–15 caverns on the salinity of the estuary will likely be too significant to mitigate by the proposed management plan.

Alternative to Solution Mining

A more practical, economical, and environmentally acceptable alternative to solution mining of the salt caverns is to excavate them by mechanized means. The cavern will require a shaft to reach the 700 m level for initiating the excavation. The excavation technique, using a cutterhead and/or a boring machine will be both efficient and appropriate for mining salt. There are two distinct benefits of this alternative: no impact on salinity of the estuary and a good market for the mined salt. Unfortunately, this alternative was not addressed in the environmental registration document or the approval.

Conclusion and Recommendations

The statement of the NS Department of Natural Resources (DNR) (cited in the NS Minerals Update, MacDonald 2004) implies that the Department is a business entity. Therefore, the Department needs to involve the citizens (the investors) for examination of the cost and benefits of its activities. DNR, together with the NS Department of Environment, also needs to provide opportunities for the community (potentially affected by a proposed project) to review the proposal for a mining project of any size and give its comments.

Adequate regulations and environmental assessments are required, which include mechanisms to ensure full exposure of a proposed project and informed consent of the potentially affected communities.

In its contribution to the development of Coastal Policy of NS (in progress), DNR should consider prohibiting mineral or stone extraction in coastal zones where the mining activities will negatively impact the terrestrial habitat, watersheds, marshes, groundwater, and marine life.

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Session I

Conservation Ecology

Chair: Marianne Janowicz, Bay of Fundy Ecosystem Partnership, Charlottetown, Prince Edward Island

OVERVIEW OF A TALKING CIRCLE ON CONSERVATION

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From a BoFEP Management Committee retreat held in the summer of 2006, came the idea of bringing two cultures (Native and non-Native) together using the word "conservation." This would be seen as an opportunity to interact and share dialogue in order to explore the existing relationship, as well as a future potential relationship, between the two. The format chosen would be an informal "talking circle" consisting of equal numbers from each culture. Such an event took place on February 26, 2009. Support for the "circle" included CCNB (Conservation Council of New Brunswick), BoFEP (Bay of Fundy Ecosystem Partnership), the Southern Gulf of St. Lawrence Coalition, Saint Thomas University Native Studies. and the Passamaquoddy First Nation. Since the "circle" lacked the discipline of a "workshop" and because the use of story telling would consume any time allotment that one day could possibly provide; the event needed to be viewed as a beginning to dialogue and not an end product. Discussion would often slide away from the main topic of "conservation", not to change the focus of the meeting but to expose the different approaches to the same subject and the reasons for these differences. For before we can understand each other; before we can agree to any approach to any subject, we need to overcome these differences. Though we speak the same words; we may hear different things! A video and a report will summarize the event; however, the true follow-up to the "circle" must include getting individuals together to address specifics pertinent to their own agendas, which may be done by region or subject. Only in this way can the door between the cultures be kept open to let meaningful dialogue take place. It is not enough to "assume" we understand each other, knowing that there are inherent problems in communication.

SAFEGUARDING THE BAY OF FUNDY

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The Bay of Fundy is home to several globally significant and unique coastal and marine ecosystems such as large intact salt marshes, sand dunes and beaches, kelp and rockweed forests, and productive bays. With 100 billion tons of sea water flowing in and out of the Bay of Fundy each tide cycle, more than the combined flow of the world's freshwater rivers, the Bay's powerful tides and associated upwellings create an extremely dynamic and nutrient rich system which supports an incredible diversity of invertebrates, plants, fish, birds and marine mammals. Several of these species depend on the Bay during critical stages of their lifecycle.

At the mouth of the Bay of Fundy marine mammals, including the highly endangered North Atlantic right whale, are attracted to the rich food supply the Bay provides. The strong currents and upwelling result in extremely productive waters full of zooplankton which become crucial feeding grounds for species like North Atlantic right whales. Very few places on Earth provide the immense amount of food needed for the 15 metre long right whales, who consume up to one ton of zooplankton per day, to survive.

Only 350 North Atlantic right whales exist today and two thirds of this population spend the spring and summer months in Canadian waters. In an attempt to help the right whale population recover, the Department of Fisheries and Oceans designated two Right Whale Conservation Zones in 1994. These zones were established in key summer congregation areas to reduce the likelihood of ship strikes and entanglement in fishing gear. One zone is located in the Roseway Basin off the southwestern tip of Nova Scotia and the other in the Bay of Fundy near Grand Manan. Additionally, in 2003, the International Maritime Organization of the United Nations rerouted the main shipping lane in the Bay around the conservation zones. These conservations efforts are important first steps but again do not adequately protect the habitat that the whales depend on for survival.

At the upper end of the Bay, each metre the tide recedes reveals an extensive mudflat landscape teeming with life. From microscopic zooplankton and algae to small mud shrimp called corophium that burrow into the mud and can reach concentrations as high as 30,000 shrimps per square metre. Each summer, this rich concentration of life attracts hundreds of thousands of migrating shorebirds en route to Central and South America where they over-winter. The mudflats provide critical stopover habitat where the birds replenish their fat reserves by feeding on the energy-rich invertebrates before continuing their journey. Some shorebird species, such as the semipalmated sandpiper, consume so much prey that they actually double their weight during their two week stay in the upper bay. These fat stores are essential to fuel the 3,000–4,000 km non-stop flight over the Atlantic that each bird must make to reach their wintering grounds. Because of its shear ecological significance, the upper Bay of Fundy has been designated as a site of critical importance by the Western Hemispheric Shorebird Reserve Network. Unfortunately, this designation has no legal teeth. It fails to provide any habitat protection for the ecologically-rich areas of the upper Bay of Fundy, which is of great concern because the mudflats are increasingly being threatened by human activities.

The health of the Bay of Fundy is imperative not only to the survival of wildlife, but also to the survival of the many coastal communities and traditional livelihoods that depend on the bay's resources. We have already seen a dramatic decrease in stocks of valuable commercial species in the Bay. The days of handlining for groundfish species are gone and the dwindling numbers of active fishermen are now only able to make a living through harvesting invertebrate species such as lobster, scallops, clams and algal species such as Irish moss. These changes have led to severe economic adversity for some coastal communities around Nova Scotia and have required the local people to exude true strength and resilience in the face of this hardship.

The substantial decline in fish stocks shows the Bay of Fundy is in trouble. Pollution, overfishing, habitat destruction, industrial development, and construction of tidal barriers are just a few of the many factors that are jeopardizing the health of the Bay and we have not even begun to fully understand the cumulative impacts of these threats. What we do know is that any further degradation of the Bay could put the wildlife species and fishermen who depend on them in serious peril. The communities of Digby Neck and Islands fought together over the past few years to successfully prevent the proposed White's Point quarry which would have had severe adverse environmental impacts. In this case an environmental disaster was averted, but the outcome may not be the same in for future proposals. Nova Scotia urgently needs more permanent solutions in place to protect the rich ecosystems of the Bay.

The current overall lack of marine habitat protection in the Bay of Fundy is alarming to say the least. Without real protection, the rich ecosystems of the Bay of Fundy will not be able to sustain the incredible diversity of life in the face of growing industrial development and harmful fishing practices. CPAWS-NS, alongside several other community groups and environmental non-governmental organizations, is working to ensure that ecologically significant habitats around the Bay of Fundy are protected.

CPAWS-NS has two major conservation campaigns underway to turn the vision of preserving the beauty, health, ecological integrity and traditional livelihoods of the Bay of Fundy into reality. CPAWS-NS is campaigning for Parks Canada to fulfill its commitment of establishing a National Marine Conservation Area in the Bay of Fundy. We have been actively promoting the Digby Neck and Islands area as an ideal candidate site for NMCA establishment which would provide legal protection from industrial activities that could impact marine life in the area while being compatible with, and beneficial to, existing local fishing and tourism industries. We are also working to better understand and protect the globally unique horse mussel reefs which perform a number of crucial ecological roles in the bay including providing habitat, increasing biodiversity and biological productivity. These reefs are the largest known in existence and are being threatened by destructive fishing gear. CPAWS-NS wants to stop damage to these reefs, and work with fishermen and government to find ways to permanently protect these important and vulnerable marine features as part of a healthy Bay of Fundy ecosystem. Protecting these two key areas are critical steps that must be taken in order to maintain the ecological integrity of the Bay, and the traditional livelihoods of local communities.

Youth from Digby Neck visit the site of the defeated Whites Point Quarry proposal, Photo Credit: CPAWS-NS

WHOSE OCEAN PLAYGROUND?

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When you hear that only 5% of Nova Scotia's coastline is in public ownership, and only a fraction of that is formally protected, do you ever wonder how this happened? How things ended up like this? How has the public been cut-off from the coast? How have our coastal ecosystems, including our iconic beaches, coves, and salt marshes been degraded so much?

Nova Scotia's communities are also becoming increasingly cut off from the sea. Ask any teenager in one of our coastal communities if they'll be living and working in their hometown in 5–10 years, and you probably won't hear too much in support of that. No opportunities, no jobs, no future is more likely what you'll hear. You'll also probably hear from some that they wished they could stay in their hometowns and make a living there and enjoy being close to nature. Nova Scotians have lived in harmony with the coast for hundreds of years. Generations have seen that the land and water always provided enough to keep families and communities thriving. So, what's changed? What's happened?

Lots actually, but it didn't happen overnight. Our coast has seen a remarkable transformation toward increasing development. Many of these changes have been incremental, so maybe not always noticeable. Other times, they have happened so quickly and so egregiously, that they're hard to ignore. Every wetland filled, subdivision approved, and habitat degraded has finally added up to a catastrophic environmental state that was inconceivable only a generation ago. Even more dangerous is that without ever having witnessed the productivity of what our coastal environment was once like, Nova Scotia's youth might think this degraded state is the way it's always been, or even worse, the way it should be.

"*Shifting Baselines*," a concept discussed by Daniel Pauly at the University of British Columbia's Fisheries Centre, describes a syndrome where fisheries scientists record inappropriate baseline data for populations that have already undergone change. Setting a baseline at an already degraded level can lead to sub-optimal planning and management, and impede future recovery. If you apply this notion to the environment that youth on our coast are experiencing, then today's landscape of private cottages, industrial mega-projects, and no more fish left in the ocean might be viewed as nothing out of the ordinary, nothing amiss. That couldn't be further from the truth.

There's some good news though. After years of grassroots campaigning by people all over Nova Scotia, the government has finally agreed to develop a Coastal Management Framework by 2010. CPAWS-NS is firm in its commitment to ensure this framework includes an effective land use plan, better zoning and protection of coastal wetlands and beaches, more marine protected areas, and an expanded conservation funding package to purchase high-priority ecological sites for protection. In short, the Coastal Management Framework will only be helpful if it's a good plan with strong environmental policies and widespread community support.

From Cape Sable to Cape Breton, CPAWS-NS has seen that youth are leading, not sitting back and letting things happen. They're calling for solutions themselves and are eager to talk about it. CPAWS-NS was on hand this fall when Barrington Municipal High School students met local MLA Sterling Belliveau to talk about conserving the beaches in their backyards. We also heard from youth in Bear River working to restore their freshwater connection to the Bay of Fundy. The students of Islands Consolidated School in Digby County are surveying community members and preparing recommendations to present to the Nova Scotia government when community consultations begin later this year. The youth are making things happen.

As Nova Scotia embarks on the process of drafting a Coastal Management Framework, it is critical that we recognize the current degraded state of our coastline and coastal ecosystems, and set a goal or baseline for a healthy coastal environment we want to see return once more. Hearing from tomorrow's stewards of our coastal resources will help ensure we make the right choices and draft the right policies today.

POSTER* SESSIONS

* Some posters have been augmented with papers from the presenters

Session J. Ecology

LEARNING TO CRAWL BEFORE LEARNING TO WALK: MACRO- & MESO-TIDAL WETLAND RESTORATION (COMPENSATION) IN ATLANTIC CANADA

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In Nova Scotia, an estimated 62% in provincial area of saltwater wetlands, and as much as 80% for the Bay of Fundy, has been lost or significantly degraded over the past 400 years. In 2005, the first two salt marsh restoration compensation projects were undertaken at Cheverie Creek and Walton River (Bay of Fundy). A third tidal barrier removal project took place in 2006 and restoration activities are currently underway at two additional sites, bringing the total number of projects in the province to five. This poster will highlight the research activities, partnerships, and legislative measures leading to the success of these projects. The GPAC (Global Programme of Action Coalition) Regional Monitoring Program is being used as part of each project to monitor hydrology, soils & sediment, vegetation, fish, birds and invertebrates. Each restoration site is paired with a natural salt marsh and a minimum of one year pre-restoration and five years of post-restoration monitoring is conducted. The results from the pre- and first year of post-restoration monitoring for the two Bay of Fundy restoration sites will be looked at in detail to illustrate some of the lessons learned regarding the ecological condition of NS salt marshes and the response to restoration efforts.

First Prize - Graduate Poster

DIEL AND SEMI-LUNAR CYCLES IN THE SWIMMING ACTIVITY OF THE AMPHIPOD *Corophium volutator* IN THE UPPER BAY OF FUNDY

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Although movement of individuals has important consequences on population dynamics and various ecological interactions, it is often difficult to quantify fully. We investigated the temporal variation in the number of the amphipod *Corophium volutator* swimming in the water column during periods of immersion over the intertidal mudflat of Peck's Cove in the upper Bay of Fundy, in spring-summer 2006. Swimming is an important mode of dispersal, since the number of swimming amphipods can peak at over 30,000 individuals within a 20-cm-diameter, stationary plankton net over a period of immersion of ~4 h. Amphipods swim throughout spring-summer, but abundance in the water column is less in May than in the other months. As well, amphipods swim during the day and night, but the number swimming shows periodicity in relation to diel time of high tide, with peaks when high tides occur around 1:45 a.m. Finally, the number of amphipods swimming shows periodicity in relation to lunar cycles, with peaks around the time of new moon and full moon. We developed a statistical model describing the swimming activity of *C. volutator* based on month, diel time of high tide, and day of the lunar calendar. The model accurately predicts the timing of peaks, but does not predict well the amplitude of the highest peaks. Overall, the model gives a very good approximation of the number of swimmers (61 % of the variation is explained) and provides a strong basis for future modeling of spatial population dynamics of *C. volutator*.

First Prize - Undergraduate Poster

EFFECTS OF DENSITY OF THE AMPHIPOD C*orophium volutator* ON SEDIMENT PROPERTIES ON A MUDFLAT

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Introduction

The tube-dwelling amphipod *Corophium volutator* can occur in very high densities on intertidal mudflats in the upper Bay of Fundy (Peer et al. 1986; Barbeau et al. in press). These amphipods are one of the main food sources for migratory shorebirds passing through the Bay of Fundy (Hicklin and Smith 1979). In the past, it has been observed that as populations of *Corophium* crash and recover, changes occur in the mud properties (Shepherd et al. 1995). The relationship between *Corophium* density and sediment properties, specifically sediment stability, is not well understood.

Corophium interact with sediment in several ways. They construct and strengthen U-shaped burrows, which may stabilize sediments (Meadows and Tait 1989; Meadows et al. 1990). However, they may destabilize sediments by feeding on surface biofilm, removing epipelic diatoms (Gerdol and Hughes 1994a) that secrete cohesive mucopolysaccharides (Daborn et al. 1993). *Corophium* also filter feed, and may resuspend particles (Nielsen and Kofoed 1982).

The objective of this study was to examine the effect of different densities of *Corophium* on sediment properties such as chlorophyll *a*, water content, organic content, average particle size, erodibility, sediment penetrability, and reduction-oxidation potential.

Methods

A factorial experiment using cylindrical cages (15 cm diameter x 15 cm height) was conducted at Peck's Cove, New Brunswick, mudflat in the upper Bay of Fundy from 10 July to 7 August 2008 (see Peer et al. (1986) for a map of the area). The cages were made from clear pipes of polycarbonate plastic, and had three windows on the side (each 2 cm x 11 cm, and 5 cm down from the top) covered with 250 µm mesh (Figure 1). The top of the cages was covered with 183 µm mesh, held on by two cloth elastics. Upon deployment, the cages were pushed into the sediment to the level of the windows (i.e., 5 cm of the cage was above the mudflat surface), and the mud inside the cage was removed and replaced by sieved mud (using a 250 µm metal sieve to remove macroinvertebrates). The two factors investigated in the experiment were density of *Corophium* and time. One of 4 densities of *Corophium* was randomly allotted to each cage: 0, 1000 (low), 5000 (medium) and 20,000 individuals/m^2 (high). Natural, uncaged areas were sampled as a control. *Corophium* density in the natural sediment ranged from 1,500 to 70,000 individuals per m^2 during the experiment. Cages and control areas were destructively sampled at one of 6 times over 28 days (Day 1, 5, 7, 14, 21 and 28). There were 4 replicates for each density–time combination (for a total of 96 cages and 24 control areas).

Some of the response variables were measured *in situ*; these included:

- sediment temperature using a thermometer,
- sediment penetrability by dropping an object from a known height and measuring the depth that it penetrated in the mud, and
- redox using a redox meter.

Corophium density and the other sediment properties were sampled using cores which were then taken back to the lab and processed. This included:

- sieving (250 µm mesh), counting and sizing Corophium individuals from 6.7-cm diameter cores (depth to the anoxic layer), and converting to dry biomass,
- chlorophyll *a* in 1-cm diameter sediment cores (2-mm depth) using an acetone extraction procedure and spectrophotometry,
- water content by quantifying weight loss after drying sediment samples from 2-cm diameter cores to constant weight,
- organic content by loss on ignition of dried sediment samples above,
- particle size distribution of the resuspended, ashed sediment samples above using a particle size analyzing machine (Malvern Mastersizer), and
- erodibility by measuring sediment loss from 5.2-cm diameter cores in a recirculating flume with sea water (Instant Ocean®).

The data were analysed using ANOVAs. Refer to Savoie (2009) for more details.

Figure 1. Deployed cages (15 cm diameter) on the mudflat at Peck's Cove, NB

Results

Corophium Biomass

Amphipod biomass within each of the treatment levels was fairly stable during the experiment, indicating that the density treatment levels remained distinct (Figure 2).

Chlorophyll *a*, Water Content and Organic Content

Chlorophyll *a* concentration decreased with increasing *Corophium* density ($p < 0.001$, Figure 3). Water and organic content did not differ significantly amongst the caged treatments ($p > 0.40$).

Average Particle Size, Erodibility, Penetrability and Redox

Average particle size tended to increase ($p = 0.10$) and erodibility in mid-core decreased ($p = 0.01$) with increasing *Corophium* density (Figure 4 and 5). Sediment penetrability ($p = 0.14$) and redox potential ($p > 0.3$) did not differ significantly amongst the caged treatments.

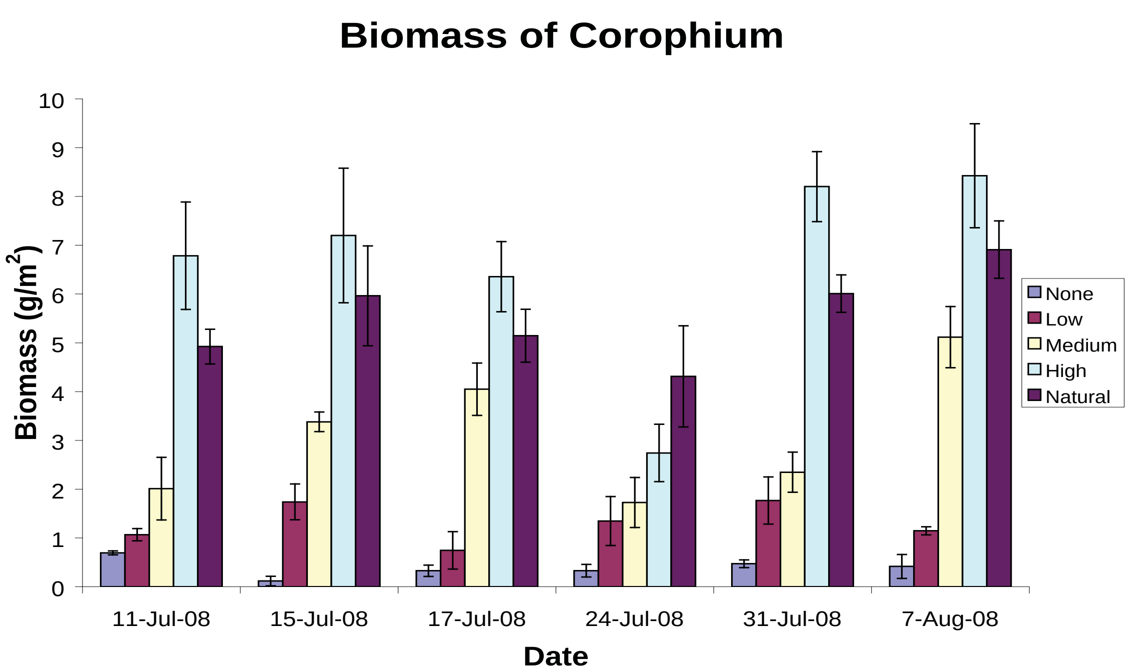

Figure 2. Biomass (dry weight, mean ± SE) of *Corophium* per m^2 in each of the different nominal treatment levels of *Corophium* density

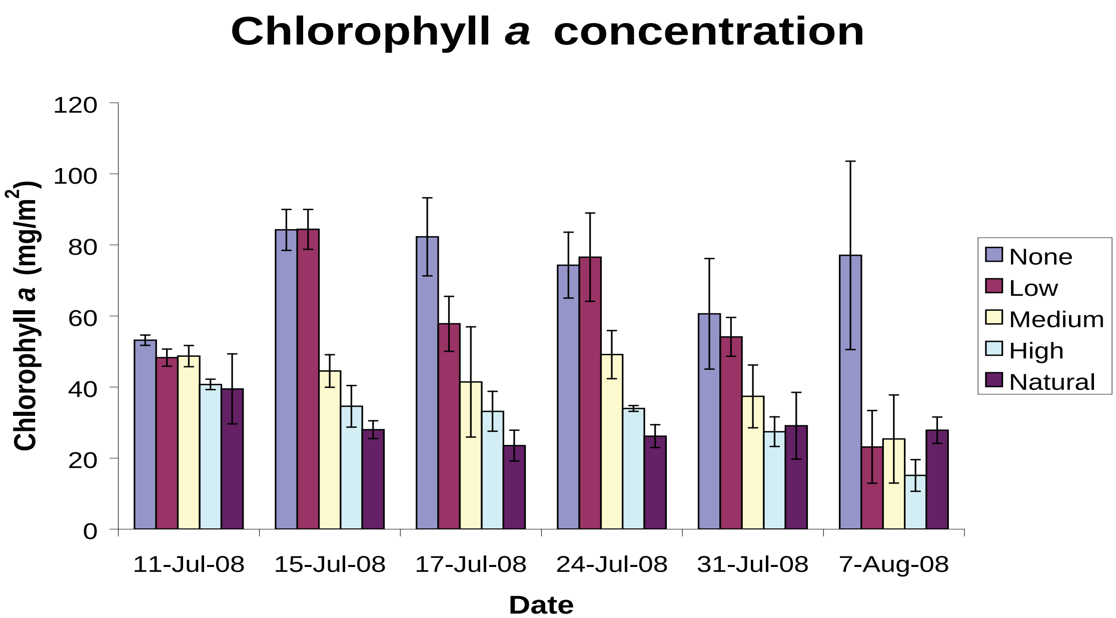

Figure 3. Chlorophyll *a* concentration (mean ± SE) in the top 2 mm of the sediment in the different nominal treatment levels of *Corophium* density

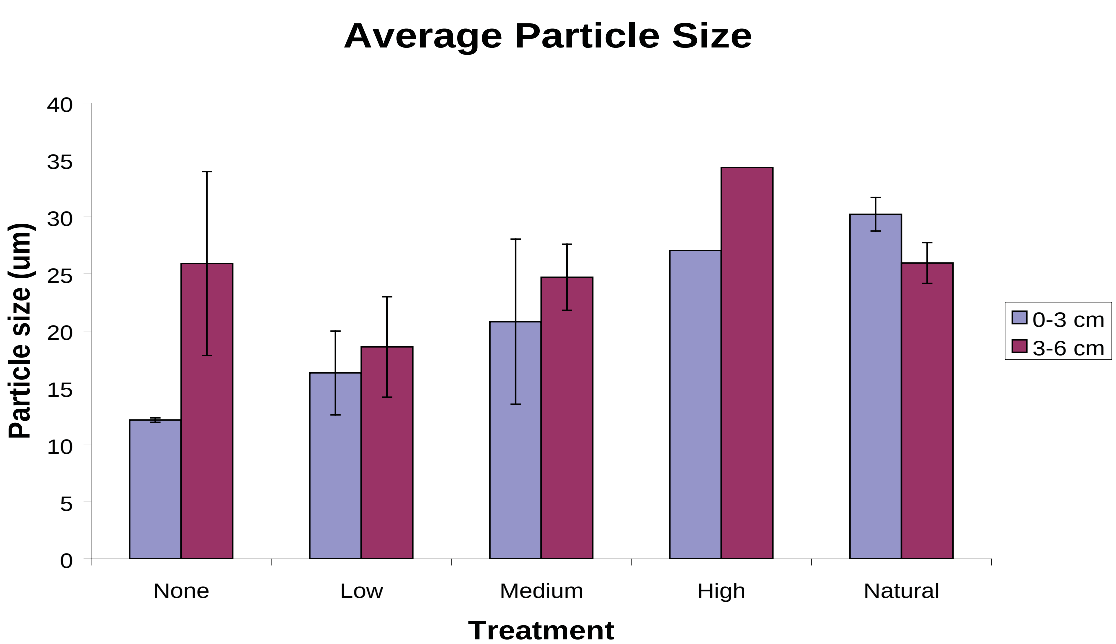

Figure 4. Volume weighted mean particle size (mean ± SE) at two depths in a sediment core in the different nominal treatment levels of *Corophium* density for Day 14 of the experiment

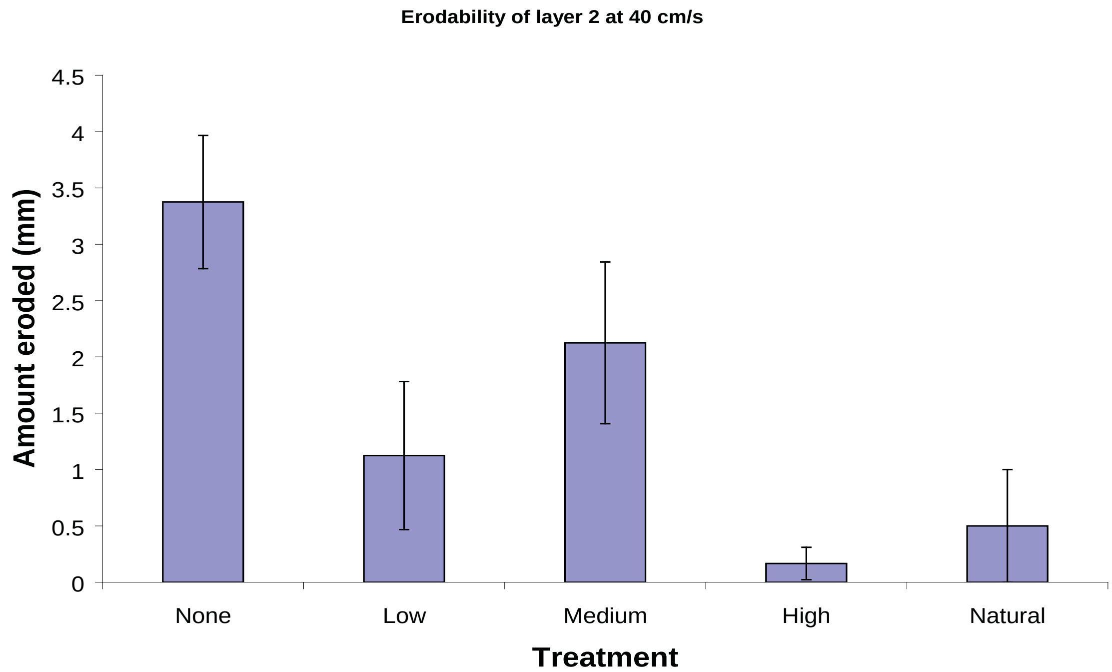

Figure 5. Erosion (mean ± SE) of a sediment core at a depth of 3.5 to 4.0 cm (Layer 3) in the different nominal treatment levels of *Corophium* density for Day 21 of the experiment. Amount eroded was measured after 10 min at a water speed of 40 cm/s

Discussion

The results of this experiment support the hypothesis that *Corophium* have an effect on some sediment properties and that varying densities of *Corophium* causes variation in sediment properties. The experiment also showed that the cages had a procedural effect (Savoie 2009), altering the natural flow and budget of water because of the wall design; however, because all cages experienced the effects to the same degree, any difference caused by *Corophium* should still be detectable.

A sediment variable that responded strongly to *Corophium* density was chlorophyll *a*. Increased chlorophyll *a* concentration with decreased *Corophium* density very likely reflected increased abundance of diatoms (Eaton et al. 1995; Trites et al. 2005). Epipelic diatoms have been shown to stabilize the top few millimetres of sediment, due to secretion of mucopolysaccharides which bind the sediment grains together (Holland et al. 1974; Paterson 1989; Daborn et al. 1993; Gerdol and Hughes 1994b). Unfortunately, we were unable to assess if an increase in chlorophyll *a* (i.e., diatoms) correlated with decreased erodibility of the sediment surface. We were delayed in processing the erodibility cores and had to freeze them. We then discovered that frozen and thawed cores had much higher surface erosion rates than fresh cores (Savoie 2009), and so do not have confidence in our surface erodibility data.

Interestingly, erodibility at mid-core (3.5–4.0 mm depth, which seemed unaffected by freezing and thawing) decreased with increased *Corophium* density. This may be related to *Corophium* reinforcing their burrows with an adhesive secretory material (Meadows et al. 1990). This material is made up of threads 1–2 µm in diameter which are bound to sediment particles.

The trend of increased average particle size with increased *Corophium* density may be due to bioturbation by *Corophium* preventing the smallest particles from settling out. Also, biofilm, which proliferates in the absence of *Corophium*, is capable of binding fine particles (de Brouwer et al. 2000). Thus, increased *Corophium* density and consequent decreased biofilm (measured as chlorophyll *a*) may have lead to small particles being washed away rather than trapped.

Other sediment variables, organic content, water content, penetrability and redox, did not show a strong pattern with *Corophium* density. We have concerns about sieving the mud (to remove macro-invertebrates) at the start of the experiment, which destroys the micro-structure of the sediment, and about a cage effect, especially in the latter half of the experiment. So, it is still not clear whether *Corophium* have an overall stabilizing or destabilizing effect on mudflats. Further research in this field is needed and different experimental designs should be tried out.

Acknowledgements

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Second Prize - Undergraduate Poster

ABUNDANCE OF RIBBED MUSSELS (*Geukensia demissa*) IN SALT MARSHES LOCATED IN CONTRASTING TIDAL REGIMES: NORTHUMBERLAND STRAIT *VS.* UPPER BAY OF FUNDY

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Introduction

A positive interaction between saltwater cord grass (*Spartina alterniflora*) and ribbed mussels (*Geukensia demissa*) has been documented in southern New England (Bertness 1984). Specifically, ribbed mussels facilitate colonization or advancement of *S. alterniflora* unto the mudflat by stabilization of sediments and increase of soil nutrients. *S. alterniflora* increase the reproductive success of ribbed mussels within salt marsh environments (Bertness 1984). However, this interaction as well as the ecological role of ribbed mussels have not been studied within salt marshes of Atlantic Canada.

The tidal regime within Atlantic Canada is more varied than in New England. The Bay of Fundy has macrotides and turbid waters, whereas the Northumberland Strait has microtides and relatively clear water (Baerlocher and Moulton 1999; Desplanque and Mossman 2004; Canadian Hydrographic Services 2009). The very large tides and higher suspended sediment load in the Bay of Fundy compared to the Northumberland Strait may decrease the ability of animals, such as ribbed mussels, to filter feed and therefore may affect their distribution (Thomas 1983; Jorgensen 1996).

The objectives of this preliminary study were to assess possible differences in community structure, as well as quantify densities of saltwater cord grass and ribbed mussels in two salt marsh environments in Atlantic Canada, namely the upper Bay of Fundy and the Northumberland Strait.

Methods

Two salt marshes, John Lusby in the upper Bay of Fundy and Cape Jourimain in Northumberland Strait (Figure 1), were sampled in October 2008. In each salt marsh, three transects were placed perpendicular to the low water line, and were separated by at least 200 m. Transects spanned from above the high marsh zone (from the *Spartina pectinata* or *Juncus* spp. region) to the water edge of the low marsh zone; they were 449–580 m and 71–270 m long in the John Lusby marsh and Cape Jourimain marsh, respectively. They were sampled in a stratified random manner using twelve quadrats (0.5 m x 0.5 m) per transect. Within each quadrat, plants and animals were identified, and plant stems and animal individuals were counted. To calculate densities of saltwater cord grass and ribbed mussels, only quadrats falling in the low marsh zone were used.

PRIMER analysis, using a presence/absence transformation, was used to assess differences in community structure between the two salt marshes (Clarke and Warwick 2001). Specifically, ANOSIM was used to determine the differences between community samples using a similarity matrix, and the percent contributions of the most important species to the difference were determined. Multidimensional scaling was used to plot the data.

Results

The community structure of the John Lusby and Cape Jourimain salt marshes was significantly different based on PRIMER analysis (R = 0.127, p = 0.002; Figure 2). The difference between the salt marshes was mainly due to the abundances of common grass species (e.g., *Spartina* spp.) and the presence/absence of marine invertebrate species, namely gastropods and ribbed mussels (Table 1).

Ribbed mussels were found in the Cape Jourimain salt marsh, but were absent in the John Lusby salt marsh (Figure 3). Density of saltwater cord grass was higher in the John Lusby salt marsh than in the Cape Jourimain salt marsh.

Figure 1. General location of the two salt marshes in Atlantic Canada (adapted from Google Maps)

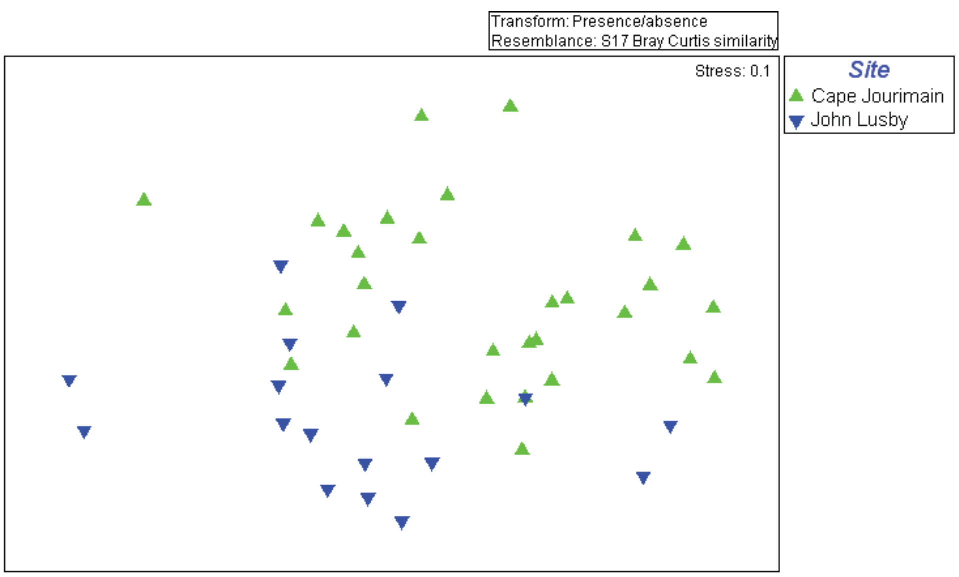

Figure 2. Multidimensional scale plot showing the difference in community structure between two salt marshes, Cape Jourimain (upright triangle) and John Lusby (upside-down triangle), in Atlantic Canada

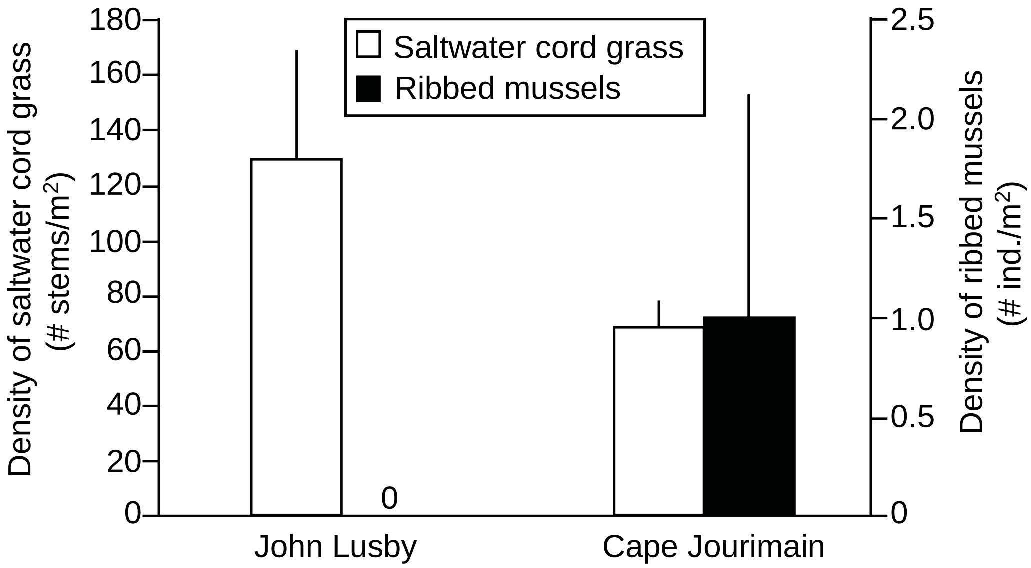

Figure 3. Mean (± SD, n = 9) densities of saltwater cord grass and ribbed mussels in the low marsh zone of the Cape Jourimain salt marsh (Northumberland Strait) and John Lusby salt marsh (Bay of Fundy)

Species	% contribution
Spartina alterniflora	13.48
Spartina patens	13.17
Melampus sp.	9.98
Spartina pectinata	9.09
Littorina saxatilis	6.19
Solidago sempervirens	6.02
Glaux maritima	5.97
Atriplex spp.	4.91
Triglochin maritima	4.42
Geukensia demissa	4.15
Juncus gerardii	2.76
Limonium carolinianum	2.68
Puccinella americanus	2.54
Hordeum jubatum	1.72
Juncus baltica	1.67
Gammarus sp.	1.63

Table 1. Percent contribution of various species to the significant community difference between Cape Jourimain salt marsh (Northumberland Strait) and John Lusby salt marsh (Bay of Fundy)

Discussion

In this preliminary study, the community structure of a salt marsh in the Northumberland Strait and one in the upper Bay of Fundy was different. A prominent difference was the absence of marine invertebrate epifauna and filter feeders (including ribbed mussels) within the John Lusby salt marsh. Filter feeders may have limited success inhabiting the upper Bay of Fundy because of negative effects of high suspended sediment load on filtering abilities (Baerlocher and Pitcher 1999; Ellis et al. 2002). More salt marshes need to be sampled in each of the tidal environments to assess the generality of this pattern.

At the scale of salt marshes in two different water bodies, we did not observe a positive correlation between the densities of ribbed mussels and saltwater cord grass. In the future, intensive sampling of the low marsh region of multiple salt marshes is planned to quantify the within-salt marsh relationship between these two organisms. The ecological role of ribbed mussel in the salt marshes of Atlantic Canada is also planned to be studied.

Acknowledgements

We thank the Canadian Wildlife Service (Environment Canada) for permission to access the sites, and David Drolet and the 2008 class of Coastal Marine Ecology at UNB-Fredericton for data collection.

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MONITORING LONG-TERM CHANGE IN INFAUNAL DIVERSITY, ABUNDANCE AND DISTRIBUTION IN MINAS BASIN MUDFLATS

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The Minas Basin, with some of the highest tides in the world (15 m), is characterized by extensive mudflats which comprise one third the total area of the basin during low tide. Extensive sampling in the Southern Bight of the Minas Basin occurred in 1977–1978 (Gratto 1978) with 900 samples collected over 40 km of coastline. Polychaetes represented approximately half of the species identified in these samples. Key areas (e.g., Kingsport and Avonport) were re-sampled in July 2007, with replicate samples from low to high tide zones. Species richness and abundance data from 2007 will be compared with the Gratto 1978 study and long-term trends in infauna communities will be examined. This system is highly dynamic, so there is a need for new baseline information in these areas. Shepherd et al. (1995*)* revealed a 12% increase in silt and clay at Kingsport since the late 1970s. Since species presence and abundance in mudflats depends primarily on sediment grain size, organic content, and water content, changes in species richness and abundance at Kingsport are likely. With renewed interest in tidal power development in the Bay of Fundy, changes in sediment distribution from altered tides and currents are a possibility. Depending on the magnitude of the proposed tidal power project, there may be associated changes in the distribution of infauna in the intertidal zone of the Minas Basin. Long-term monitoring of the system before and after the tidal power development will be crucial to understanding environmental effects. Preliminary analysis of Kingsport samples are presented here. Avonport species identification and a detailed sediment analysis of both Avonport and Kingsport will take place summer 2009.

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THE CHANGING SANDS OF BIODIVERSITY IN THE MINAS BASIN (BAY OF FUNDY, CANADA)

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The holocene history of the Minas Basin has been incredibly dynamic. Within the last 7,000 years, the Minas Basin has been transformed from a river to an estuary, and within the last 4,000 years has developed into a megatidal estuary with 15 m tides that move 14 billion tonnes of sea water twice daily. This highly productive ecosystem has historically been rich in mudflats and salt marshes but within the last 300 years, 98% of the original 40,000 acres of salt marsh has been 'reclaimed' for farming and more recently, sediment flow has been compromised by causeways and beach stabilization programmes. Attempts to catalogue the biodiversity of the basin began in the 1920s, peaked in the 1970s, and collectively report 440 species of animals. The primary source of historic data for our study is an extensive survey of intertidal life based on 900 samples covering 40 km of coastline (Gratto 1978). Our goal is to re-sample key locations (e.g., Evangeline Beach) following the 1977 transects. Preliminary analysis suggests substantial change has occurred in this 30 year period. For example, equivalent sampling effort (1977, 2008) in the mid-intertidal zone found that density of infauna doubled (from 17,800 to 40,767 individuals/ m^2). While the number of species remained unchanged, 4 of the 12 species found in 2008 were not recorded from that site in 1977. In 1977, three species made up 62% of the mid-intertidal infauna (*Eteone longa*, *Pygospio elegans* and *Streblospio benedicti*). In contrast, samples from 2008 were dominated by *Chaetozone setosa*, representing 53% of individuals sampled, an increase from only 6% in 1977. These data suggest that the Minas Basin is currently undergoing major transitions in its mudflat communities. Understanding these transitions is key to understanding the basin itself as the mudflats, now that most of the salt marshes have been lost, are major sources of productivity in this dynamic ecosystem.

References

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A DISAPPEARING ACT? MONITORING EELGRASS (*Zostera marina*) DECLINE IN KEJIMKUJIK NATIONAL PARK, NOVA SCOTIA, CANADA

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Eelgrass (*Zostera marina*), considered a keystone habitat in Atlantic Canada, has been experiencing continued decline in many parts of this region. Long-term monitoring of eelgrass extent and condition was initiated in Keji Seaside, Kejimkujik National Park in 2007. Comparison of eelgrass coverage based on mapping conducted in 1987 and again in 2007–2008 indicates a loss of approximately 64 ha (~88%). Although the original cause of decline is unknown, our investigations suggest that several factors may be contributing to continued decline. Swim transects of the remaining bed conducted in 2007, followed up by trap surveys in 2008, indicate high densities of juvenile and adult European green crabs (*Carcinus maenas*). Floating mats of dislodged shoots contained a large proportion of shoots with signs of green crab disturbance (shredded bundle sheaths and whole, live plants neatly sliced off at the base). Exclosure experiments are proposed for the summer of 2009 to investigate the impact of green crabs on the eelgrass bed. Eelgrass condition surveys detected several plants partially covered with the invasive golden star tunicate (*Botryllus schlosseri*). Otherwise, epiphyte coverage was considered low and eelgrass wasting disease was not detected. Water quality analyses conducted in 2008 indicate that salinity and water clarity are strongly controlled by episodic large precipitation events, which result in freshwater inputs rich in CDOM (coloured dissolved organic matter) from surrounding wetlands. Dissolved inorganic nitrogen (DIN) and phosphate concentrations marginally elevated above nearby open-ocean concentrations were occasionally observed in the lagoon between May and September 2008, but were not high enough to be considered a threat to eelgrass health.

Session K. Information

USE OF SCIENTIFIC INFORMATION IN DECISION MAKING FOR EFFECTIVE MARINE RESOURCE MANAGEMENT

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Scientific information on the marine environment has been produced over the years by international advisory agencies. In spite of the availability of information, it is uncertain whether it is being efficiently utilized by members of the wider community of researchers and policy makers. This is evident in the continuing declining trends in the global state of the marine environment and fisheries and this impacts a wide range of stakeholders. The primary question being asked in this graduate study is whether the information provided by selected international organisations (grey literature) is being used or considered by senior managers and other decision makers, resulting in better resource and environmental protection decisions. The study seeks to understand the following: how scientific communication occurs in public policy decision making with regard to what is to be studied and who determines this; information pathways and uses in policy-making settings; and nature of policy directives. The study incorporates a methodology that looks at the impact of grey literature on environmental subjects using citation searching, content analysis, and surveys. The study will also consider adaptations/alternative methodologies for specific geographical regions, such as the Caribbean, which may result in the development of new ways of measuring the influence of grey marine management literature in the digital age. The objectives of this study and expected results can assist the Bay of Fundy Ecosystem Partnership in promoting its vision of facilitating effective communication and timely sharing of information amongst its partners.

Use of Scientific Information in Decision Making for Effective Marine Resource Management

Suzuette S. Soomai

Marine Affairs Program, Faculty of Management, Dalhousie University

Abstract

This study examines scientific information use and influence in managing the shrimp and groundfish resources in the Brazil-Guianas Continental Shelf. The study will use surveys and content analysis to identify information pathways among various stakeholders. The opportunities for and barriers to effective and efficient use of scientific information will be described.

Introduction

Fig. 1 The Brazil-Guianas Continental Shelf.

- The Shelf extends along the north-east coast of South America (Fig.1).
- Scientific information on the status of the shrimp and groundfish resources is produced by national fisheries agencies in association with fisheries advisory bodies:
  - **FAO** (UN-Food and Agricultural Organization)
  - **CRFM** (Caribbean Regional Fisheries Mechanism)
- This information is largely available as grey literature (reports are not controlled by commercial publishers).
- Continuing declines in the fisheries affect a wide range of stakeholders.
- Information may not be used efficiently by managers and policy makers.

Guiding Questions

How is information from fisheries agencies used by decision makers?

Does this information result in better resource management decisions?

How is scientific information communicated in public policy decision-making?

- What information do fisheries managers need?
- What questions are being asked of scientists by fisheries managers?
- What information has been produced by scientists?
- How is management advice conveyed to policy makers?

What are the information pathways in policy-making for local fisheries?

Methods

The study runs from May – August 2009 and will use :

Content analysis

To examine available grey literature for:

- scientific information
- management advice
- requests for information
- mechanisms for communicating information

Surveys

To study sample populations drawn from Trinidad and Tobago and from Venezuela.

About 40 participants will be selected from the five major stakeholder groups in the fishery (Fig. 2):

- Scientists
- Managers
- Policy makers
- Fishing Industry
- Fisheries Advisory Bodies

Expected Outcomes

Improved understanding of:

- pathways of information sharing among the five main stakeholder groups.
- opportunities and barriers for using scientific information for fisheries resource management.
  Is the information useful; too much, too little information; production too late, too early?
- contrasts in information pathways in Trinidad and Tobago and in Venezuela.

Formulation of recommendations for increasing the effective use and influence of scientific information in the fisheries policy process.

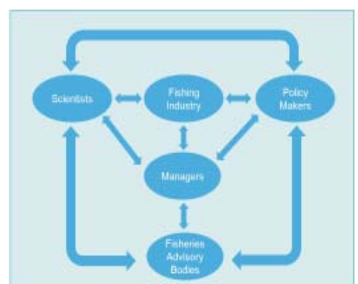

Fig. 2 Hypothetical flow of information among the stakeholder groups

Benefits to BoFEP

- The objectives and expected results of this case study can be applied in general to any resource management scenario.
- This study can assist BoFEP in promoting its vision of facilitating effective communication and timely sharing of information amongst its partners.

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8th BoFEP Bay of Fundy Science Workshop
Acadia University, Wolfville, NS
May 26 - 29, 2009

THE GULF OF MAINE COUNCIL ON THE MARINE ENVIRONMENT: AN INVESTIGATION OF THE USE OF ITS GREY LITERATURE PUBLICATIONS

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Although many governmental and intergovernmental organizations publish vast quantities of grey literature, the diffusion and impact of this literature are rarely studied. Our study of the output of the Gulf of Maine Council on the Marine Environment (GOMC) begins to fill this gap. In the twenty years since GOMC was created, it has generated a large and diverse body of publications. Among the array of over 300 publications produced directly by the Council, or in collaboration with other organizations, are action plans, annual reports, technical reports, conference proceedings, background documents, newsletters, newspapers, magazines, fact sheets, brochures, maps, and a comprehensive Web site. Published in print and digital formats (now primarily in digital formats available on the Council's Web site), GOMC provides a complex publishing history for investigation. To determine the influence of GOMC publications, citation data for GOMC's major reports was drawn from Web of Science, Google, and Google Scholar. This data demonstrates that the grey literature output of GOMC was cited over lengthy periods, but grey literature tends to be cited primarily by other grey literature. Although open access and powerful search engines are improving access, a reliance on grey literature as the primary means of publication continues to pose hurdles for influencing scientific research, public policy, and public opinion. The impact of this literature can be muted because of the limitations of its dissemination and perceptions of its quality. Based on these findings, this poster outlines steps to overcome the dissemination and perception hurdles.

The Gulf of Maine Council on the Marine Environment: An Investigation of the Use of Its Grey Literature Publications

Bertrum H. MacDonald, Ruth E. Cordes, Peter G. Wells, & Danielle M. Cossarini

Dalhousie University Information Management, Resource and Environmental Studies, and International Ocean Institute

Abstract

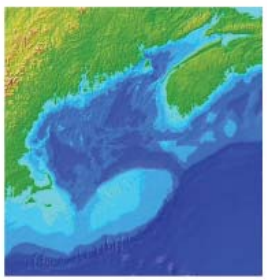
Our research studies the influence of information produced as "grey literature" by the Gulf of Maine Council (GOMC). To date we have indentified the types of GOMC publications, and examined their diffusion. We plan to extend our research by interviewing GOMC informants, and analysing policy documents and website use.

Introduction

- GOMC is an international, intergovernmental body focused on the marine environment of the Gulf of Maine and the Bay of Fundy. The philosophy underlying the Council's work since 1989 is that activities on land ultimately affect the sea, especially in shallow coastal areas.
- GOMC produces grey literature both in print and online. With over 300 publications, GOMC provides a complex publishing history.
- Awareness of grey literature is problematic, despite powerful search engines and open access.

Guiding Questions

- What has GOMC published, where and how?
- What do citation analysis and other methods show about the distribution and use of GOMC publications?



Methods

Our methods have included:

- Identifying GOMC publications by searching
  - the GOMC website
  - library catalogues
  - web search engines
  - article databases
- Locating citations to GOMC documents by searching
  - Web of Science
  - Scopus
  - Google
  - Google Scholar
- Analysis of citations

GOMC Publications

- GOMC has produced many types of publications (see Table 1).
- GOMC grants have supported publications produced by other agencies.
- GOMC work has been reported at conferences and in journal articles.

Table 1. Types and numbers of GOMC Publications*

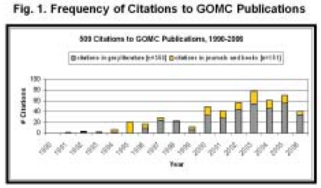
Council Publications	
Reports and fact sheets	122
Background documents	38
Action plans and annual reports	29
Brochures and posters	10
Serials	4
Miscellaneous	9
Council Supported Publications	
Reports and background documents	24
Miscellaneous documents	25
Reprints of Council authored documents	14
Conference papers, journal articles and abstracts	37

* As of 15 November 2006

Current Findings

Citation data shows increased use of GOMC reports over time (Fig. 1).

Fig. 1. Frequency of Citations to GOMC Publications



Reports and journal articles describing GOMC's Gulfwatch Contaminants Monitoring Program were selected for further analysis.

Comparison of citations to Gulfwatch publications in grey literature (Fig. 2a) and in journal articles (Fig. 2b), show that grey literature is more likely to cite other grey literature.

Fig. 2a. GOMC Gulfwatch: Citations in Grey Literature

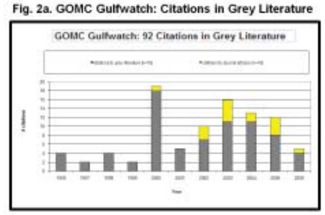
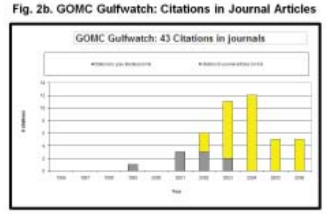
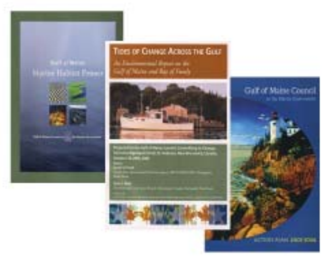


Fig. 2b. GOMC Gulfwatch: Citations in Journal Articles





Planned Research

Our continuing research includes:

- Interviews of key informants to document dissemination pathways of GOMC's print and online publications.
- Content analysis of public policy documentation to assess the use of GOMC's publications.
- Analysis of GOMC website use and surveys of readers of selected publications such as the *GOM Times*.

Selected References

R.E. Cordes, B.H. MacDonald & P.G. Wells (2006) Gulf of Maine Council Publications and Their Use

B.H. MacDonald, R.E. Cordes & P.G. Wells (2007) Assessing the Diffusion and Impact of Grey Literature Published by International Intergovernmental Scientific Groups: The Case of the Gulf of Maine Council on the Marine Environment. *Publishing Research Quarterly* 23(1):30-46.

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8th BoFEP Bay of Fundy Science Workshop
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May 26-29, 2009

FROM SCIENCE TO POLICY AND DECISION MAKING: INVESTIGATING THE USE AND INFLUENCE OF MARINE ENVIRONMENTAL GREY LITERATURE

Bertrum H. MacDonald,[1] Peter G. Wells,[2] Ruth E. Cordes,[3] Gregory R. G. Hutton,[1] Julie Woods,[1] and Suzuette Soomai[4]

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Publication is currently an extensive phenomenon because it is easily achieved with widely accessible digital technologies. Annually, thousands of publications are generated worldwide, often as grey literature. However, distribution and access to these publications can be problematic, even in the presence of open access systems, the Internet, and powerful search engines. Are the extensive resources (upwards of $1 million per title) devoted to the production of such publications justified? This question is particularly significant in environmental contexts where decisions affecting the fate and future of terrestrial and marine-based ecosystems could and should be informed by currently available scientific information. This poster outlines the framework and objectives of a research project being pursued by the authors. Using three major case studies of governmental organizations focused on marine environmental protection, the project is investigating several questions including: what is the influence of scientific grey literature? In policy decision-making contexts are research reports published as grey literature perceived differently than research published as papers in scientific journals (even when grey literature may undergo similar quality checks as journal papers)? And, how should publications be designed for effective discovery and ultimately for impact? Through use of a suite of research methodologies (citation analysis, content analysis of public policy documents, interviews of key informants in public sector management, and surveys) comprehensive understanding of information and knowledge diffusion and use in public sector settings is being developed. This research is of importance to many environmental organizations that communicate with audiences through grey literature.

From Science to Decisions: Influence of Marine Environmental Grey Literature

B.H. MacDonald, P.G. Wells, R.E. Cordes, G.R.G. Hutton, J.L. Woods, S.S. Soomai & D.M. Cossarini
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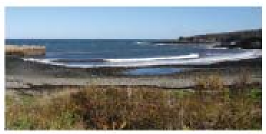
Abstract

Our research studies the influence of information published as "grey literature" by four governmental marine environment and resource organizations. Results to date are enhancing our understanding of the production, diffusion, and use of such information, which is now largely available online. Barriers to effective use of information are also being identified.



Introduction

- There is wide recognition that the world's marine ecosystems are at risk due to overexploitation and various human pressures.
- Numerous environmental and resource studies could inform policy makers who must make timely decisions, manage risks effectively, and take action when warranted.
- Many agencies publish in grey literature formats.
- Grey literature is information produced at all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers.
- Awareness and retrieval of grey literature is not guaranteed despite powerful search engines.

Publications of four governmental organizations are being studied:

- **GESAMP** (UN-Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection)
- **GOMC** (Gulf of Maine Council on the Marine Environment)
- **FAO** (UN-Food and Agriculture Organization)
- **Environment Canada**

Guiding Questions

- What have the four organizations published, where, and how?
- What is the evidence of distribution and use of these publications?
- Which approaches will demonstrate influence of the publications?
- How can marine environmental information in grey formats be more influential in decision making?

Methods

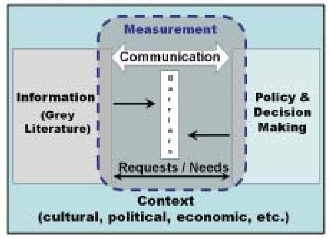
Our methods have included:

- Creation of databases of each organization's publications and citations.
- Analysis of citations to determine
  - Frequency and pattern of citations over time.
  - Sources of citations.
  - Geographic location of citing authors.
  - Subject areas of citing publications.
- Content analysis of publications for characteristics promoting distribution and awareness.

Results

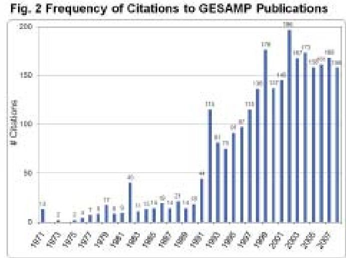
This research on the influence of marine environmental information on policy and decision making is guided by the framework outlined in Fig. 1.

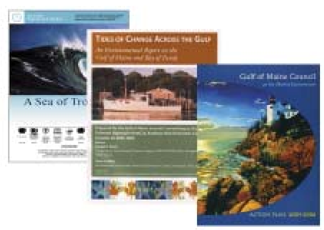
Fig. 1. Guiding framework



Citation data extracted from Web of Science shows increased use of GESAMP reports over time (Fig. 2).

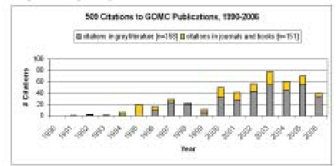
Fig. 2 Frequency of Citations to GESAMP Publications





Citation data extracted from Web of Science and from the Internet also shows increased use of GOMC reports over time (Fig. 3).

Fig. 3. Frequency of Citations to GOMC Publications



GESAMP's influence is shown by citations from Google Scholar and Google, which represent influence (e.g., online reports or papers) or are superfluous (web ephemera). In Google Scholar 99.5% of the citations represent influence (Table 4a) compared to 75% of Google searches (Table 4b).

Table 1a. Citations Located With Google Scholar

Most Cited GESAMP Reports	Google Scholar Hits	Citations Showing Influence	Superfluous Citations
Top 5	352	352	0
Next 5	235	232	3
Total	587	584	3
	Percentage	99.5	0.5

Table 1b. Citations Located With Google

Most Cited GESAMP Reports	Google Hits	Citations Showing Influence	Superfluous Citations
Top 5	253	186	67
Next 5	215	164	51
Total	468	350	118
	Percentage	74.8	25.2

Recent Presentations & Publications

- B.H. MacDonald, P.G. Wells, & R.E. Cordes. "Who Reads and Uses Grey Literature? The Case of Publications of Two Intergovernmental Environmental Groups." Paper presented to Society for the History of Authorship, Reading and Publishing. Oxford Brookes University, Oxford, 25 June 2008.
- B.H. MacDonald, R.E. Cordes, & P.G. Wells. "Assessing the Diffusion and Impact of Grey Literature Published by International Intergovernmental Scientific Groups: The Case of the Gulf of Maine Council on the Marine Environment," *Publishing Research Quarterly* 23, no. 1 (2007): 30-46.

Benefits to BoFEP

- Assistance with
  - Selection of appropriate measures for evaluating use and influence of information on the Bay of Fundy.
  - Dissemination of Fundy Information generated through BoFEP to maximize its use in policy decisions.
- Generation of new research questions and projects for the Fundy Informatics WG.

Discussion & Next Steps

- Our results clearly demonstrate use and influence of publications of two of the intergovernmental organizations, GOMC and GESAMP.
- Multiple data sources are needed to build a comprehensive understanding of use and influence of grey literature.

Our current research includes:

- Extending citation analyses of all four organizations.
- Interviewing public sector managers in Canada, US, the Caribbean, and Europe regarding use of grey literature.
- Developing methods for evaluating the influence of such literature on decision making in environmental fields.

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TRACKING THE USE AND INFLUENCE OF MARINE ENVIRONMENTAL INFORMATION – APPLYING METHODOLOGIES FROM AN INTERGOVERNMENTAL GROUP CASE STUDY

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Numerous significant, multi-stakeholder situations regarding marine environments and related policy decisions could be informed by authoritative scientific information. Such scientific information is often available, much of which is grey literature published by governmental and non-governmental organizations. Recently, publication and dissemination of scientific information have undergone significant change, largely due to the widespread diffusion of digital technologies and Web access. This poster outlines a composite metric of citations which aims to provide a more holistic understanding of the influence of grey literature published in print and digital formats. It draws on a review of the arguments for webometrics—the study of Web-based citations—and an analysis of citation data for an international intergovernmental advisory group on marine concerns, collected from Web of Science as well as from Google and Google Scholar. The analysis of citations arising from periodicals, monographs, and Web-based documents provides informative insights into how shifting publishing practices are changing the ways researchers are citing scientific information. The poster describes methodologies to improve understanding of the influence of such literature in an information economy characterized by rapid communication and over abundant sources. The influence of the environmental information published about the Bay of Fundy can be evaluated using the methodologies employed in this case study, a process that will highlight methods for increasing understanding of the influence of Bay of Fundy environmental information.

Tracking the Use and Influence of Marine Environmental Information: Applying Methodologies from an Intergovernmental Agency Case Study

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Abstract

This study identifies a methodology to improve understanding of the influence of grey literature published in print and digital formats. The study is based on analyses of citation data regarding the UN-based Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), the data collected from Web of Science, Google, and Google Scholar.

Introduction

- The quantity of scientific information has increased significantly over the past century and much of this information is published as grey literature.
- This literature, often freely available online, can contain important information for local or international issues .
- Methodologies for determining use and influence of grey literature are currently underdeveloped.
- Citation analysis techniques provide evidence of influence, but, are limited by relying on Web of Science data.
- Grey literature's influence can be better understood by using multiple sources of citation data.

Guiding Questions

- What sources of unique citation data are overlooked when citation analysis relies only on data from Web of Science?
- What sources of citation data contribute to a more comprehensive metric for measuring the influence of grey literature?

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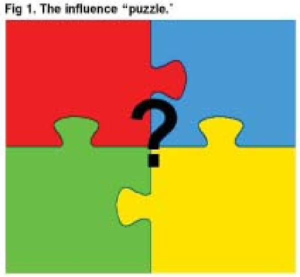
Methods

- A case study using GESAMP's publications was undertaken.
- Citation data was collected from Web of Science, Google, and Google Scholar.
- Specialized searches conducted in Google identify websites linked to www.gesamp.net.
- Citation data from multiple sources was assembled and evaluated. Each source contributed a piece to the puzzle representing grey literature's influence.
- Each piece shows part of the total which can only be understood when assembled.

Fig 1. The influence "puzzle."



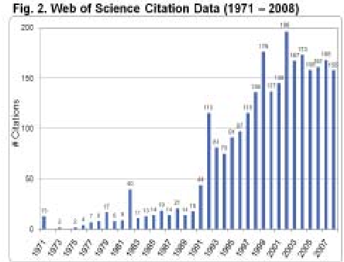
Results & Discussion

- Web of Science, Web links, Google and Google Scholar each contributed unique citation data.

Web of Science

- Citations to GESAMP publications indexed by Web of Science demonstrate use in top peer-reviewed journals over time (Fig 2).

Fig. 2. Web of Science Citation Data (1971 – 2008)



Web Links

- Links between websites show connections closely resembling direct citation.
- Nineteen websites link directly to www.gesamp.net (Table 1), the majority of which come from UN agencies. Other government and NGO links were also identified.

Table 1. Google Link Search Results

UN Sources (13 links)	# of Links
FAO, UNEP, WMO, etc.	9
GESAMP	4
Non-UN Sources (6 links)	
European Commission	1
Oceanographic Center	1
Environmental Directories	1
Peri-urban mangrove forests as filters and potential phytoremediators of domestic sewage in East Africa	1
Conservation International	1
Large Marine Ecosystems of the World	1
Total	**19**

Google & Google Scholar

- Citations from Google Scholar and Google, either represent influence (e.g., online reports or papers) or are perfunctory (web ephemera).
- Over 99% of the citations in Google Scholar represent influence (Table 2a) compared to 75% of Google results (Table 2b).

Table 2a. Citations Located With Google Scholar

Most Cited GESAMP Reports	Google Scholar Hits	Citations Showing Influence	Perfunctory Citations
Top 5	352	352	0
Next 5	235	232	3
Total	587	584	3
	Percentage	99.5	0.5

Table 2b. Citations Located With Google

Most Cited GESAMP Reports	Google Hits	Citations Showing Influence	Perfunctory Citations
Top 5	253	186	67
Next 5	215	164	51
Total	468	350	118
	Percentage	74.8	25.2

Conclusion & Next Steps

- The three datasets described here show evidence of the use of GESAMP's literature from several different sources.
- Producers of grey literature need to look beyond Web of Science for evidence of their publications' influence.
- Future studies will examine other potential sources of citations, including monographs (i.e., books and government documents).

Relevance to BoFEP

- Much of the information concerning the Bay of Fundy is published as grey literature which could inform managerial, scientific, and policy decisions.
- This study elucidates methods on information use and influence valuable to the sustainable management of the Bay of Fundy.

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Session L. Conservation

TAKING STOCK OF CURRENT CONSERVATION LEVELS ON THE SCOTIAN SHELF AND BAY OF FUNDY

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WWF-Canada, in partnership with the Department of Fisheries and Oceans, the Canadian Parks and Wilderness Society (CPAWS), and the Ecology Action Centre, recently undertook a gap analysis to determine how well the current collection of federal closures, marine protected areas and other measures serve to meet Eastern Scotia Shelf Integrated Management (ESSIM) objectives. Comparing these management measures with various habitat types, we are provided with a snapshot of existing conservation levels for each seabed feature as well as for the region as a whole.

CONSERVATION MONITORING OF A WORLD HERITAGE SITE

Melissa Grey, Jenna Boon, and Melanie Cookson-Carter

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The Joggins Fossil Cliffs, located in Chignecto Bay (a northern arm of the Bay of Fundy), is Canada's newest site inscribed on the UNSECO World Heritage List. The inscription was based on the outstanding universal value of the cliffs' geology and fossil content to promoting a deeper understanding of the life and times of the Pennsylvanian Period (Upper Carboniferous). With the addition of Joggins to the World Heritage List and the opening of the Joggins Fossil Centre, increased tourism in the region is expected. Since the Centre opened in April, 2008, there have been approximately 30,000 visitors to the area, about three times more than previous years. Effects of this increased tourist activity will need to be closely monitored to ensure that the integrity of the property is not compromised. The newly formed Joggins Fossil Institute (JFI) has worked in conjunction with community groups and government agencies in order ensure that the value of these cliffs is lasting and appreciated. The JFI will create a monitoring program which will be used for reporting purposes on the conservation status of the property to UNESCO. The program will include a proposed six indicators, ranging from presence of litter to percent coverage of flora and fauna and will be observed bi-yearly through collecting, surveillance, and monitored plots. UNESCO has noted that the most significant potential impact on the property is the removal of resources (specifically fossils), therefore, management plans will need to address this through educational signage and beach monitoring.

MANAGING TIDAL CHANGE

Natasha J. Barker

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Different approaches to coastal management were studied around three estuaries with some of the highest tidal ranges in the world; the Bay of Fundy in Canada (world's highest); the Severn estuary in the United Kingdom (Europe's highest); and the Penzhinskaya Guba in Siberia (Russia's highest). The research investigated three areas of resource management: (1) land use management in response to flood risk and tidal surge, (2) opportunities for renewable energy using tidal power, and (3) public awareness and marketing the tide for tourism.

The three estuaries share dynamic tides but extreme differences in culture, population and wilderness. Communities have evolved near estuaries for resources, trade and leisure – but need to co-exist with the rich natural environment if development is to be sustainable. The contrast between resource utilisation around the Severn estuary with over 3 million people, compared to the Bay of Fundy with less than 1%, and Penzhinskaya with less than 0.1%, of that population, posed useful questions for how we seek sustainable development. The potential for conflict between man and nature is high around developed estuaries such as the Severn estuary. With vastly different population levels and degrees of development, the study explored the evolution of the three estuaries and current management issues.

PRELIMINARY IMPLEMENTATION OF A HYDROLOGIC FLOOD MODEL TO SIMULATE OVERTOPPING OF A DYKE IN THE BAY OF FUNDY

Casey O'Laughlin

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The risk of flooding in response to tidal surge is great for low-lying coastal zones. A rising sea level is associated with higher than average tides, from which current tide barriers are not sufficient for protection. Using ArcGIS 9.2, a GIS-based approach was adopted to analyze the impacts of flooding caused by surging tides for two marshes in the Windsor, Nova Scotia, area: Newport (NS27) and Tregothic (NS68). This project aims to quantify 1) the per-zone volumetric capacity using a detailed digital elevation model (DEM); 2) the rate of water input during overtopping events; and 3) the corresponding time taken to fill each zone. Results demonstrate that Tregothic Marsh is highly vulnerable to tidal surge flooding and the marsh body can be rapidly inundated under all scenarios considered.

Session M. Fish and Fisheries

CLAM MANAGEMENT IN THE BAY OF FUNDY: COMPARING NOVA SCOTIA AND NEW BRUNSWICK

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Project Coordinator, Coastal CURA, Halifax, Nova Scotia (coastalcura@smu.ca**)**

The traditional and sustainable harvest of soft-shell clams that has been carried out along the rich and abundant shores of the Bay of Fundy by small-scale clam harvesters, both Aboriginal and non-Aboriginal, for thousands of years. Only in relatively recent times has the harvest of clams and its environment undergone tremendous change, resulting in the commercial and recreational fishery that we see today. The similarities in challenges being faced by clam harvesters on both sides of the Bay include habitat destruction and contamination to a need for shellfish restocking. In Nova Scotia, the privatization of 1,682 ha of beach in St. Mary's Bay has taken away a traditional harvest area and placed it in the hands of a private leaseholder for 10 years. The common goals for the fishery that are held by, and unite, harvesters from Nova Scotia and New Brunswick are: a) the restoration of the ecological health of the clam resource; b) enhanced local capacity in clam fishery management; c) effective strategies in product marketing, including eco-labeling; d) supportive collaborations between clam harvesters and other organizations and agencies. In keeping with the latter of these goals, harvesters have aligned themselves with local ACAP community organizations: Eastern Charlotte Waterways (NB) and the Clean Annapolis River Project (NS). These collaborations are providing clam harvesters with the resources and capacity needed to reach their goals of community focused clam fishery management.

EVALUATION OF SHORT-TERM CHANGES IN ROCKWEED (*Ascophyllum nodosum*) FOLLOWING CUTTER RAKE HARVESTING IN MAINE

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North Atlantic intertidal areas are often dominated by the rockweed *Ascophyllum nodosum* which can grow to greatest length and mass on wave protected shores. The hold-fasts and three-dimensional canopy of rockweed beds provide habitat for intertidal invertebrates and fish, and offer a place for attachment of their eggs and epiphytic algae. Rockweed is harvested for use in cosmetics, processed foods, domestic animal feeds and fertilizers. It has been harvested commercially for decades in the Gulf of Maine; however a recent increase has raised public concern in Maine and re-stimulated interest to evaluate some basic potential impacts.

A field experiment was conducted using a before-after control-impact (BACI) experimental design with stratified random destructive sampling to evaluate some potential effects of harvesting. The study site was located in Shackford Head State Park, Cobscook Bay, Maine to minimize uncontrolled disturbance from anthropogenic activities. In July 2008, biomass and epifaunal species assemblages on thalli of rockweed taken from 0.1 m^2 quadrats, 4 per stratum (high, mid, low intertidal), were assessed in adjacent control and experimental plots (Figure1).

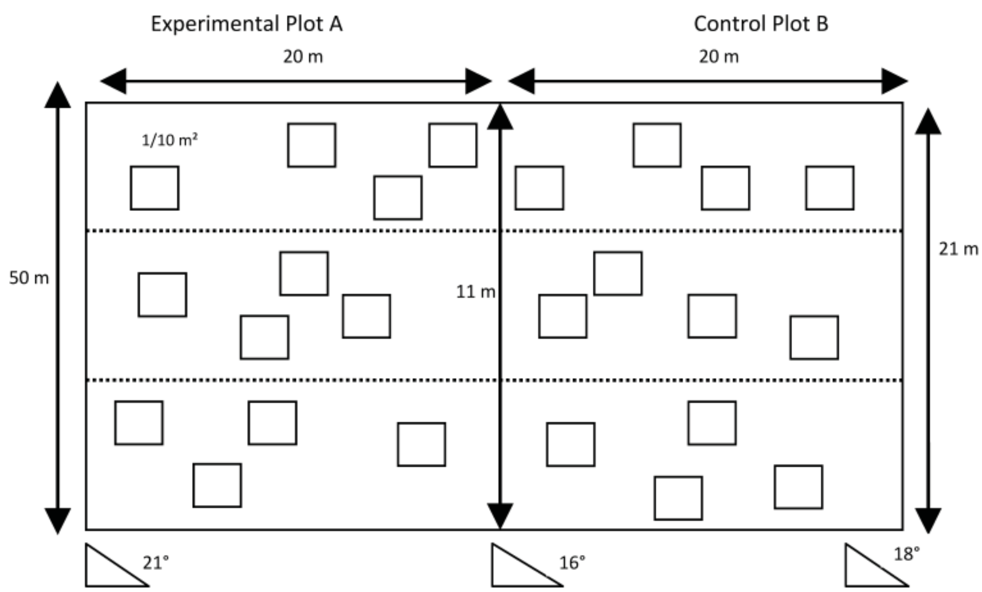

Figure 1. Schematic representation of sample plots and experimental design used to evaluate the effects of cutter rake harvesting of rockweed, *Ascophyllum nodosum*, at Shackford Head State Park, Cobscook Bay, Maine

Plants including holdfasts were scraped from rocks, drained of excess water and weighed. Individual strands were examined for attached and mobile epifauna, and eggs. Immediately after sampling, rockweed was harvested in the experimental plot by a professional harvester from Acadia Seaplants Limited, New Brunswick, using a cutter rake (Figure 2). Harvesters followed Maine Department of Marine Resources harvesting regulations and their operations documented. During harvesting, plants were not cut below 15 inches before the first branch of the primary thalli. Not more than 17% of the biomass was removed and an estimated 1.25 wet tons were harvested by one person in 1.5 h. Both plots were re-sampled in September leaving two months of recovery for the harvested experimental plot.

Figure 2. Cutter rake used for commercial harvesting of rockweed, *Ascophyllum nodosum*

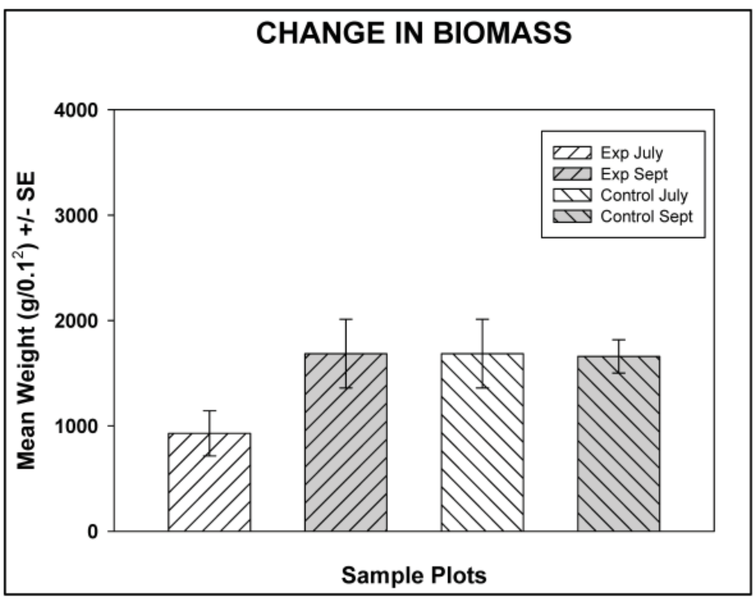

Figure 3. Change in biomass of rockweed *Ascophyllum nodosum* at Shackford Head State Park, Cobscook Bay, Maine, from July to September in control and experimental plots. Rockweed in experimental plot was harvested in July and increased significantly ($P<0.05$) in biomass by approximately two months later in September.

Certain properties of rockweed weight changed during the recovery phase. September biomass was significantly greater ($P<0.05$) in the harvested plot, while the control plot showed no significant change (Figure 3).

There was a significant ($P<0.05$) direct linear relationship between the number of thalli and weight (Figure 4). Weight of thalli from both control and experimental plots was greater in September.

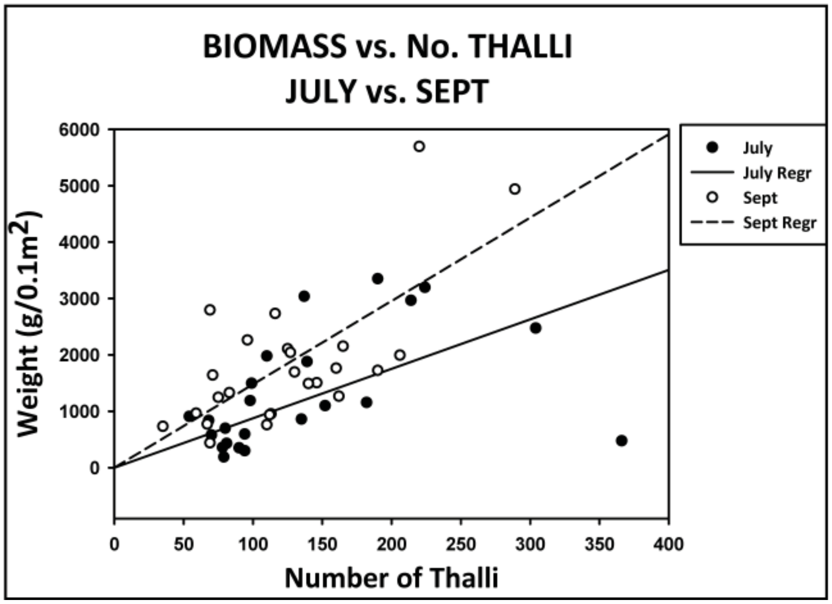

Figure 4. The linear relationship between number of thalli in a sample of rockweed *Ascophyllum nodosum* and weight from combined control and experimental plots at Shackford Head State Park, Cobscook Bay, Maine. Weight of thalli increased from July to September.

The mean density of all periwinkles combined (*Littorina littorea, L. obtusata, and L. saxatilus*) found below the understory on the substrate changed significantly (ANOVA, $P<0.05$) from July to September (Figure 5). Within plots, results of statistical analysis differed. The density of snails on the substrate did not differ significantly between July and September within the experimental plot, however, density in control plots did (Student Newman-Keuls Test, $P<0.05$).

Epifaunal species decreased in frequency from July to September in both experimental and control plots (Figure 6). Though it was more pronounced in the control, these differences were not significant (Wilcoxon Signed Rank Test, $P<0.05$).

Most epifaunal species decreased in frequency in both harvested and control plots except the bryozoan *Flustrellidra hispida* (Figure 7). Potential effects of rockweed harvest appeared to be nested within changes in epifaunal frequency that may be related to seasonality.

This study supports previous results that demonstrated cutting rockweed produces increased biomass (Lazo and Chapman 1996; Ugarte et al. 2006). There were no significant effects of harvesting on the density of snails or epifauna during the two month duration of this study.

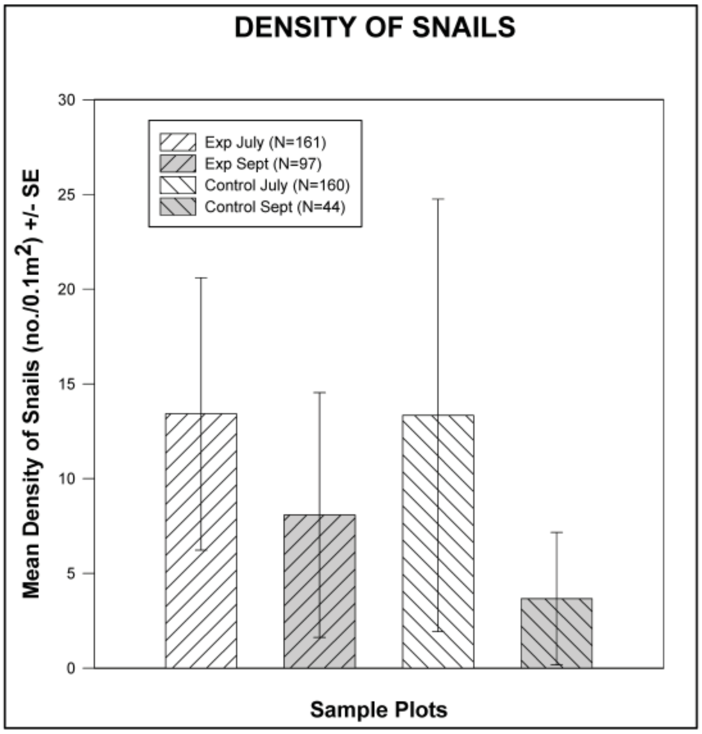

Figure 5. Density of all species of periwinkles (*Littorina littorea, L. obtusata, and L. saxatilus*) combined, in control and experimental plots during July and approximately two months later in September after harvesting at Schackford Head State Park, Cobscook Bay, Maine

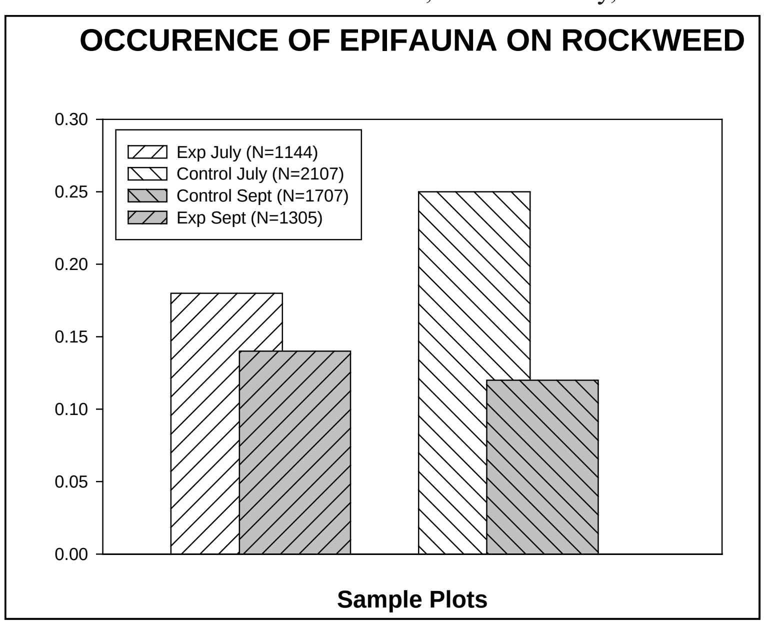

Figure 6. Occurrence of epifauna on rockweed *Ascophyllum nodosum* thalli from control and experimental plots in July and approximately two months later in September after harvesting at Shackford Head State Park, Cobscook Bay, Maine (N = number of thalli examined)

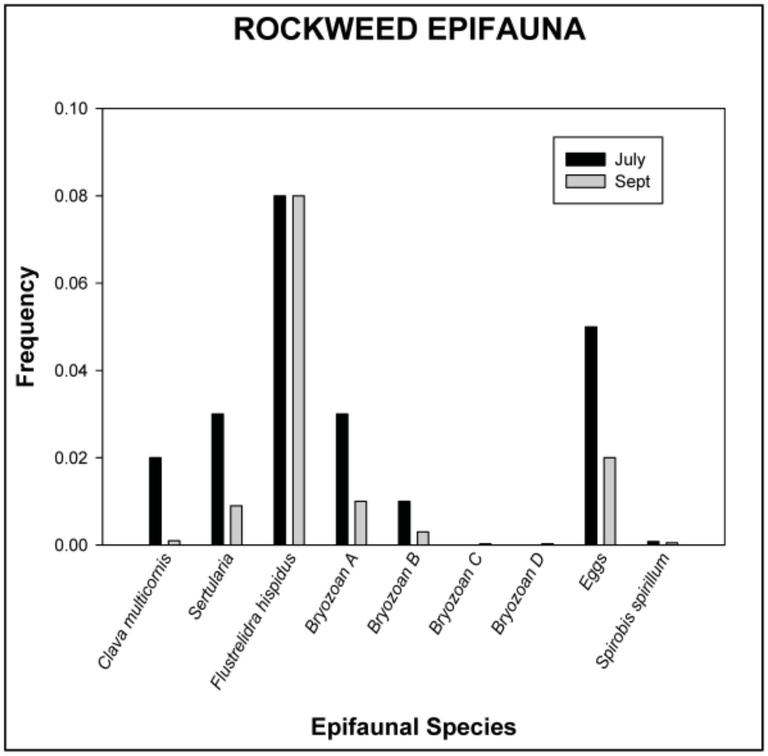

Figure 7. Frequency of species epifaunal on rockweed *Ascophyllum nodosum* at Shackford Head State Park, Cobscook Bay, during July versus September in control and experimental plots combined. July observations were made before rockweed was harvested from the experimental plot.

Acknowledgements

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THE MINAS BASIN LOBSTER STOCK, ITS FISHERY AND THE MOVEMENTS OF TAGGED LOBSTERS

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Abstract

The Minas Basin lobster stock supports a well defined fishery that operates in the Minas Basin during spring-summer (May 1 – July 31) and fall (mid October – end December). Although the lobster fishery in this region is open during winter a fishery is not possible because of ice cover. The fishery is exploited by approximately 14 fishers from ports on the north (Parrsboro) and south sides (Delhaven) of Minas Basin and ports on the Nova Scotia shore of the Bay of Fundy (Halls Harbour). Fishing effort is limited by the large tides of Minas Basin that cause lobster buoys to submerge except around high water and low water slack; a period of about 2–4 hours in each case. During 2008 we sampled the lobsters taken from fisher's traps in three areas: Minas Channel, central Minas Basin and off Halls Harbour. Trap haul daily yields were high in both in the spring-summer and fall. Lobsters sampled from fishers traps ranged from 60–130 mm CL and the proportion of shorts:markets was about 1:2. The sex ratio in the catch was approximately 1:1 and there was a good representation of berried females. We tagged and released about 2600 lobsters. During the spring–summer fishery, tagged lobster were all shorts (>82.5 mm CL). In the fall we fished before the season opened and were able to tag both shorts and market lobsters (<82.5mm CL). To date, most tag returns have been from inside Minas Basin. However, one of our tagged lobsters from off Halls Harbour was recaptured in Digby Gut during late fall suggesting these lobsters move considerable distances. This study was undertaken as part of a broad examination of the fishery resources in Minas Basin and the impacts that may occur from tidal power development in the inner Bay of Fundy.

Introduction

The American lobster, *Homarus americanus* (Milne-Edwards 1837) is found roaming the ocean floor from Labrador to North Carolina. Lobsters can be found from the low tide mark out to deep waters (e.g., Georges Bank, Bay of Fundy) but are generally fished close to shore in depths ranging from 1 to 30 m (Robichaud and Pezzack 2007). They gravitate to the cobble bottom where they can hide from predators in the crevices between the rocks and still capture food. Lobsters can also dig away sand and gravel from under a rock, making a tunnel or burrow that may be occupied by two or three lobsters of different sizes.

In the Bay of Fundy, mating occurs between July and September (Robichaud and Pezzack 2007) when the female lobster is in the soft shell state, which is shortly after larval release and molting. As many as 20,000 eggs (1 mm in diameter) are then released from the ovaries, fertilized and attached to the swimmerets on the underside of the abdomen. At this point, the female lobster is considered to be "berried."

Hatching of the eggs occurs in July and August (Robichaud and Pezzack 2007) and the planktonic larvae pass through four larval instars (4–10 weeks) within the upper 10 m of the water column. Towards the end of stage IV, they become negatively phototactic and settle to the bottom. During the first year of its juvenile life, a young lobster will molt about 10 times and reach a length of 2.5 to 3.8 cm. In preparation for molting, the lobster weakens the shell as the flesh reabsorbs some of the calcium that hardens it. During this time, lobsters seek out a rocky crevice or burrow for protection from predators. As lobsters grow, they molt less and less frequently and by the time they are market size (>82.5 mm carapace length) they generally molt only once a year. While the new shell is still soft, the lobster absorbs sea water and gains about 15% in size and 40–50% in weight (Robichaud and Campbell 1995). The new exoskeleton accommodates the lobster for a year or more as it grows flesh and gains weight.

In the Bay of Fundy (BOF) most lobsters mature between 95 and 109 mm CL (age 7–10 years), with male lobsters usually becoming sexually mature at smaller sizes than females (Robichaud and Pezzack 2007). Males grow faster than females, largely because females may go two years between molts when they are breeding. For the first few years, lobsters remain hidden in or near their shelter to avoid predation. As they approach adult size, lobsters are known to migrate seasonally to shallower waters in summer and deeper waters in winter (Robichaud and Pezzack 2007). These movements may amount to a few kilometers. In the Bay of Fundy, Gulf of Maine, the offshore regions of the Scotian Shelf and off New England, lobsters can undertake long distance migrations of 10s to 100s of kilometers (Campbell 1986; Campbell and Stasko 1985; 1986; Robichaud and Lawton 1997).

Lobster is Canada's most valuable seafood export, contributing as much as CAD 1 billion in export sales (Agriculture and Agri-Food Canada 2004). Commercial landings for lobsters in Nova Scotia in 2005 totalled about 21,000 metric tonnes (MT) live weight. The total catch of lobsters in the Maritimes region was approximately 30,000 MT (Figure 1). Nova Scotia contributes the highest dollar value when it comes to lobsters from the Maritimes—an estimated CAD298 million out of a total CAD440 million (Fisheries and Oceans Canada 2008).

The waters of Atlantic Canada are divided into 41 Lobster Fishing Areas or LFAs . Each area has its own season, varying in length from eight weeks to eight months (Agriculture and Agri-Food Canada 2004). The Bay of Fundy's lobster season spans an eight month period in four LFAs (Figure 2). The seasons are: spring–summer (May–July) and fall–winter (October–December).

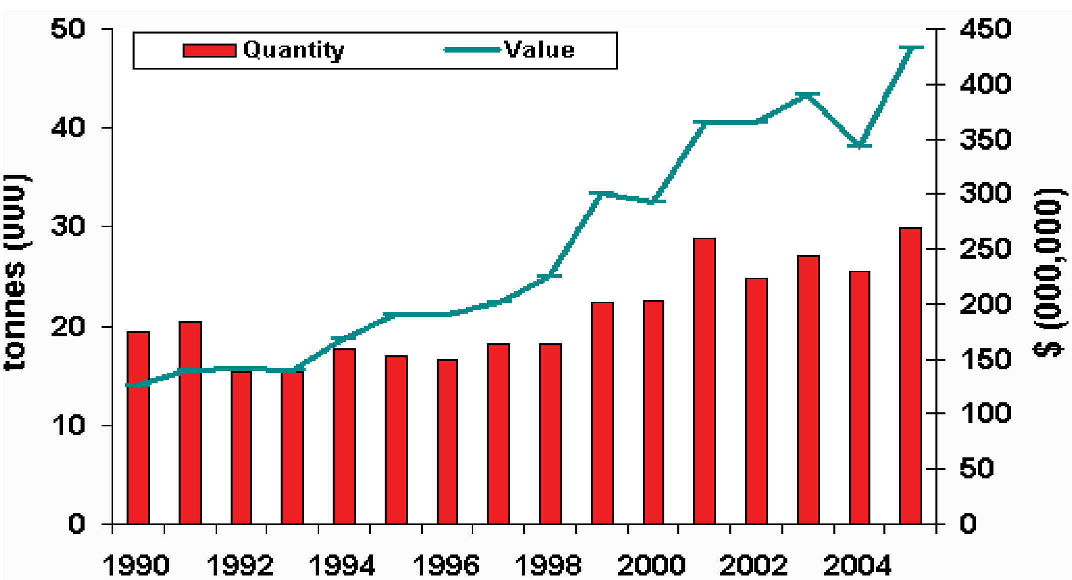

Figure 1. Maritimes Region lobster, landed quantities and values for 1990-2005 (Source: Fisheries and Oceans Canada 2008)

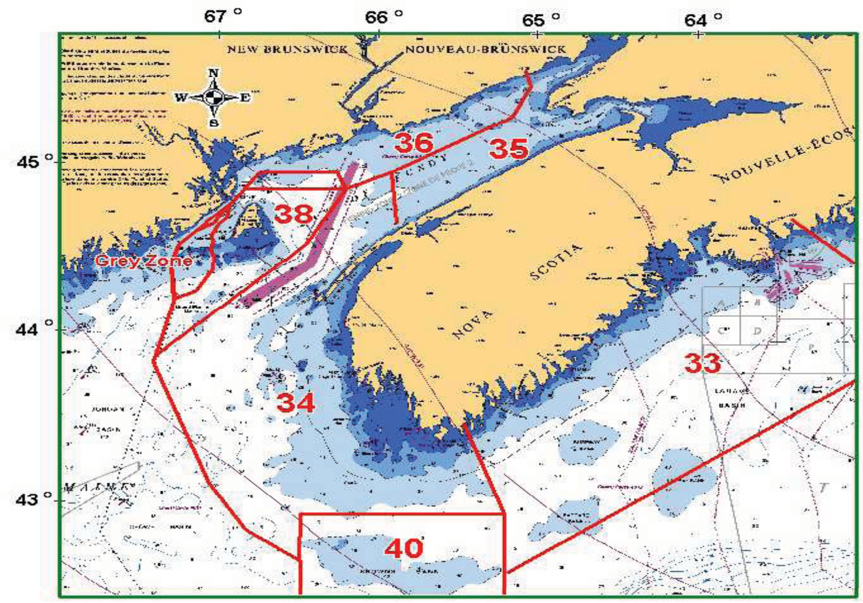

Figure 2. Bay of Fundy/ Gulf of Maine showing LFAs 35, 36, 38, the Grey Zone (LFA 38B) and adjacent LFA 34

Aim of Study

A lobster tagging study was conducted in 2008 to assess the lobster population of the Minas Channel and Basin and their movements near the location of the proposed demonstration site in the Minas Passage. The work addresses lobster population characteristics and movements in relation to potential impacts of the demonstration of tidal in-stream energy conversion (TISEC) devices.

Methods

To collect population and lobster movement data on both small and large lobsters, field work involved a tagging program during the summer and fall of 2008. DFO scientific research permits were obtained for both periods. Lobster fishers were informed of the study via posters, personal contact, emails, mail-outs, and via newsletter.

The tagging program was conducted during the summer and fall seasons:

- June–July (commercial fishing season): tagged and released 1,191 lobsters from Minas Basin and Minas Passage (5 days) and off Halls Harbour (3 days). Tagging was limited to small (sub-legal size) lobsters and egg-carrying (berried) females.
- October (prior to fishing season): tagged and released 1,442 lobsters from the middle of Minas Basin. Tagged lobsters included both commercial-sized lobsters and shorts. All tagging was conducted from a chartered fishing vessel (2 days) from Parrsboro.

Lobsters were measured for carapace length (CL) and the sex and stage were recorded. During the spring–summer season (pre-molt), only shorts (lobsters < 82.5 mm CL) and berried (egg-bearing) females were tagged and released. A sample of two wharf totes of approximately 200 market lobsters (> 82.5 mm CL) for landing were measured and sexed when opportunity allowed (Table 1). During the fall (post-molt and pre-fishing season) sampling trips, all captured lobsters were measured, sexed, tagged, and released.

Tags used were Floy yellow, plastic, streamer tags with a printed ID number and return address on each tag so that each lobster could be identified from tag returns. The tags were inserted into the flesh on the top of the abdomen between the second and third segments. Floy streamer tags were adopted because they have excellent retention (98%), cause minimal harm to lobsters, and remain in place past at least 1 molt.

Instantaneous total mortality (Z) was determined by assuming that 5 mm carapace length increments represented one year of growth. We selected this measure since the post-molt mean size of market lobsters in the Minas Basin population changed by approximately this length as short lobsters from the pre-molt period (spring–summer) entered the market population during the post-molt (fall) period, before exploitation by the fishery.

Most lobster fishers in the region participated in the tag return program. They were mailed or brought into the Estuarine Centre in exchange for a $5 per tag reward. In some cases, information from 1 or 2 tags was telephoned in by fishers or DFO personnel. Fishers were requested to provide information on date and place of capture but, unfortunately, specific details were not always provided by all fishers who submitted lobster tags. This factor, and challenges in maintaining position of the lobster boat in the field while tagging was underway, limited the analysis of distances traveled by lobsters to general patterns of movement (kms).

Distance of lobster movement was estimated as the straight line distance from point of tagging to point of recapture in kilometers (km). Exploitation (μ) was determined as:

Date Sampled	**# Tagged**			**Ratio**	**Mean Length (mm CL)**		
(Pre & Post Molt)	**Male**	**Female**	**Berried**	**M:F**	**Male**	**Female**	**Berried**
June 9 2008	45	41	30	0.91	74.5	76.8	100.3
June 10 2008	71	90	44	1.27	25.8	75.8	98.3
June 13 2008	88	73	50	0.83	75.8	76.4	100.9
June 25 2008	67	58	41	0.87	77.8	77.0	99.6
June 27 2008	45	62	23	1.38	77.9	77.8	97.3
July 23 2008	45	42	4	0.93	77.2	77.9	103.5
July 28 2008	100	72	4	0.72	84.5	79.6	105.5
July 30 2008	62	33	1	0.53	85.3	79.8	100.0
October 5 & 6 2008	854	541	47	0.63	87.3	84.1	95.3
All Tagged Pre-Molts	523	471	197	0.90	72.3	77.6	100.7
All Tagged Post-Molts	854	541	47	0.63	87.3	84.1	95.3

Table 1. Compilation of data on tagged lobsters collected in both the spring–summer (pre-molt) and fall (post-molt) seasons, by specific dates, and mean carapace length (CL)

$$\mu = r/m$$

where:
μ = exploitation rate
r = total number of tags returned from fishers and
m = total number of lobsters tagged

Results

Ten days were spent sampling on fishing vessels, 8 during the spring–summer season (June and July) and 2 during the fall (October; Table 1). During these trips, a total of 971 traps were hauled (97.1/d). Daily catches ranged from 400–500 kg and the mean catch/trap of market lobsters was 4.6 kg. On average, 4.7 lobsters were tagged per trap. During summer, catch per unit effort (CPUE) was 2 times higher in Minas Basin than in the Bay of Fundy off Halls Harbour (Figure 3). CPUE in Minas Basin was 2–3 times greater during October than during June (Figure 3).

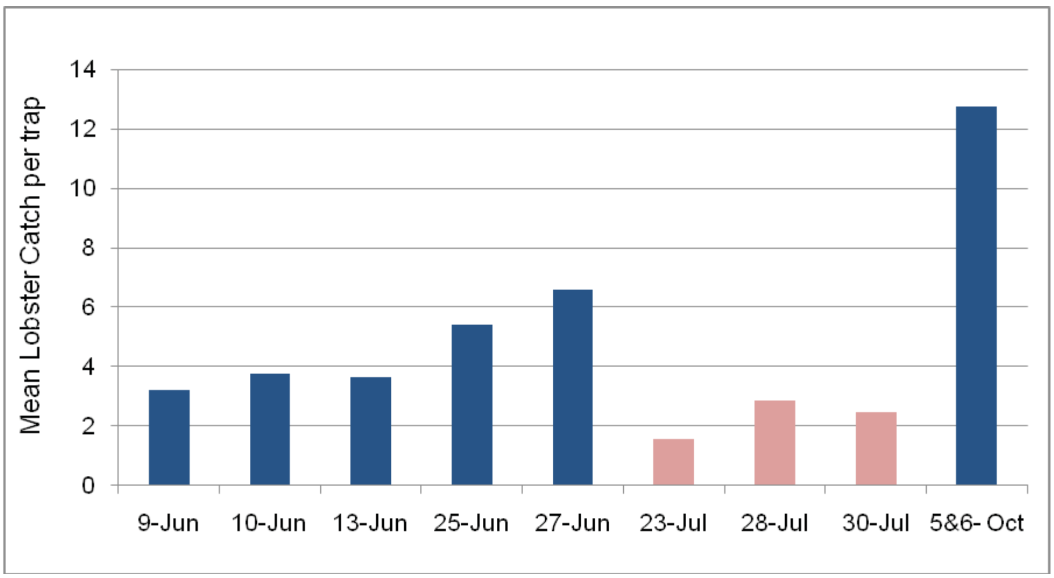

Figure 3. Catch (number) per unit effort (trap) of combined male and female (berried and non-berried) lobsters in the Minas Basin (blue) and off Halls Harbour (pink)

Total Tagged (Pre-Molt)	1191
Total Tagged (Post-Molt)	1442
Grand Total Tagged	2633
Overall Mean Carapace Length (Pre-Molt)	83.55 mm
Overall Mean Carapace Length (Post-Molt)	88.93 mm

Table 2. Total number and carapace length (mm) of lobsters tagged in both the pre-molt and post-molt seasons

A total of 2,633 lobsters were measured and tagged: 1,191 during summer and 1,442 during fall (Table 2). The carapace length (CL) of lobsters captured during the summer season ranged from 45 - >130 mm, and during the fall season, CL ranged from 50 - >130 mm. In summer, the average CL of market lobsters (>82.5 mm) was 97 mm, the mean CL of berried females was 101 mm, and the mean CL of the shorts (CL, <82.5 mm) was 76 mm. During the fall season the average CL of market lobsters, berried females and shorts, was 93.3 mm, 95.3 mm and 76.5 mm, respectively.

Short lobsters tagged during summer ranged from 45–84 mm CL (Figure 4) and the M:F ratio was approximately 1:1 (Figures 4 and 5). Market lobsters sampled during summer ranged from 85 to 130+ mm CL (Figure 6) and the sex ratio was dominated by females. Lobsters tagged during fall (post-molt) ranged from 50–130+ mm CL (Figure 7). The fall sex ratio (M:F 1:0.63) was dominated by males. The inclusion of 82.5–84 mm CL lobsters in the short category was because fishers allowed a 3 mm CL error due to the asymmetry of carapace length (shorter on one side than the other) to avoid landing any lobsters that could be considered short.

A total of 244 berried females were tagged and released during the study. Almost 4 times as many berried females were captured during the summer season than during the fall season (Table 1), which was probably because of larvae release during August and September. During the summer season the mean CL (100.7 mm) and range of CL of berried females was greater than during the fall (mean CL = 95.3 mm) (Table 1; Figure 8).

Mortality

Since the first few length classes (under 80 mm CL) lacked true representation in the population due to possible escape through the trap vents (Figures 4, 6 and 7), these were excluded when determining mortality rates (Ricker 1975). Estimated total instantaneous mortality (Z) during the summer season was 1.04 for males and 0.77 for females (Figure 9). Total instantaneous mortality for males during the fall season was 0.78 and for females, 0.85 (Figure 10).

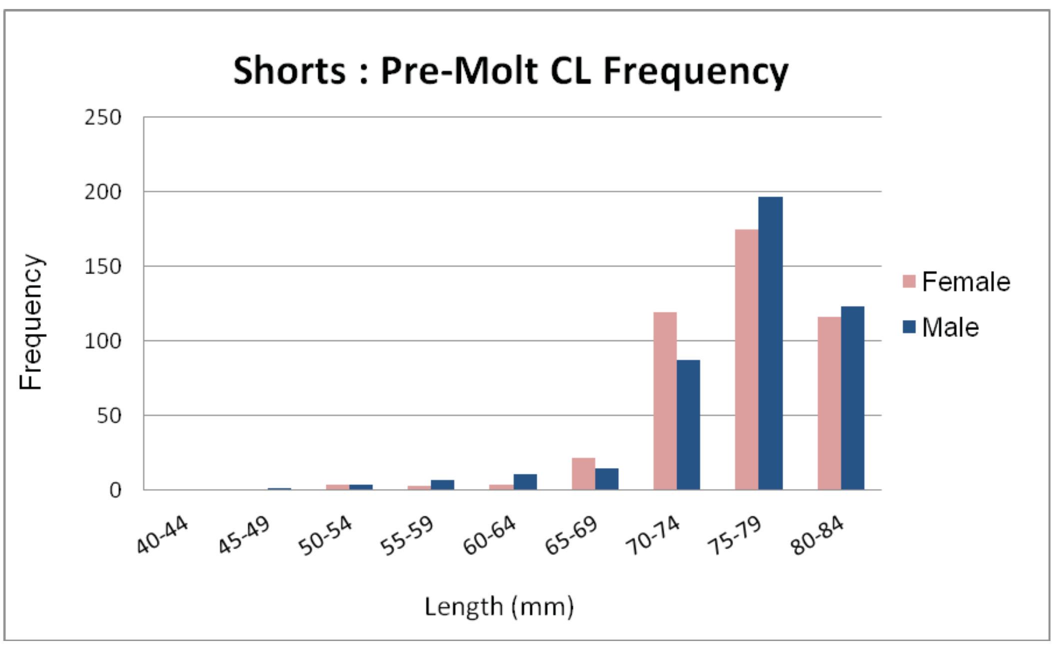

Figure 4. Carapace length frequency of male and female short lobsters during spring–summer (June–July), grouped by carapace length, in 5-mm size classes

There was a significant increase in the CPUE during the fall period (October, Figure 3) due to shorts entering the market population and therefore not able to escape through the trap vents. It should be noted that catch and effort data for the Minas Basin/Passage and the site off Halls Harbour in the Bay of Fundy, cannot be extrapolated to the entire region.

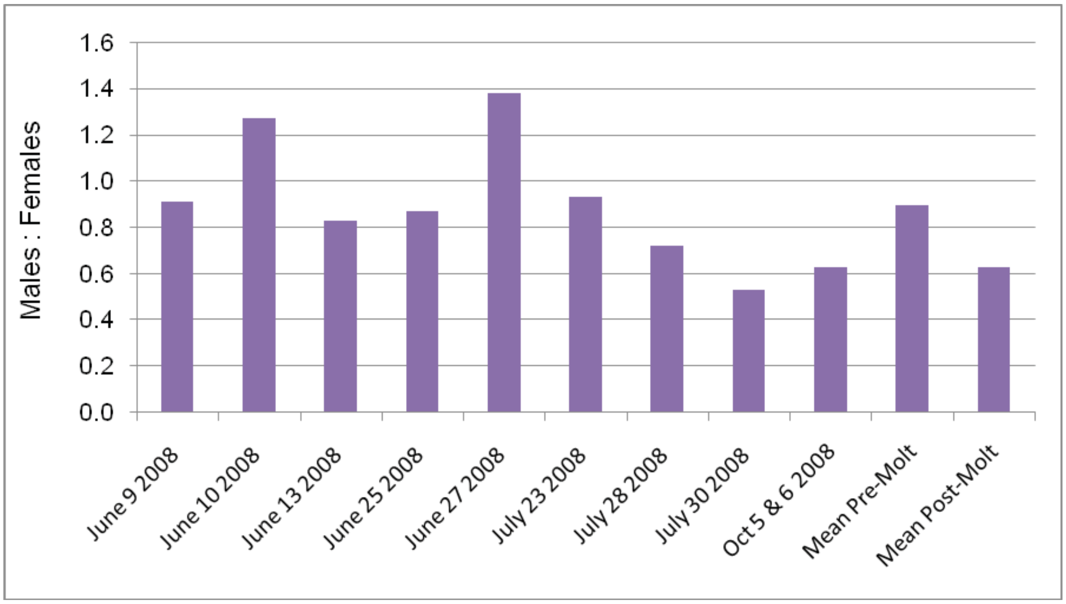

Figure 5. Sex ratio of males:females (berried and non-berried) for spring–summer and fall seasons, including the mean ratio for each season

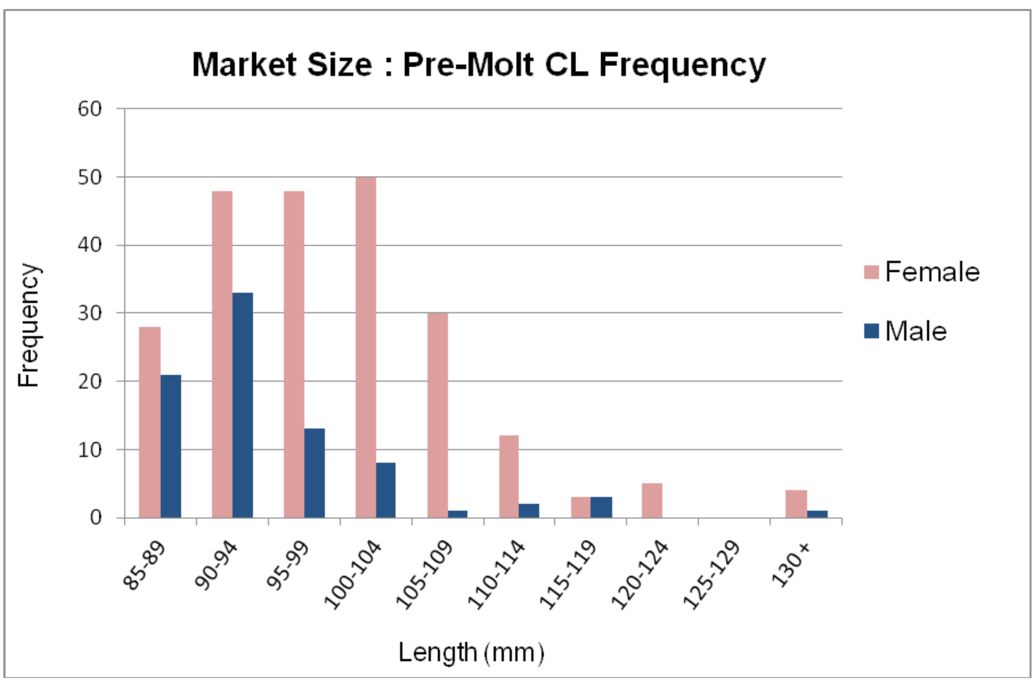

Figure 6. Length frequency of market size male and female lobsters during spring–summer (June–July), grouped by carapace length, in 5-mm size classes

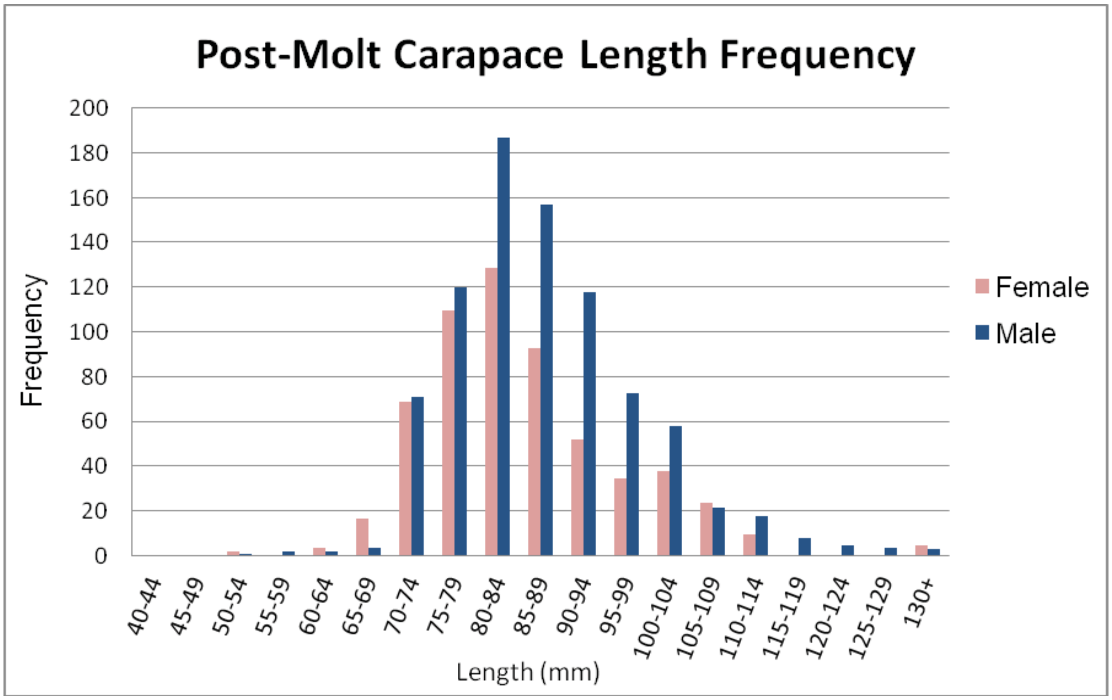

Figure 7. Length frequency of male and female lobsters during fall, grouped by carapace length, in 5-mm size classes

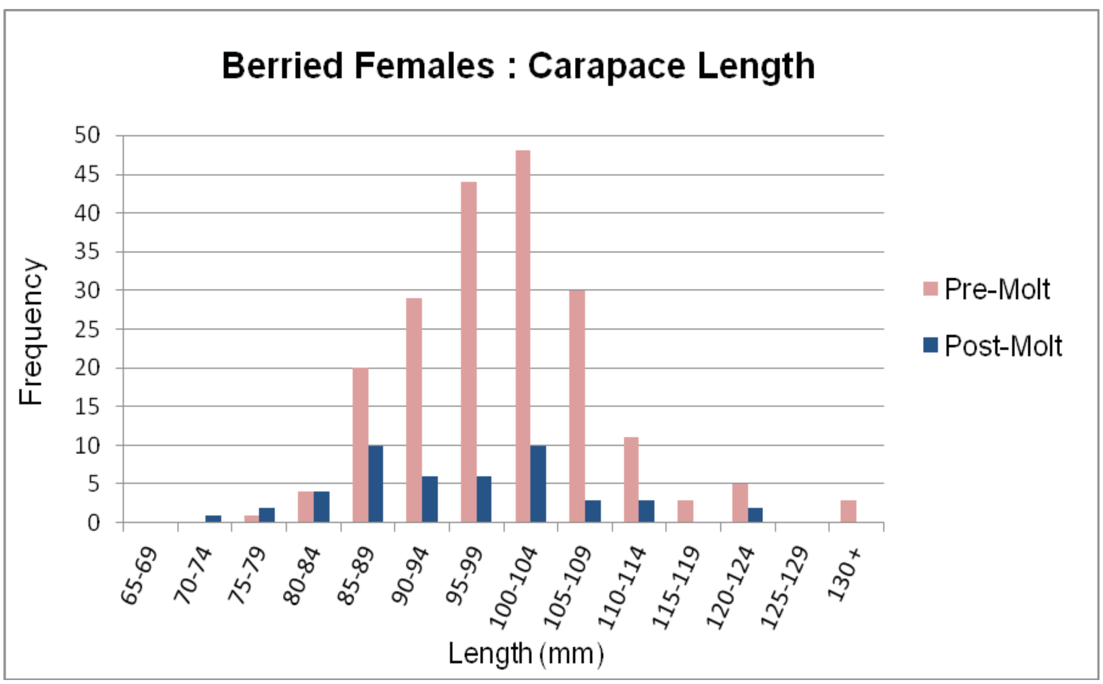

Figure 8. Length frequency of berried female lobsters during the spring–summer (pre-molt) and fall (post-molt) seasons grouped by carapace length, in 5-mm size classes

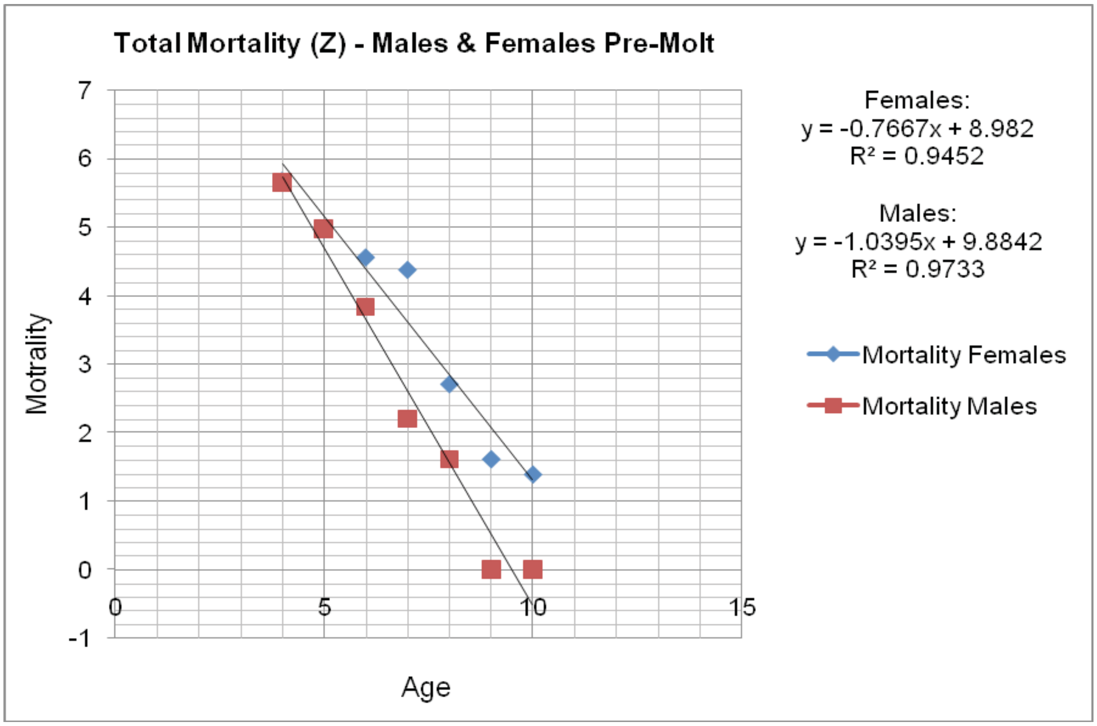

Figure 9. Total instantaneous mortality (Z) of males and females in summer (pre-molt) season

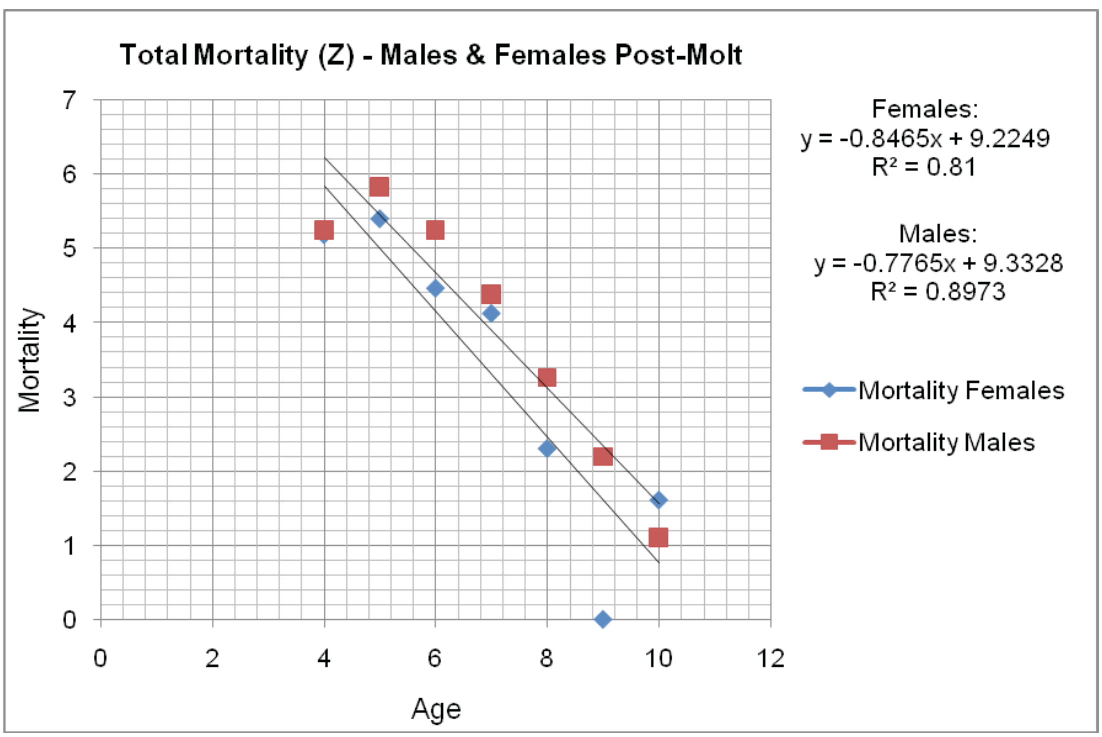

Figure 10. Total instantaneous mortality (Z) of males and females in the fall (post-molt) season

Tag Returns

In this study, lobsters from both the spring/summer and fall tagging periods were recaptured. As of March 31, 2009, 395 tags were returned by fishers for an estimated exploitation rate (μ) of 15%. However, we believe this to be an underestimate of the exploitation rate as several fishers reported observing lobsters with tags that they did not remove and return.

Thus far, lobsters tagged inside Minas Basin have shown little movement and none were recaptured outside the Basin. There has been no evidence to date of migration of lobsters through the Minas Passage. But one lobster, tagged off Halls Harbour, was recaptured off Digby Gut, a movement of approximately 200 km.

Discussion

Catch per unit effort (CPUE) clearly varied during the two fishing periods as a function of lobster abundance relative to molting and fishing pressure. We observed the highest CPUE in early October just prior to the fall lobster fishing season after the late summer molt and the entry of a new cohort of short lobsters into the market population and before exploitation began. Mortality rate of males and females in the pre-molt period indicated that males had higher mortality, presumably due to the release of berried females, but during the post-molt period male and female mortality estimates were almost the same.

Population characteristics of the Minas Basin lobster stock were similar to past studies (Robichaud and Pezzack 2007). There was a wide range of sizes in the market catch (82.5 - <130 mm CL) with an abundance of large lobsters (+90 mm CL) and berried females. Short lobsters, although probably underrepresented because of escape through trap vents, were abundant indicating there is still excellent recruitment occurring in the Bay of Fundy and Gulf of Maine lobster stock (Wahle and Steneck 1991; Robichaud and Pezzack 2007)

In this study, tagged lobsters from both the pre and post-molt periods were recovered. As of late March 2009, there was a 15% return of tags. Thus far lobsters tagged in the Minas Basin have demonstrated limited movement. Discussions with lobster fishers suggest that there is seasonal movement inward in Minas Basin toward Cobequid Bay during spring–summer, and outward movement toward Minas Channel during autumn. The fishers explained that they moved their fishing efforts inward and outward during the two seasons to exploit the region of maximum lobster abundance. Unfortunately, limited tag return location data (i.e. not all fishers provided this information) made it difficult to define movement patterns.

Lobsters tagged off Halls Harbour, however, dispersed much farther, with one captured as far as the Digby Gut. Long-distance movement of tagged lobsters is well known in the Bay of Fundy–Gulf of Maine (Campbell and Stasko 1986; Robichaud and Lawton 1997). Further tag returns in 2009 may continue to show this pattern of lobster movement in the inner Bay of Fundy. We expect to receive additional tags and will report on the results as they become available.

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TIDAL ENERGY DEVELOPMENT: DEVELOPING A CONCEPTUAL FRAMEWORK FOR INTEGRATING ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACT INFORMATION FOR ENVIRONMENTAL MANAGEMENT DECISIONS, WITH PARTICULAR REFERENCE TO THE LOBSTER FISHERY IN THE UPPER BAY OF FUNDY

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Abstract

Nova Scotia is moving ahead to develop the tidal energy resources of the Bay of Fundy using a new technology called tidal in-stream energy conversion (TISEC). As there has been no previous experience with TISEC operation in the Bay of Fundy, there is no foundation on which to evaluate impacts or to develop indicators for monitoring and assessment. What is currently understood of TISEC socio-economic and environmental impacts is based largely on impact predictions. This study proposes a conceptual framework based on concepts from the National Research Council (1990) to develop an effects monitoring program, collect appropriate impacts and research data and integrate data into the environmental impact assessment decision process. An approach was suggested to identify and prioritize potential TISEC project interactions with environment and socio-economic components over the project lifecycle. Potential effects of TISEC development and operation on the lobster population and fishery were selected for indicator development. Management questions and an adaption of a Pressure-State-Impact-Response model (OECD 1993) were used to identify indicators and indices to monitor potential changes in lobster populations and the fishery. Recommendations emphasize the importance of a long-term monitoring program to assess development impacts over the project lifecycle, the need for incremental TISEC development with approval to proceed to the next phase based on evidence that no significant adverse impacts have occurred, and careful assessment of capacity to directly scale short-term monitoring results to a commercial level development. Implementation of the recommendations made by this study and reports by, Jacques Whitford (2008) and NS Department of the Environment (2008) is considered essential in addressing public and community concerns relating to implications of TISEC development to the Bay of Fundy ecosystem and its lobster fishery.

Introduction

Globally, tidal in-stream energy conversion (TISEC) energy technology is in its early stages of development. Globally, few prototypes have been tested under natural conditions or for an extended period of time. Approximately 25 full scale or near full scale prototypes are undergoing short-term sea trials (SEI 2006) in various locations. However, monitoring results are not yet available. Current anticipation of impacts is based on single prototype device testing over short timeframes (Ball 2002) and these are undergoing sea trials elsewhere. To date, there has been no demonstration of multiple devices on a commercial scale to assess potential short-term or cumulative environmental or socio-economic impacts on land or to the marine environment or to determine whether such effects are additive, synergistic or antagonistic. Results of these trials may not necessarily be relevant to the Bay of Fundy. It is also not known if monitoring results of single demonstration units can be scaled to multiple unit commercial developments operating over the long term. The lack of previous demonstration or environmental impact assessment experience with TISEC operation in the Bay of Fundy means that there is no related information upon which to assess impacts, guide the design of a monitoring program, or select indicators appropriate to the Bay. Approval in Nova Scotia to move forward with full-scale commercial TISEC development will require proof that single prototype devices and incremental additions of turbines do not result in significant negative environmental or socio-economic impacts. A monitoring program with an appropriate selection of indicators is needed and presents a challenge given all the unknowns.

The area selected for study was the primary TISEC project area—the Minas Basin which includes Cobequid Bay, the Minas Basin, Southern Bight, the Minas Passage, the Minas Channel as the project area. Two key project–environment interactions were chosen for indicator development: 1) environmental effects of TISEC energy extraction on the lobster population abundance and distribution resulting from potential changes in tidal currents, sediment distribution patterns, and habitat; and 2) socio-economic impacts of TISEC development and operation on the lobster fishery and surrounding communities. The specific research questions were:

1. What are the key components of a monitoring program to measure changes in socio-economic and environmental conditions from TISEC operation?
2. What kind of information is required for effective environmental management decisions related to the development of tidal energy in the upper Bay of Fundy?
3. What are the key components of a framework to guide the inclusion of socio-economic and environmental impact information into management decisions?

In view of the current proposals for TISEC development in Nova Scotia, this study: a) identified types of information considered essential for environmental impact assessment; b) identified potential environmental and socio-economic-TISEC interactions over the project lifecycle, selecting interactions involving the lobster population and fishery for further study; c) examined potential impacts of TISEC development on the lobster population and fishery; d) identified potential environmental and socio-economic potential indicators to monitor changes in the lobster population and fishery to address specific management questions; and e) developed a conceptual model for the design of an effects monitoring program and to integrate monitoring information into the environmental impact assessment (EIA) decision process. The full study is reported by Hinch (2008). This paper gives highlights.

Methods

A literature review was conducted to provide background information on ecological and socio-economic conditions and issues of concern in the Minas Basin and to identify and prioritize anticipated tidal project environmental and socio-economic effects/interactions over the project lifecycle. Key predicted/proposed environmental and socio-economic interactions involving the lobster population and fishery were selected for indicator development. A Pressure-State-Impact-Response model adapted from OECD (1993) was used to identify potential TISEC impact scenarios for the lobster fishery and population as the basis for identifying indicator indices or categories. A series of management questions related to the impact scenarios were posed to address needs for baseline[1] and impact data. A selection of indicators was chosen from the literature for each indicator category/indice in response to management questions as the basis of a lobster population and fishery monitoring index. A conceptual effects monitoring framework was adapted from NRC (1990) to identify next steps to ensure that current baseline information, research and effects monitoring data are factored into the EIA decision process.

[1] Baseline is defined as the "original (unimpaired by man) environmental or ecological conditions set at some arbitrary time. In the context of environmental effects (impact) monitoring 'baseline data' characterizes environmental conditions prior to project development against which subsequent changes following development can be detected through monitoring" (Beanlands and Duinker 1983).

Results

Information Sufficiency, Requirements, and Sources for Environmental Management Decisions

Five kinds of information are needed for decision purposes relative to TISEC development. These include: 1) accurate measurement of the tidal energy resource; 2) knowledge of Bay of Fundy baseline conditions (biological, physical, socio-economic); 3) knowledge of project development site and reference site conditions and characteristics; 4) knowledge of project-environment interactions; and 5) monitoring effects of TISEC devices under natural Bay of Fundy conditions over the project lifecycle.

Information for decisions relating to TISEC development must be derived from three primary sources: 1) the synthesis and collation of existing environmental and socio-economic information to establish the baseline condition; 2) research to identify and address information gaps; and 3) monitoring of TISEC devices operating under natural Bay of Fundy conditions to identify/verify and assess impacts, engineering design performance and cost predictions and to assess cumulative environmental and socio-economic change resulting from incremental additions of TISEC devices over time.

Components of a Monitoring Program

Management Questions

Environmental management questions should consider both short-term and long-term/cumulative changes from energy extraction on lobster sustainability and baseline conditions. Questions to assess short-term impacts relate to local effects of small numbers of TISEC devices on lobster abundance, distribution, health, migration, reproductive capacity, settlement, recruitment, distribution/abundance of predator prey species, avoidance and attraction responses to TISEC devices. Questions also relate to potential changes in physical parameters including sediment distribution, suspension load, seabed morphology, and water column characteristics. Management questions for long-term environmental effects should consider: a) cumulative effects of multiple devices operating in the Minas Passage on the lobster population; b) potential cumulative effects on lobster of other activities occurring in the same area; and c) cumulative effects of TISEC operation on natural processes (e.g., tidal currents, water levels, sedimentation, hydrodynamics), habitats, and consequent lobster movements and migration to/from the project area in response to these changes. A key question is whether lobsters can withstand effects of multiple stressors effects, including the effects of climate change (e.g., potential changes in prey species, invasive species), fishing pressures, noise and electromagnetic resonance emissions from TISEC operations.

Similarly, socio-economic questions relate to both short-term and long-term effects of TISEC operation on lobster fishery sustainability. Short-term questions focus on baseline fishery characteristics (e.g., employment, landings, fishing effort/efficiency, market demand/supply, local economic effects, management practices, and current socio-economic wellbeing of fishers and coastal communities). Long-term cumulative effects questions relate to potential cumulative changes in baseline socio-economic conditions (e.g., social well-being, quality of life, fishery income), as incremental additions of TISEC devices increase the size of the project area and potentially the size of the fishery exclusion zone. Questions also relate to the ability of the lobster population to adapt to changes in benthic habitat, the extent to which lobster move from the project area/exclusion zone to zones accessible to the fishery, and the ability of the fishery to adapt to possible fluctuations in stock availability with TISEC project area expansions. Examples of environmental and fisheries management questions are included in Tables 1 and 2.

A. Short term – Changes to Baseline Conditions

1. What is the current stock abundance and distribution of lobsters in each segment of the Minas Basin?
2. What is the size structure of the lobster population within the Minas Channel, Minas Passage and Minas Basin?
3. What is the status of health of the lobster population?
4. What are the migratory patterns of lobsters in the Minas Channel, Minas Passage and Minas Basin?
5. What is the current reproductive capacity of the lobster population? Where are breeding females located, spatially and temporally?
6. What is the level of recruitment for lobster populations in the Minas Basin area and their range of distribution?
7. What is the impact of energy extraction on habitat substrate in the upper Bay of Fundy?
8. What are the current tidal current circulation and sediment suspension, distribution, settlement patterns, in the upper Bay of Fundy (modeling)? How do these patterns affect lobster productivity?
9. What are the current sediment characteristics, suspension load, seabed morphology, and turbidity parameters in the upper Bay of Fundy?
10. What is the current chemical composition of the water and temperature and salinity profile? How do these characteristics affect lobster distribution and health?

B. Short term – Changes from TISEC Operation

1. How much energy is removed from the tide from the operation of a single device?
2. What level can be extracted without causing change in lobster habitats leading to reductions in lobster abundance, and productivity?
3. To what extent does energy extraction effect local tidal current flow, speed, and direction (e.g., vortices, wake effects, turbulence, wave reflection or defraction)?
4. How does TISEC operation affect larval dispersion and settlement?
5. How does energy extraction effect local sedimentation processes (scour effect, erosion around the device)? Do these eroded areas provide appropriate habitat for lobster adults and do adults aggregate in these areas?
6. How does TISEC operation change local sediment dynamics (change in suspended sediments, seabed characteristics, movement, and sediment type)?
7. How does TISEC operation alter the quality of the water column?
8. How does short-term TISEC operation affect lobster movement/migration (avoidance or attraction response)?
9. What is the survival rate of larvae and post-larvae (stage 4) moving through the TISEC device?
10. What is the collision risk for lobster predator and prey species?
11. What is the effect of sound generated by TISEC operation on lobster migration and health?
12. Does the presence of the device provide a sanctuary effect to offset any loss in lobster habitat from substrate changes due to tidal energy extraction? To what extent do TISEC devices contribute to lobster productivity in providing an artificial reef or refuge for fish and lobster populations?

Table 1. Environmental management questions relating to the lobster population (Source: Hinch 2008)
(continuted overleaf)

C. Long-term TISEC Operation – Change to Baseline Conditions

1. How do baseline conditions (noted above) change over time?
2. What are the impacts of TISEC operation on the water column (e.g., stratification, upwelling, light penetration and ultraviolet exposure) on larval survival?
3. What are the impacts of TSEC operation on lobster predators and lobster prey (collision risk)?
4. What are the impacts of bycatch by the lobster industry of key prey species, e.g., rock crab or predator species on the lobster population?
5. To what extent do new depositional patterns contribute to increased lobster production by creating new habitat for the lobster and benthic community?
6. How will TISEC operation affect lobster predator and prey abundance over time?
7. What constitutes an acceptable and unacceptable level of change to environmental and biological conditions/characteristics of the Bay of Fundy?

D. Cumulative Impacts from TISEC Operation and Other Stressors

1. How will the establishment of an exclusion zone in the project area, impact lobster population numbers over an extended period of time?
2. How do current flows and directional patterns, wave and sediment dynamics (suspension, movement and distribution, re-deposition) change with increasing numbers of TISEC devices in operation and what is the impact on lobster health, productivity, and survival?
3. What is the long-term impact of changes in water quality (from discharges of hydraulic fluid and oil spills and noise from TISEC operation on lobster health & productivity?
4. How does energy extraction affect upwelling and stratification in the Minas Basin area and what is the impact on the lobster productivity and recruitment?
5. How are invasive species populations changing in the upper Bay of Fundy (distribution, abundance, diversity) and how will they impact the health and productivity of the lobster community?
6. How will TISEC operation contribute to greenhouse gas reductions & coastal productivity?
7. How will climate change (temperature change, ocean acidity levels) affect marine resources, ocean circulation, coastlines, trophic structures, and in turn lobster productivity, predator-prey relationships and recruitment?
8. How will energy extraction causing reduced turbulence and turbidity levels affect stratification, light and nutrient supply in the upper Bay and what will be their impact on benthic community and lobster production?
9. How will the lobster populations abundance and distribution change as a result of the combined impacts of TISEC energy extraction and other development activities that contribute to change in physical processes (e.g., pollution in the water column, noise, circulation, sediment dynamics)?
10. What is the combined effect of all multiple stressors mentioned above (e.g., combined effects of pollution/MEQ, productivity, noise and EMR emissions, habitat disruption, increases/decreases in predator and prey species) on lobster productivity, migration, distribution, and survival?
11. What is the capacity of the lobster population to adapt to multiple stressors/impacts over time while maintaining overall health, integrity and function?
12. Is the lobster population sustainable? What actions will be taken to ensure sustainability?

Table 1. (Cont'd) Environmental management questions relating to the lobster population (Source: Hinch 2008)

AA. Short Term – Changes to Baseline Conditions

1. What is the current number of people involved in all aspects of the lobster fishery?
2. How many lobster fishermen and licensed boats are registered in the Minas Basin area, and how have these numbers changed over the past 20 years? Where are the home ports for these boats?
3. What levels of growth in the commercial and traditional lobster industry are projected over the next 20 years?
4. What are the current lobster landings (by weight and value) in lobster fishing area # 35 and within each fisheries statistical district surrounding the upper Bay of Fundy? (i.e., FSD 40,41,42,43,44)? Do these landings values accurately reflect actual population numbers?
5. Where are lobster fishing grounds located in the Minas Channel, Minas Passage and Minas Basin?
6. What is the current employment rate within the lobster fishery?
7. What is the average employment income and range for lobster fishermen?
8. What percentage of the income of lobster fishery households is derived from the lobster fishery?
9. How have landings changed over the past 20 years and how are they projected to change 20 years in the future?
10. How have lobster fishing effort and efficiency changed over the past 20 years?
11. What influence do fishing effort and efficiency have on lobster landings and change within the lobster population (to lobster biomass, recruitment) and to available stock?
12. What is the current market demand/supply ratio for lobster and how is this ratio anticipated to change over the next 20 years? What are the causes of this change?
13. What is the current export market value ($ and weight) and how is this anticipated to change over the next 20 years?
14. How have past development activities (particularly other fishery practices) affected lobster habitat, productivity and landings?
15. What are the patterns of lobster migration between the Minas Passage and Minas Basin? i.e., What percentage of the lobster population migrates from the Minas Passage into the Minas Basin to become available to the lobster fishery outside the exclusion zone?
16. What is the current and anticipated demand/need of the lobster fishing community for social services? Is the current level of service sufficient to meet requirements?
17. How do lobster fishermen feel about their current quality of life and social well-being?
18. What is the current contribution of the lobster fishery in the upper Bay of Fundy – relative to other fisheries? to the overall local economy?
19. What other existing or planned developments are having or are anticipated to have social and economic impacts on the lobster fishery in the project area?
20. How have past lobster management practices affected lobster habitat, and ultimately lobster stock abundance and the fishery?

Table 2. Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery (Source: Hinch 2008) (continued overleaf)

BB. Short Term – Changes from TISEC Operation

1. Does the presence of the TISEC device provide a sanctuary effect for lobster and if so, how does it affect lobster productivity and ultimately, lobster landings?
2. To what extent will the establishment of an exclusion zone affect access to lobster fishing grounds?
3. Will the exclusion zone affect the ability of lobster fishermen to provide a sustainable income and lifestyle for their families? If so, to what extent will landings and income levels change?
4. How will the exclusion zone affect boat passage between Minas Channel and Minas Passage?
5. How does the exclusion zone impact lobster fishermen's perception of their quality of life and social well-being, and attitudes toward social and development change in the community?
6. What employment opportunities might be available to fishermen within the TISEC industry? Would fishermen be willing to accept these positions if offered?
7. Can a negotiated agreement between the TISEC industry and the lobster fishery be struck to provide access for lobster boats to fishing areas (appropriate access points and schedule)?
8. How will the cost of housing, housing availability and affordability change with the influx of new residents associated with TISEC development? How will these changes affect the lobster fishing community?
9. To what extent will demand for goods and services change as a result of TISEC development? How will these changes affect lobster fishermen and the fishery?
10. To what extent will the price of goods and services change as a result of TISEC development? How will the price of lobster change?
11. How will the availability/supply of goods and services to the general and fisheries communities change as a result of TISEC development?
12. How will the presence of TISEC development activity change fishermens' perceptions of the visual quality/appearance of the sea landscape and in turn the quality of their lives?
13. What are fishermens' concerns/perceptions of the potential impacts of TISEC operation on lobster habitat, water quality, and ambient noise levels in the upper Bay of Fundy? on lobster predator and prey species?
14. What are fishermens' opinions on the appropriateness of TISEC technology design in terms of its capacity to cause/avert environmental impacts to fisheries, lobster resources, and to protect conservation/special designation areas in the upper Bay?
15. How will TISEC development change fishermens' perceptions of social well-being and quality of life in the lobster fishing community and for their own family? i.e., To what extent will TISEC operation affect their personal welfare, the health of their community, and their ability to maintain their culture and way of life?
16. Do fishermen believe that TISEC development will provide them equitable opportunity to maintain or enhance their income and lifestyle within the lobster fishery?
17. What are fishermens' attitudes toward potential social change within the general population and the lobster fishing community from TISEC development?
18. What changes are anticipated by fishermen to their own lives and fishing community from TISEC development? How would fishermen respond to these changes?
19. Are there programs, policies, and regulations in place elsewhere that have addressed access issues that might be applied in Nova Scotia? Is it possible to provide partial access to fishing grounds at specified times and locations?
20. What will be the effect of various levels of access on lobster landings?
21. To what extent does the exclusion zone itself lead to an increase in lobster productivity and lobster stock availability to the fishery?

Table 2. (Cont'd) Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery

CC. Long Term – Changes to Baseline Conditions

1. How have baseline conditions (noted above) changed between a short and longer period of TISEC operation?
2. What is the long-term effect of reduced fishing pressure in the exclusion zone on lobster stocks and landings?
3. How will lobsters respond to the reef effect created by TISEC devices (avoidance due to sound/EMR, attraction to fish communities or new habitat)? How will the reef effect lobster numbers?
4. How will TISEC energy extraction ultimately change habitat characteristics and quality for lobster settlement? How will habitat changes affect lobster abundance, distribution, and availability of stock in the upper Bay?
5. To what degree will the creation of an exclusion zone contribute to growth in the lobster population and fishery landings?
6. How will TISEC operation affect employment/unemployment rates and income levels in the lobster fishery?
7. How many lobster fishermen over time will exit the fishery as a result of the economic impacts of the exclusion zone?
8. To what extent will lobster migrating from the exclusion zone into the Minas Basin, contribute to lobster stock landings?
9. How will lobster fishermens'quality of life and social well-being change within the lobster fishing community and community at large, with increasing TISEC operational time and numbers of devices installed?
10. What is the capacity of the lobster fishery to adapt or recover from fluctuations in the lobster population/stock availability over time?
11. Does the presence of the TISEC device provide a sanctuary effect to the extent that increased productivity offsets any losses in lobster numbers from habitat disruptions due to tidal energy extraction?
12. What constitutes an acceptable or unacceptable level of change to the fishery?
13. To what extent will TISEC development will allow fishermen to maintain or enhance their livelihood within the lobster fishery?

DD. Long Term – Cumulative Assessment–Cumulative Changes from TISEC Operation

1. How will altered habitat affect lobster productivity, distribution, health, abundance, predator-prey relationships and the future availability of lobster to the fishery?
2. How will climate changes alter trophic structure, species presence, composition, abundance, density, and distribution in the upper Bay and what effect will these changes have on the lobster population? How will these changes affect the lobster fishery?
3. What is the combined effect of all multiple stressors (e.g., combined effects of pollution/MEQ, noise and EMR emissions, habitat disruption, increases/decreases in predator and prey species, fishing pressure/efficiency, climate change, invasive species, and other fishing practices, etc.) on lobster productivity, migration, distribution, survival and in turn, the sustainability of the lobster fishery?
4. How do cumulative changes from the commercial operation of TISEC farms, alter the perceptions of social, economic, and cultural well being and health of lobster fishing communities in the upper Bay of Fundy?
5. To what extent can an ecosystem and fishery recover following removal of tidal energy devices in the Bay of Fundy?

Table 2. (Cont'd) Management questions relating to potential socio-economic effects of TISEC operation on the lobster fishery

Selection of Indices and Indicators of Change

Selection of appropriate indices and indicators is essential in the design of a monitoring program that is capable of measuring current environmental and socio-economic conditions and changes over time and space. Six potential environmental indices were identified from Pressure-State-Impact-Response (PSIR) scenarios including: population abundance and stock status; environmental features/marine environmental quality (MEQ); resiliency; reproductive capacity/health; ecosystem interactions/effects; and sustainability. Also eight possible socio-economic indices were identified including: fishing pressure; human population demographics; lobster fishery characteristics; public service needs and availability; quality of life and social well-being; market condition; human resiliency or adaptive capacity; and management response/action. In total, over 75 potential environmental and socio-economic indicators were identified for 15 indices (Tables 3 and 4).

Key Elements of an Effects Monitoring Framework

In the absence of previous monitoring information, the challenge in understanding impacts from development over incremental development phases can be addressed through the collection of effects monitoring data obtained by testing/demonstrating prototypes and subsequent incremental additions of turbine devices operating under natural conditions in the Bay of Fundy. Key in obtaining impact data for decision purposes is the design of an appropriate effects monitoring program and information management framework that identifies information requirements, indicates where relevant information exists, how knowledge/information gaps can be filled, and how to organize and integrate information in a form useful for decision makers (Cicin-Sain and Knecht 1998). Figure 1 (based on concepts in NRC 1990) is a conceptual framework to develop an effects monitoring program, the results of which are integrated into environmental impact assessment and policy/regulatory development processes. The framework ensures that the design of the monitoring program considers both public and government issues and concerns and is based on the collection/collation and synthesis of baseline information and knowledge, original research to fill information gaps and respond to management questions, and the collection of TISEC effects monitoring data at all stages of the project including construction, operation and maintenance and decommissioning. Feedback loops provide opportunities for decision makers to refine/redefine program objectives and questions (i.e. to rethink the approach and objectives, or reframe management questions) as new information becomes available over the course of development (e.g., on interactions or impacts, requirement for more sensitive, additional indicators) or as program review or impact assessment requires change.

Discussion

There are many challenges in the development of a monitoring program for TISEC assessment in the Bay of Fundy. They inclued: a) the establishment of the baseline and reference condition; b) the separation of natural variability from TISEC development impacts; c) temporal and spatial monitoring; d) definition of the project boundary area; e) the selection of appropriate effects monitoring indicators; and f) the assessment of cumulative effects/change over the project development lifecycle.

a) Baseline and reference conditions. To assess development impacts, developers need to establish the baseline condition against which to measure change. The common practice is to choose a reference site or location which is undisturbed or in as natural a condition as possible which possesses the same /very similar environmental conditions as the selected development site. Theory suggests that differences in conditions between the reference and development sites over the project lifecycle provide a measure of impacts caused by development, provided that the reference site is not itself impacted by other kinds of human activities. Care specifically needs to be taken to ensure that the reference site remains as free as possible from human impact over the project lifecycle.

Key indices or features	Indicator	Issues addressed & management questions addressed (question #)
Population abundance/ stock status	- Landings - Population (density & biomass) - Spatial distribution - Source of recruits - Migration patterns - Catch rate - Fishing effort - Legal sizes (moult classes) - Berried female numbers - Pre-recruit numbers	- Measurement of stock size, availability, catchability, fishing effort, fishing efficiency - Community structure, status, spatial & temporal distribution, and change in stock size (Question #: A1,A2, A3, A4, A6, B1, B4, B7, B8, B9, B10, B11, C4, C6, C7, D1, D3, D9, D10, D11, D12)
Productivity	- Landings - Settlement densities - Spawning areas/aggregations (location, numbers) - Pre-recruit abundance	- Community structure, species abundance, potential for recruitment - Potential change in biomass & population growth (Question #: A6, A8, B1, B3, B4, B8, B9, B10, B11, C5, C7, D1, D3, D4, D5, D6, D7, D8, D10, D11, D12)
Environmental features/ Marine Environmental Quality (MEQ)	- Ambient noise and produced noise from TISEC operation - Sediment dynamics (suspension, movement, settlement) - Upwelling& stratification - Current circulation patterns (flow, speed direction) - Habitat quality & substrate character - Temperature - Salinity/conductivity - Turbidity and visibility - Chlorophyll *a* - Nutrients (P and N) - Bacteria - Dissolved oxygen - Lobster tissue examination (contaminants, bacteria, disease) - Extent of migration - Greenhouse gas emission levels	- Evaluation of habitat and environmental conditions necessary for population growth & development - Availability of suitable habitat for larval settlement & adult development - Species tolerance or sensitivity & response to change in physical and chemical parameters (Question #: A7, A8, A9, A10, B1, B2, B3, B4, B5, B6, B10, C1, C2, C5, C7, D2, D3, D4, D6, D7, D8, D9, D10, D11, D12)
Resiliency	- Maintain ability to reproduce; - Able to develop naturally; - Ability to either increase population numbers or return to a considered or established baseline population number	- Assess extent to which lobster population can recover from change resulting from multiple stressors and maintain structure, function, and integrity (Question #: D11)

Table 3. Suggested Lobster Population Index: indices and indicators for measuring potential change from tidal energy extraction (using information from Charles et al. 2002; FRCC 2007; DFO 2007a; DFO 2007b; and Wells 2005) (Source: Hinch 2008) (continued overleaf)

Key indices or features	**Indicator**	**Issues addressed & management questions addressed (question #)**
Reproductive capacity/ health	- Recruitment rate (settlement density) - Average size and proportion of each group of recruits - Size of stock of mature spawning lobsters - Size specific sex ratios - Maturity size - Reproductive success (health condition, distribution, and abundance of berried females) - Eggs per recruit - Interactions with adjacent lobster populations/recruitment - Disease incidence	- assessment of health status - prediction of reproductive success & potential growth in population numbers, and future stock availability - determination of the effectiveness of lobster management plans (Question #: A3, A5, A6, A10, B1, B10, C7, D3, D4, D5, D7, D8, D10, D11, D12)
Ecosystem interactions or effects	- Upwelling and nutrient fluxes - Stratification (water column) - Climate change (temperature, uv exposure, water acidity levels; habitat change) - Fishing practices - Abundance of predator/prey species - Loss of predator/prey species and lobster larvae from TISEC operation - By-catch of predators/ prey/invasive species - Cumulative impact/change (combined effects of multiple stressors, e.g., habitat change, pollution, fishing pressure, predator-prey relationships, stratification, light penetration, other industry impacts)	- assessment of the effects of other environmental factors influencing population abundance, distribution & growth - appreciation of the complexity of cumulative effects/changes resulting from multiple stressors (Question #: C3, C4, C6, D1, D2, D4, D5, D6, D7, D8, D9, D10, D11, D12)
Sustainability	- Sustained recruitment (source of recruits, migration patterns, pop. influx; connection to other populations); - Sustained stock abundance and biomass - Effective production (see productivity above) - Biodiversity (species richness, presence, abundance, & equitability) - Sustained abundance of prey	- assessment of the ability of the lobster population to maintain population abundance, reproductive capacity &health over time - assessment of the level of maintenance of ecosystem structure & function - determination of the effectiveness of lobster management plans - measurement of exploitation rates (see fishing effort, & ecosystem interactions or effects), the area of altered habitat & population capacity to maintain stock abundance and biomass (Question #: all)

Table 3. (Cont'd) Suggested Lobster Population Index

Key indices	**Indicator**	**Issues & management questions addressed (question #)**
Fishing pressure	- Landings (past, current and projected) - Trap hauls - Fishing location - Vessel size - Navigation equipment - Trap design - Fishing strategy - Sample at-sea size - Fishing efficiency (past, current, projected) - Catch rate/effort (catch per unit of effort) - Changes in extent of fishing area - Change in level of effort - Level of exploitation - Lobster habitat disruption/change - Bycatch of lobster by other fisheries - Bycatches of non-lobster species - Bycatches of lobster predator or prey species	- Changes in population numbers due to fishing effort/practices/efficiency (Question #: AA9, AA10, AA11, AA14, AA15, AA19, A20, BB1, BB20, CC1, CC2, CC8, DD1, DD2, DD3, DD4, DD5)
Pop. demographics	- Population numbers (lobster fishery pop., licensed # boats by port) - Population characteristics and projected changes from TISEC development - Population growth/change (Lobster fishery - historic and projected change) - Level of education - Skills development	- Change in community characteristics as a result of changes in development activity or economic growth (Question #: AA1, AA2, AA3, AA18, AA19, BB5, BB6, BB9, BB10, BB11, BB17, BB18, CC1, DD4, DD5)
Lobster fishery characteristics	- Lobster migration patterns - Available biomass - Recruitment rate - Available stock - Reef effect (on population numbers) - Annual catch rate/landings and historic trends - Location, number and extent of fishing grounds - Catch projections - Condition of the stock - Changes in composition of catch - Overfishing - Seafood quality - Level of incidental mortality or by-catch - Substrate impacted by dev't /fishing practices - Fishery policies, regulations, practices - Area of coastal waters off limits to the fishery - Effectiveness of lobster management programs & strategies - Overall health of the lobster fishery	- Historic, current conditions, and anticipated changes in health & abundance of the lobster stock - Effectiveness of stock management programs (Question # AA4, AA5, AA11, AA12, AA15, AA18, AA20, BB1, BB2, BB3, BB9, BB21, CC1, CC2, CC3, CC8, CC11, CC12, DD1, DD2, DD3, DD4, DD5)

Table 4. Suggested Lobster Fishery Index: Indices and indicators for measuring potential change in the lobster fishery from TISEC operation (Information derived from: Charles et al. 2002; FRCC 2007; DFO 2007a; DFO 2007b; Walmsley 2005; Lockie et al. 2005) (Source: adapted from Hinch 2008) (continued overleaf)

Key indices	**Indicator**	**Issues & management questions addressed (question #)**
Public service needs and availability	- Social services currently available and projected needs (e.g., education; medical/dental care; housing; social assistance; electricity; parks; fire; police; libraries; criminal justice; recreational/ cultural facilities; special care facilities; water & sanitation; transportation; telecommunication; & postal services)	- Assess current & anticipated demand for public services and capacity to meet needs (Question #: AA16, BB8, BB9, BB11,CC1, DD4, DD5)
Quality of life & social well-being	- Employment rate, income level and opportunities (in the lobster fishery, TISEC industry, or socio-economic & science research fields) - Percentage of household income derived from the fishery - Sustainable income and lifestyle - Cost of living (inflation) - Equitable employment opportunities (knowledge of the fishery; socio-economic & scientific research) - Population growth & social development character - Level of crime/disruptive behaviours - Perception of quality of the coastal landscape - Access to coastal & marine resources (acreage boat passage/access to fishing grounds) - Visual & operational appropriateness of technology design to minimize environmental & resource impacts - Perception of personal health - Perception of development impacts on the lobster population & fishery sustainability - Perception of unity & support within the community - Maintenance of cultural/heritage resources - Equitable distribution of benefits from development - Perception of social change from development - Contribution to society - Participation in community activities (volunteer; coastal &marine management programs) - Public awareness of coastal & marine development activity & coastal issues - Information access	- Assess community values & perceptions of current social conditions & future trends - Extent to which current & future social conditions meet social values, expectations, and needs (Question #: AA6, AA7, AA8, AA17, AA19, BB2, BB3, BB4, BB5, BB6, BB8, BB12, BB13, BB14, BB15, BB16, BB17, BB18, CC1, CC2, CC7, CC9, CC12, DD4, DD5)
Market condition	- Lobster price and price changes over time - Economic diversity/health of local retail & growth opportunities - Anticipated economic effects of other developments on the lobster fishery - Demand/supply ratio (past, current, projected) - Resource market values & growth potential (landings weight & dollar value) - Export market value &opportunity (lobster) - Housing (diversity, affordability, projected needs)	- Potential areas for market growth & development (Question #: AA12, AA13, AA18, AA19, BB10, CC1, CC12, DD3, DD4, DD5)

Table 4. (Cont'd) Suggested Lobster Fishery Index

Key indices	**Indicator**	**Issues & management questions addressed (question #)**
Human resiliency or adaptive capacity	- Ability to adapt/accept change, uncertainty, & risk - Capacity to learn from experience & crises - Ability to anticipate the unexpected - Capacity to alter activities/reorganize to minimize threat to livelihood - Willingness to learn/experiment with new approaches - Ability to collaborate, resolve conflicts, and share information	- Asses community/individual capacity to adapt to stress or change while maintaining health (Question #:BB3, BB6, BB9, BB10, BB11, BB12, BB14, BB15, BB16, BB17, BB18, CC1, CC4, CC5, CC6, CC7, CC9, CC10, CC12, DD1, DD2, DD3, DD4, DD5)
Management response/ action	- Management actions/responses to address: a) bycatch management b) level of species richness c) designation of protected areas and species d) conservation/protection of threatened species e) invasive species f) oil and hydraulic fluid spills and leakages g) lobster population sustainability h) lobster fishery sustainability i) loss of priority lobster habitat /habitat degradation j) extent of exclusion zone and level of access provided to fishing grounds k) levels of unemployment in the fishery - Measurement of level of public acceptance/satisfaction with management action: a) ability to balance TISEC energy development with a sustainable lobster population and fishery b) community perceptions of industry, TISEC development project and government action c) community perceptions of quality of life, social wellbeing, and health d) funding availability for research, e.g., - impacts of TISEC energy extraction/operation over time with increasing numbers of turbines on substrate, physical coastal processes, and natural populations & fisheries; - impacts of climate change and fishery practices/pressures on species composition, distribution, abundance & availability to the fishery; and e) funding grants given for NGO Bay of Fundy research	- Extent to which management actions/responses meet management policy, program, & regulatory goals, objectives, & targets - Effectiveness of lobster management programs & management actions/responses (Question #: BB2, BB3, BB7, BB19, BB20, CC1, CC2, CC7, CC11, CC12, DD1, DD2, DD3, DD4, DD5)

Table 4. (Cont'd) Suggested Lobster Fishery Index

b) Natural variability. Results of previous studies of ecological systems indicate that natural systems are complex, incompletely understood, oftentimes chaotic, and are constantly undergoing change (Wells 2005). Natural ecological change is subtle, gradual or abrupt, and varies both temporally and spatially (Wells 1999; Wells 2005). An assessment of TISEC development impact however relies/depends on the ability to separate natural ecosystem change from change resulting from TISEC operation and change resulting from combinations of effects (e.g., synergistic, antagonistic). Changes in conditions at both the reference and development sites would be measured over the project lifecycle and continually compared with original measurements at both sites. This practice should separate natural change variation (occurring at the reference site) from change due to TISEC operation (at the development site) as long as the reference site itself is free from further anthropogenic impact.

c) Temporal and spatial monitoring considerations. Areas close to the TISEC operations must be monitored over an appropriate time and space to define an appropriate baseline, the extent of natural variability and identify a reference site against which to measure change from development activities. In the absence of baseline information/data, it is important that developers and researchers take the appropriate time to establish baseline information through original research and the collection and synthesis of existing distributed information/data. Without this baseline, the assessment of impacts/implications of change is not possible. Once the baseline is established, long-term funding must be provided to allow monitoring to continue over an appropriate time and spatial area to evaluate the degree of cumulative effects and change through each sequential development stage.

d) Project boundary definition. The environmental boundary area for monitoring TISEC development effects on lobster populations can be defined by the locations of TISEC devices in the Minas Passage and lobster grounds, both bounded by the shorelines of the upper Bay. The definition of the area of socio-economic impact presents a greater challenge in that socio-economic influence typically extends well beyond the shoreline to include the Minas Basin watershed and the greater Bay. True socio-economic boundaries are influenced by both local and regional conditions. Given the international extent of the lobster export market, socio-economic influence extends across international borders. Within the context of the lobster fishery, the boundaries of current statistical district areas (STDs) could be used in defining socio-economic impact limits. These boundaries largely coincide with those of the Minas Basin watershed. It is important that proponent and regulatory agencies agree on an approach to define boundary limits for both environmental and socio-economic impacts evaluations.

e) Indicator selection. Key requirements of a monitoring program are that selected indicators provide data/information to respond to management questions, assess implications of shifts in baseline conditions (i.e. the range of variation in natural conditions) and monitor short-, medium-, and long-term cumulative interactions anticipated over the lifecycle of the project. Chosen indicators must have the capacity to measure impacts over three time scales: the short-term demonstration of prototypes/single units; medium-term operation of pre-commercial incremental additions of devices; and long-term operation of a commercial scale turbine array (involving potentially 200 or more devices in Minas Passage). Indicators used for short and medium monitoring timeframes may remain the same but the number and type of indicators to assess cumulative impacts may require adjustment to assess a broader array of interactions /impacts currently unknown and/or unanticipated.

f) Cumulative effects monitoring. Cumulative environmental and socio-economic implications of TISEC development may only become apparent as TISEC devices are added incrementally and operated over long periods of time. It is important that monitoring programs have the capacity to monitor and distinguish TISEC related changes from those resulting from other activities including other developments, the effects of changes in fishing practices, and effects of changes resulting from natural variability. As such, the monitoring program must have the flexibility to add indicators as needed to assess not only the implications of a broader number and range of natural and development changes over time and the potential interactions among these changes (e.g., synergistic, additive, antagonistic), but also the effects of incremental additions in numbers of operating TISEC devices. Cumulative effects modeling could be used as a planning tool to anticipate cumulative impacts and the appropriate indicators needed in later development phases.

The literature review indicated that many key management questions/issues pertaining to the development of TISEC as a new energy source are unresolved. Although each question is important and will likely be addressed through original research, effects monitoring, or the EIA process, six are of primary concern to the sustainability of the lobster population and fishery in the Minas Basin. The first relates to the amount of energy that can be extracted from the tides without detrimental effects on lobster habitat, abundance, productivity, and distribution in the upper Bay of Fundy. The second issue pertains to the lobster population capacity to adapt to multiple stressors/effects over time and sustain health, integrity, and function. Responses to these issues can be derived from continuous effects monitoring and assessment of cumulative changes to lobster populations and the fishery with development increments. The third issue concerns the need for a clear understanding of the baseline condition and what is considered to be a reasonable, acceptable and significant level of change for both lobster fishery and population from TISEC development. The fourth issue relates to the need to identify/establish the level of acceptable change in environmental and socio-economic conditions and the point in development at which proponents would be required to halt further additions of devices or to remove devices from marine waters to avoid undesirable significant cumulative effects. Socio-economic impact assessment will play a primary role in defining levels of public acceptance of change. The fifth issue relates to the need for research on lobster population size, recruitment in the Minas Channel, Minas Passage and Minas Basin, the extent of the project fishery exclusion zone, degree of fishery access to the exclusion area, and degree of lobster migration and movement from the exclusion zone to areas accessible to the fishery. Inaccessibility to lobster grounds is considered a primary socio-economic concdern. Both the TISEC industry and the lobster fishery serve valuable purposes and need to determine a way of working within the same marine area. Cooperation to resolve space use and resource access issues will ensure the sustainability of both industries. The final issue pertains to the concern that short-term results from demonstration projects may be used to determine whether development should proceed directly to commercial scale. Assumptions that results of short- and medium-level development can be scaled to commercial level must be avoided as impacts with incremental development may be additive, synergistic, exponential, or antagonistic. Incremental development should proceed only on the basis that scientific monitoring confirms that there are no significant adverse environmental and socio-economic effects.

Recommendations

A major focus of this study was the development of a conceptual framework for the integration of impact monitoring information into EI, policy and regulatory management decisions within the context of the upper Bay of Fundy. It is recommended that regulatory agencies and the proponent consider this framework as a guide to decision making, and policy and regulatory development. Within the context of this conceptual framework (Figure 1), recommendations suggest a series of actions to obtain available information, generate impact monitoring data to respond to management questions, and ensure that all relevant data and information on the Bay of Fundy are considered in the EIA decision process.

Overall, the study makes four key recommendations. First, the province of Nova Scotia should expedite development of a Nova Scotia integrated coastal and ocean management (ICOM) strategy to place TISEC within the context of other coastal developments and resource uses. While the Nova Scotia Provincial Oceans Network (NSPON) is in process of developing such a strategy (circa July 2008), it is recommended that the government provide all possible support to expedite this process, drawing on the expertise and broad base of knowledge in universities, coastal communities, and fisheries to assist/provide advice wherever possible. Second, regulators together with stakeholders should define acceptable levels of change in environmental and socio-economic conditions for each stage of TISEC development. Third, the effects monitoring program must have an appropriate number and kind of indicators for measurement of effects over the project lifecycle and allow the addition of indicators as needed to assess unanticipated effects and fill critical information gaps. Regulators and proponents should consider the conceptual framework and lobster population and fishery indicators identified in this study when designing the monitoring program. Fourth, proponents must be granted the appropriate time to establish the environmental and socio-economic baseline conditions and to select reference condition sites to separate natural ecosystem variability and changes from other activities from change resulting from TISEC development. Fifth, TISEC development should proceed cautiously on an incremental basis, with approval to advance to the next development level based on evidence that no significant negative environmental or socio-economic impacts have occurred. Assumptions must not be made that the results of short-term prototype demonstrations or medium scale development can be directly extrapolated to a commercial scale project. TISEC development must proceed as indicated by the province on an incremental and precautionary basis. Monitoring of impacts must take place with each incremental addition of devices as a condition of operation. Sixth, it is recommended that the 29 recommendations of the Jacques Whitford (2008) SEA and NSDOE (2008) reports including those specifically related to fisheries be implemented. Specifically these fisheries recommendations call for: the development of a geo-referenced database of fisheries activities and resources as a planning tool; a study of exclusion zone requirements, impacts, and mitigation strategies; and the development of protocols and procedures to ensure that fishermen and fisheries stakeholders are consulted and informed at each stage of the tidal development project. Recommendations also require the appointment of the OEER and its Advisory Committee to coordinate the design and implementation of a renewable energy research program and agenda. Important to cumulative effects monitoring, Jacques Whitford (2008) recommends that TISEC development proceed only on an incremental basis with continuous monitoring at each stage of deployment as a condition of operation. In NSDOE (2008) a commitment was made by the province to remove the turbines should adverse environmental impacts become evident.

Conclusion

The capacity to assess environmental and socio-economic changes resulting from TISEC development in the Minas Basin depends on the appropriate design and coordination of a research and monitoring program to establish the baseline and reference condition, assess impacts over the lifetime of the project, and respond to management questions. Indicators must have the capacity to detect cumulative changes in environmental and socio-economic conditions with each incremental addition of TISEC devices. Research and monitoring data and information must be analyzed, interpreted and presented in a way that responds to management questions and is easily understood. Appropriate coordination, synthesis and integration of all relevant data and information into a decision framework is crucial to informed decision making. The successful implementation of recommendations made by this study and those specified in the Jacques Whitford (2008) and NSDOE (2008) reports (particularly those related to fisheries) are considered very important to the future success of the TISEC industry and to lobster fishery sustainability in Nova Scotia.

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I wish to acknowledge the NS Department of Energy for serving as internship host for this project, and Dr. Peter G. Wells, my academic advisor, for his insight and encouragement. Last but not least, I thank my husband Bill Campbell for his understanding and patience throughout the course of my studies with the Marine Affairs Program.

A copy of the entire document is available in hard copy at the Marine Affairs Program Library, Dalhousie University. As well, the poster presented during the workshop is also appended. For further information, please contact Patricia Hinch at hinchpr@gmail.com.

Tidal Energy Development: Integrating environmental and socio-economic information into management decisions with particular reference to the lobster fishery in the upper Bay of Fundy

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Abstract

Nova Scotia is planning to develop tidal energy resources in the Bay of Fundy using tidal in-stream energy conversion (TISEC) technology (Fig 1). The lack of previous experience with TISEC operation in the Bay of Fundy means that there is little information upon which to evaluate impacts, guide the design of a monitoring program, or select indicators appropriate to the Bay. This study:
a) identified information essential for impact assessment (the EIA);
b) identified potential environmental and socio-economic-TISEC interactions over the project lifecycle;
c) examined potential impacts of TISEC development on the lobster population and fishery;
d) identified potential environmental and socio-economic potential indicators to monitor changes in the lobster population and fishery; and
e) developed a conceptual model of an effects monitoring program for the EIA decision process.

Many thanks to NS Dept. of Energy as internship host and to Dr. Peter G. Wells as the academic advisor for this project and for his review of this poster.

Fig. 1 Examples of TISEC technologies

Sources: Open hydro: http://www.openhydro.com/technology.html; Clean Current: http://www.cleancurrent.com/technology/design.htm; Marine turbines: SeaGen: http://www.marineturbines.com/21/technology/.

Introduction

- TISEC design is in its early stages of development. Globally, few prototypes have been tested under natural conditions or for an extended period of time.
- To date there has been no demonstration of TISEC operation on a commercial scale on which to assess cumulative environmental or socio-economic effects.
- Approval to move forward with full scale commercial TISEC development will require proof that single prototype devices and incremental additions of turbines do not result in significant negative environmental or socio-economic impacts.
- A monitoring program with an appropriate selection of indicators is needed.

Guiding Questions

- What kind of information is required for effective management decisions related to the development of tidal energy in the upper Bay of Fundy ?
- What are the key components of a framework to guide the inclusion of socio-economic and environmental impact information into management decisions ?
- What are the key components of a monitoring program to measure change in socio-economic and environmental conditions from TISEC operation ?

Methods

Methods involved:
a) preparation of management questions to address needs for baseline and impact data.
b) preparation of a conceptual framework for the development of an effects monitoring program (adapted from NRC 1990) (Fig. 1).
c) a literature review to identify potential priority TISEC-lobster population and fishery interactions.
d) selection of indicators that respond to management questions as the basis for a lobster population and fishery monitoring index.

Results

- Two key interactions were identified for indicator development: a) environmental effects of TISEC energy extraction on the lobster population abundance and distribution from potential changes in tidal currents, sediment distribution patterns, and habitat and b) socio-economic impacts of TISEC development and operation on the lobster fishery and surrounding communities.
- Environmental indices could include: population abundance/stock status; environmental features/marine environmental quality (MEQ); resiliency; reproductive capacity/health; ecosystem interactions/effects; and sustainability.
- Socio-economic indices could include: fishing pressure; human population demographics; lobster fishery characteristics; public service needs and availability; quality of life and social well-being; market condition; human resiliency or adaptive capacity; and management response/action.
- Over 75 potential environmental and socio-economic indicators were identified (Table 1).

Sources: Cape Blomidon: http://www.holmpage.com/blomidon; Cape Split: NS Department of Energy.; Lobster: NS Department of Tourism

Figure 1. A conceptual framework for an effects monitoring program for the EIA and policy or regulatory development process (following NRC 1990)

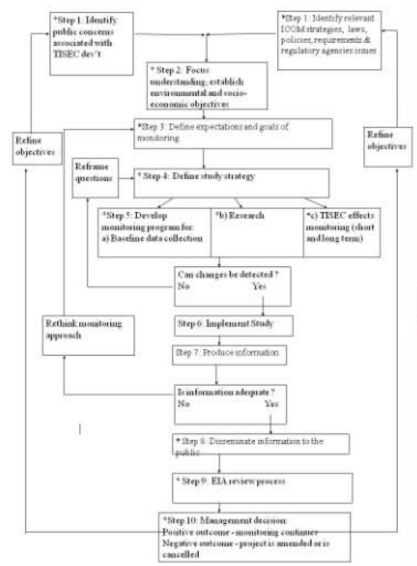

Table 1. Examples of lobster population indicators (using information from: Charles *et al.* 2002; Wells 2005; FRCC 2007; DFO 2007)

Key indices or features	Indicators
Environmental features or MEQ	- Ambient /produced noise - Sediment dynamics - Upwelling & stratification - Current circulation patterns - Habitat quality & substrate character - Temperature - Lobster tissue analysis (contaminants, bacteria, disease)
Population abundance/stock status	- Landings - Population (density &biomass) - Spatial distribution - Migration patterns - Catch rate - Fishing effort - Berried female numbers - Pre-recruit numbers - Spawning areas/aggregations - Pre-recruitment abundance
Resiliency	- Reproductive capacity - Normal growth/development - Increase in nos./return to baseline population

Discussion & Conclusions

- Assessing change from TISEC development depends on the appropriate research and monitoring program to establish the baseline and reference conditions. While much is known about Bay of Fundy ecosystem and socio-economic conditions, this information must be collated and organized to respond specifically to TISEC issues and management questions and new research must be initiated.
- What is known currently about TISEC impacts is based on short term demonstrations of prototype operation conducted elsewhere. Demonstration results need to be confirmed under Bay of Fundy conditions for short term operation of prototypes. Impacts of incremental additions of turbines also need to be assessed over the long term to evaluate cumulative effects (i.e. impacts of scale).
- Developers and regulators must avoid assumptions that short term and medium term monitoring results can be scaled to full commercial scale projects.

Recommendations

- The Province of NS should expedite development of a NS ICOM strategy to place TISEC within the context of other coastal developments and resource uses. They should consider the conceptual framework and lobster population and fishery indicators when designing an effects monitoring program.
- TISEC development should proceed cautiously on an incremental basis, with approval to advance to the next development level based on the evidence that no significant negative environmental or socioeconomic impacts have occurred.
- Regulators in conjunction with stakeholders should define acceptable levels of change in environmental and socio-economic conditions.
- Monitoring programs must measure effects over the project lifecycle and allow other indicators as needed to assess unanticipated effects.

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POPULATION CHARACTERISTICS AND MOVEMENT OF ATLANTIC STURGEON (*Acipenser oxyrinchus*) WHICH AGGREGATE IN MINAS BASIN, BAY OF FUNDY, DURING SUMMER

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Atlantic sturgeon (*Acipenser oxyrinchus*) have known populations in Bay of Fundy rivers (Saint John, Annapolis) and southern stocks may migrate into the Bay, but little is known about the sturgeon aggregation found in Minas Basin during summer. Trawl surveys between 2004 and 2008, and a directed study on sturgeon caught in commercial fish weirs during 2007 and 2008, examined 951 sturgeons: 567 of which were measured and tagged with dart tags, 333 were weighed, and 120 had pectoral spines removed for aging. Mean fork length of annual samples ranged from 129 to 140 cm and significantly differed among years. Ages from 2005 and 2007 samples ranged from 3 to 29 years. Observed length and age determinations suggest the annual aggregation is mostly immature sturgeon. The weight–length relationship for sturgeon captured in 2008 was Log W = 3.23 Log Fl - 8.76 and indicated good condition. Two sturgeon tagged in Five Islands during 2007 and two tagged in 2008 were recaptured in the southern Basin after being at large 1–2 months during respective years. Of seventeen sturgeon recaptured in the southern Basin in weirs and by trawl in 2008: 1 was originally tagged in 2004, 1during 2005, 6 during 2007, and 9 during 2008. Two multiple recapture estimates (Schnabel, Jolly-Seber) using all tagged sturgeon from 2004–2008, suggest a population of approximately 10,000 sturgeon in the Basin during summer. Each year, Atlantic sturgeon appear to enter Minas Basin along its northern shore during May and June. By July and August, they are concentrated along the southern shore and depart the Basin by September. We anticipate that distant tag returns and samples collected for mitochondrial DNA analysis will provide us with clues for the origin of the summer aggregation of Atlantic sturgeon.

Session N. Contaminants

BIOACCUMULATION OF METHYLMERCURY 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, and especially its methylated form, are of concern due to its persistence, high toxicity, known bioaccumulation and biomagnification, and suspected effects on the genetic, development and reproduction of aquatic organisms. Despite infamous pollution events of previous decades, such as occurred in Minimata Bay, Japan, where people were poisoned by consuming mercury in shellfish, little is known comprehensively about the fate of mercury in coastal marine ecosystems. There is evidence in the Maritimes that our loon, which spends its life as a juvenile in coastal marine waters and subsequently overwinters there as adults, has body mercury burdens well above inland populations. In the present study, total mercury and methylmercury were measured in the Bay of Fundy in the following environmental and ecosystem compartments: a) river water; b) sea water c) sediments; d) planktonic organisms fractionated into seven logarithmic size categories, from phytoplankton and flagellates (25 to 65 µm) to macrozooplankton (2 to 4 mm); e) pelagic organisms size fractionated from ichthyoplankton and crustaceans (4 to 8 mm) to small fish and shrimp (16 to 32 mm); f) macrophytes; g) benthic macrofauna such as mussels, lobsters and flatfish; demersal fish such as cod and haddock; h) pelagic fishes such as herring, mackerel and tuna; and j) marine mammals. Our results support the hypothesis that methylmercury is bioaccumulated in the marine food chain. Methylmercury levels consistently increase exponentially from phytoplankton (25 µm; 0.05 ± 0.03 ng/gWet) to zooplankton (500 µm; 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 sea water to tuna.

THE MERCURY FLUX OF AN EAST COAST MARINE EMBAYMENT

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The Bay of Fundy is a large, tidally energetic embayment in the Gulf of Maine of 1.38 X 10^{10} km^2. River water, seawater marine sediment, and plankton samples were collected in the spring of 2001 and the summer of 2002 with the intent of creating a mercury budget for the region. Seasonal atmospheric precipitation of mercury was obtained from the National Atmospheric Deposition Program and calculated from the seasonal rainfall averages to be 104 kg THg/y (4.4 kg MeHg/y). River water sources of mercury were calculated from the nine largest rivers emptying into the bay at 185.3 kg THg/y (9.39 kg MeHg/y). Oceanic transport was calculated from a transect of five stations sampled at standard depths to be 612 kg THg/y (186 kg MeHg/y), 711 kg THg/y (201 kg MeHg/y) and 1179 kg THg/y (358 kg MeHg/y) for residual surface, residual deep flow and tidal flux, respectively. This oceanic inflow would be balanced daily by an equivalent outflow. It is calculated that 60 kg THg/y (0.38 kg MeHg/y) are deposited within the deep sedimentation basin in the lower Bay off northeastern Grand Manan and that 22.1 Kg THg/y (0.1 kg MeHg/y) are carried into the Gulf of Maine with fine particulates. Planktonic organisms represent an additional flux into and out of the Bay of 22.1 kg THg (10 kg MeHg/y). There is, therefore, a net accumulation of mercury in the sediments of the Bay, derived largely from riverine input. The anthropogenic input is predominantly atmospheric within this region and represents less than 3.7% of the total flux.

SIXTEEN YEARS OF CONTAMINANT MONITORING IN THE GULF OF MAINE AND BAY OF FUNDY BY CANADA AND THE UNITED STATES: 1993 TO 2006

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Contaminant monitoring of blue mussel tissues has been conducted since 1993 by the Gulfwatch Program for the Gulf of Maine Council. The Council was established in 1989 by the premiers of Nova Scotia and New Brunswick and the governors of Maine, New Hampshire and Massachusetts to jointly oversee the health of the Gulf of Maine ecosystem and thereby the sustainable use of its resources. To accomplish this a network of stations was established to get a comprehensive coverage of the entire region. Many of these locations have been sampled repeatedly to distinguish any trends in the contaminant levels. It has been found that in general the level of contamination mirrored the human population density such that polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs) and many heavy metals were most concentrated in blue mussel tissues in the southwestern Gulf. Local "hotspots," however, were found for individual contaminants at various locations around the Gulf. There is also evidence for a decline in PCBs and pesticides such as DDT over the span of the program. The picture is very much complicated when examined location by location. However, silver, mercury, PCBs and DDT are declining at the most contaminated localities such as at the Sandwich, Massachusetts, site. It is hoped that in the near future the program will be expanded to place more emphasis on the suite of emerging contaminant concerns, such as other industrial compounds and pharmaceutical drugs.

DETECTING DISSOLVED ORGANIC MATTER USING AIRBORNE LASER FLUORESCENCE IN THE ANNAPOLIS VALLEY WATERSHED, NOVA SCOTIA, CANADA

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Abstract

The purpose of this research is to determine the feasibility of using a new remote sensing technique from an aircraft to detect disolved organic matter (DOM) in a fresh water body. Laser Induced Fluorescence Light Detection and Ranging (LIF LiDAR) was used to assess the water quality throughout the Annapolis Valley, Nova Scotia. The LIF LiDAR data was compared to measured dissolved organic carbon (DOC) values, taken from grab samples. The results collected in August 2008 by the AGRG using the Fluorescence LiDAR System (FLS), operated by LDI[3] out of Ottawa, will be compared to simultaneous water grab samples taken to determine the potential sensitivity and accuracy of this new and previously untested system. The current configuration of the FLS results in geometric positional errors of up to tens of meters for any given laser return and this issue will need to be resolved prior to comparison with the traditional grab sample data. The FLS system has the potential to be a valuable tool for broad watershed health assessments to determine areas with high DOM in the system which can adversely affect the health of aquatic systems by creating hypoxic or anoxic environments. It was found that LIF LiDAR is an efficient and cost saving method of obtaining water quality data on DOM in real-time.

Introduction

The use of LiDAR for water quality monitoring is useful because it covers a large area in a short period of time and displays a continuous set real-time of data rather than point data that is collected by grab samples. The continuous LiDAR data will allow researchers to analyze spatial distributions of DOC in real time, thus avoiding the use of grab samples and chemical analyses that is time consuming and expensive (Babichenko et al. 1993). There are many benefits to using LiDAR for not only water quality monitoring, but other applications as well.

Fluorescence analysis can be found in a variety of different biological studies including those of water quality monitoring, and organic matter detection. Fluorescence analysis for water quality monitoring has been tested in marine, estuarine, and fresh water environments using several different methods, including airborne LiDAR, flow-through probes, spectrofluorometers, and lab-based spectral fluorescence analysis from water samples. The most popular research topics include using fluorescence analysis for detecting dissolved organic carbon (DOC), dissolved organic matter (DOM), chromophoric dissolved organic matter (CDOM), and chlorophyll *a* (Chl-a) (phytoplankton) for determining water quality characteristics. Research in the area of DOC and DOM is of significant environmental importance due to their ability to bind and transport contaminants (Huguet et al. 2009). DOM acts as a transport mechanism for contaminants and plays a major role in the carbon balance in aquatic ecosystems therefore it is imperative that its mechanisms be studied more in-depth to understand the processes of its transport and transformation over space and time (Huguet et al. 2009).

Fluorescence occurs typically in aromatic molecules when that particle is raised to an excited state. DOM components that have been found to fluoresce are humic material and protein fractions (Steadmon et al. 2003). Fluorescence occurs after matter is excited by some form of electromagnetic radiation, i.e. a high intensity light source or a laser. When the molecule returns back to its normal energy, the energy released is in the form of light, or fluorescence. DOM has fluorescence properties and can be easily measured *in situ* (Jiang at al. 2008).

There is a gap in the current research in the area of using LIF LiDAR in fresh water ecosystems. The majority of analysis has been done in marine environments. The use of fluorescence analysis using LiDAR from an aircraft is also a fairly new endeavour overall. The researchers in this project hope to find strong correlations between LIF LiDAR data and samples collected on the ground to prove that the LiDAR results are accurate and that LiDAR is an efficient method of collecting large amounts of data in a short period of time at a low cost. Methods have been developed to detect DOM using fluorescence by looking at the spectral signatures which are produced after the substance has been excited. LDI³ has developed a spectral signature library (Figure 1) which they use in the field and in processing to compare collected data values to known values. We hypothesize that significant positive correlations will be observed between DOC concentrations in grab samples and LIF LIDAR data.

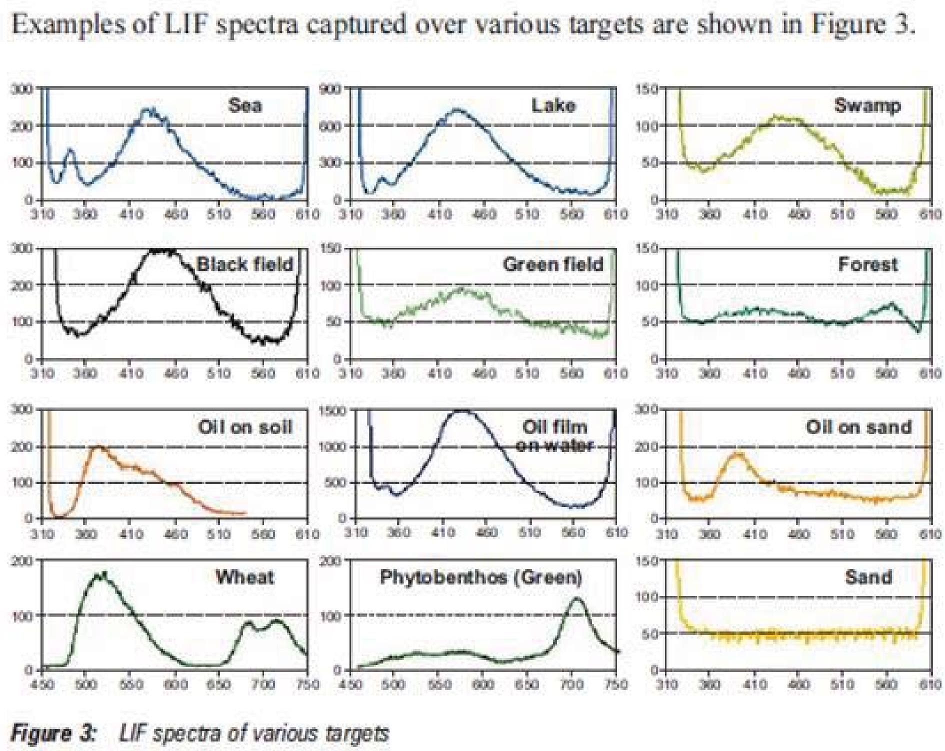

Figure 1. An example of the spectral library used to identity various targets.

Methodology

In order to test the above hypothesis, in August 2008, the LIF LiDAR system was installed in a small aircraft and flown over the Maritime provinces. On August 27th, 2008 the aircraft flew over the Annapolis Valley and collected DOM and Raman scattering data (a measure of water transparency) using an excitation wavelength of 308 nm which excites the dissolved portion of humic substances and creates a broad emission spectrum ranging from 400–450 nm (Vorobiev 2006). At around the same time as LiDAR data was being collected, water samples were also being collected on the ground. Figure 2 shows an overview of the DOM data collected from the LIF LiDAR in the Annapolis Valley. As can be seen from the figure, the highest levels of DOM (red) are located about mid-way between the headwaters of the Annapolis River and the Annapolis Basin. This figure was derived by symbolizing the data by quantities for the DOM field in ArcGIS 9.3, and symbolizing the highest data values in red. The locations of ground water samples are also located on the figure. When comparing data collected from three lakes on South Mountain (Figure 3), it can be seen high DOM levels correspond with low Raman levels and vice versa, because DOM is positively correlated with turbidity. Analysis on results from the Annapolis Basin (Figure 4) shows a dilution of DOM as the river meets the basin.

An in-depth analysis will be conducted to compare the ground water sample data to the data collected by the LIF LiDAR. The LIF LiDAR data was collected in arbitrary units, which means that the data was not a calibrated spectrum, but rather a voltage measure on the system. The data will therefore, need to be calibrated from the groundwater sample data so that the concentrations can be measured in ppm or mg/L.

Because the LIF LiDAR system lacks an inertial measurement unit (IMU), which continuously tracks an aircraft's position, the LIF LiDAR has some geometric positioning errors. The global positioning system (GPS) which was used was not accurate enough to account for the roll, pitch, and yaw of the aircraft. The water quality data from the aircraft are shifted and often show up on the map as being taken over known ground locations (Figure 5).

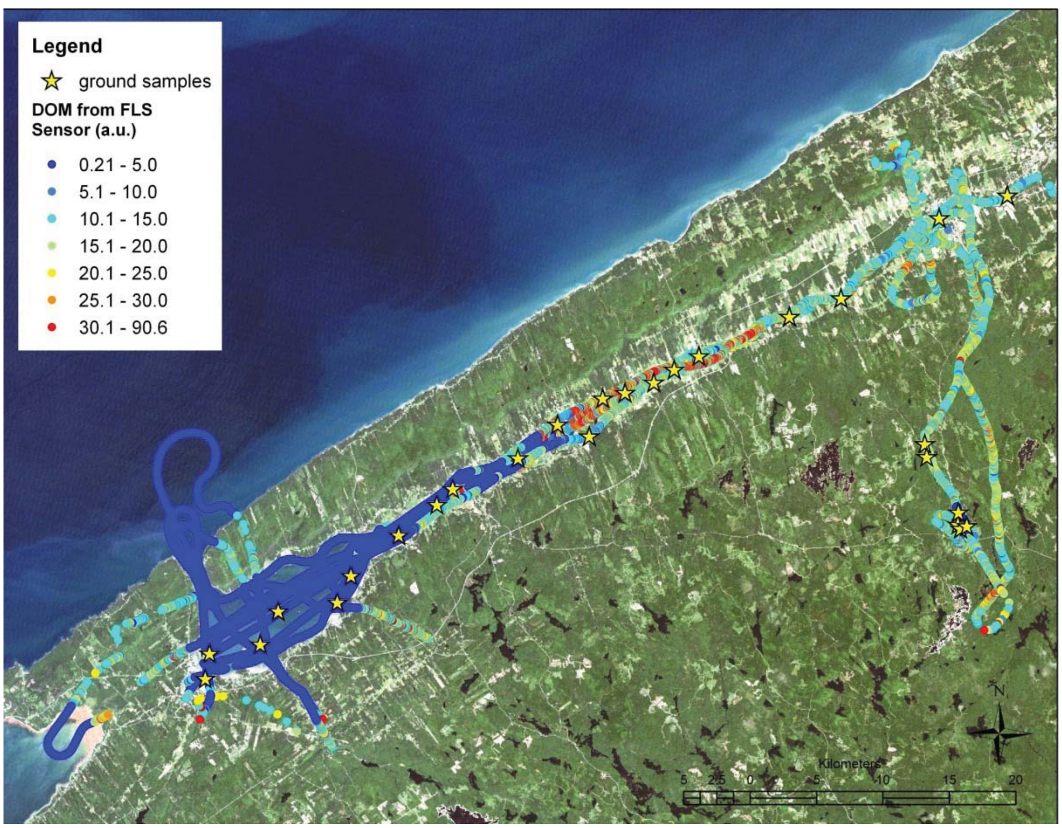

Figure 2. An overview of data collection in the Annapolis Valley

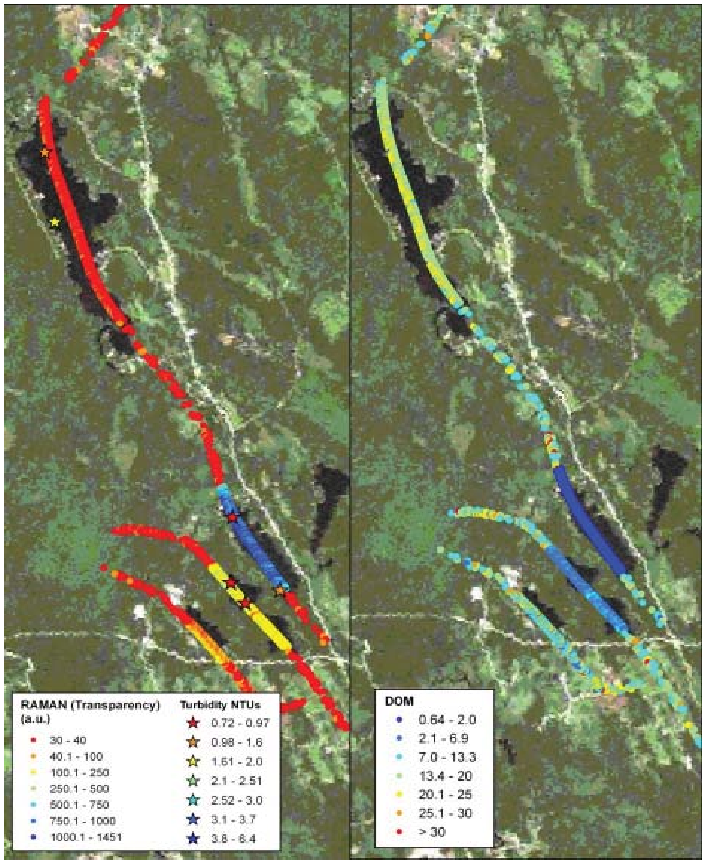

Figure 3. A comparison between Raman and DOM for South Mountain lakes

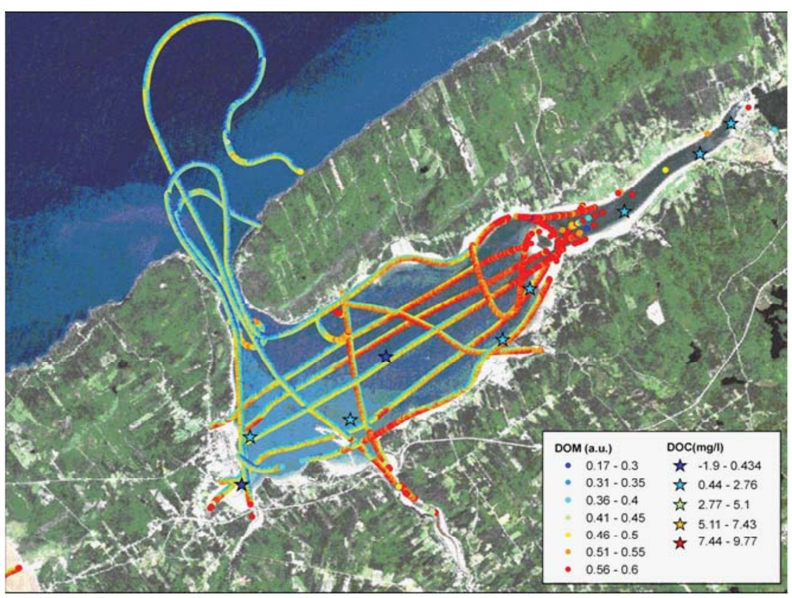

Figure 4. Flight lines over the Annapolis Basin

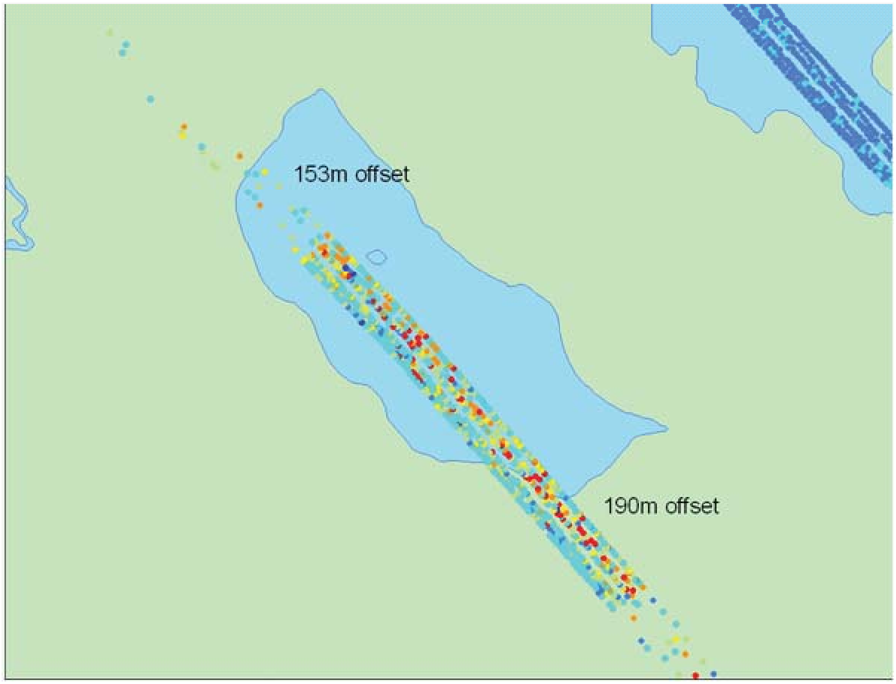

Figure 5. Offset swath data shown over a lake on South Mountain

Conclusion

This is an ongoing project which will be completed by the Applied Geomatics Research Group over the next three years. The initial stages of the project will be to rectify the geographical positioning errors and analyze the differences and similarities between the data collected by the LIF LiDAR system and the data collected on the ground. Further advancements will be made to the project as it proceeds, including the addition of an IMU to the LIF LiDAR system. The process of using LIF LiDAR to measure DOM in fresh water is in its early stages of research, and there are many advancements to be made.

The preliminary results present an indication of a dilution in the levels of DOM as the river moves into the Annapolis Basin, with higher levels of DOM in the areas of intense agricultural activity. By looking at the LIF LiDAR provided, it can be said that LIF LiDAR is an effective and efficient tool for water quality monitoring as an overall analysis of a fresh water body. The next step in the process is to correlate the LiDAR data to the ground sample data to statistically determine the similarities between the two sets of data.

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APPENDIX I

BoFEP Geomatics Mini-Workshop

Report of a Workshop held on 28 May 2009 at Acadia University, Wolfville, Nova Scotia

Submitted to GeoConnections by the ACZISC Secretariat

Atlantic Coastal Zone Information Steering Committee
26 June 2009

Table of Contents

Section 1: Introduction

COINAtlantic

COINAtlantic – the Coastal and Ocean Information Network for Atlantic Canada (see http://COINAtlantic.ca) is an initiative of the Atlantic Coastal Zone Information Steering Committee (ACZISC) – see http://aczisc.dal.ca. COINAtlantic is working to develop, implement and sustain a network of data providers and users that will support secure access to data, information and applications, for decision making by coastal and ocean managers and users of coastal and ocean space and resources.

Capacity building within COINAtlantic

As part of the GeoConnections funded COINAtlantic Phase I project, contract work was undertaken to develop material to increase the capacity of environmental non-governmental organizations (NGOs) in their use of geomatics. By participating in a collaborative initiative with the Southern Gulf of St. Lawrence Coalition on Sustainability (SGoSLCS), CoastalCURA, the Applied Geomatics Research Group (AGRG) and Environment Canada (EC), COINAtlantic was able to support the development of a ½ day training session to introduce participants to on-line geomatics.

Section 2: Proceedings

The Bay of Fundy Ecosystem Partnership's (BoFEP) holds bi-annual workshops that bring together a large number of scientists, managers and NGOs. The 2009 BoFEP Workshop was held at Acadia University Wolfville, Nova Scotia during the week of May 25th.

To take advantage of this gathering of interested participants, a Mini-Workshop on Geomatics, was organized by the ACZISC Secretariat and the BoFEP Workshop Organizing Committee.

The organizers of the BoFEP Workshop arranged a computer lab with computers for up to 15 participants. COINAtlantic adapted existing capacity-building training materials to fit a shorter 2-hour period.

The agenda was:

- Welcome and introductions
- Introduction to Geomatics overview presentation
- Gulf of Maine Ecosystem Indicators Partnership (ESIP) Overview
- COINAtlantic Exercise #1: The Basics
- COINAtlantic Exercise #2: Creating a Map
- Free for all – questions and comments
- Evaluation

The mini-workshop provided participants with a general introduction to geomatics and its use in accessing and generated map images for use in day to day publications. The ESIP overview provided an introduction to one of many programs in the region that are working to publish useful environmental information on line. More information can be found at: http://www.gulfofmaine.org/esip.

The COINAtlantic Search Utility (CSU - http://coinatlantic.ca/searchutility.html) was presented in the form of two self-directed tutorials (See Appendix 2 and 3). Individuals and small groups were allowed to explore the Utility and the available information online at their own pace. There were a number of resource people in the room to provide assistance.

Each participant was asked to complete an evaluation form. Eight forms were completed and returned providing feedback on the mini-workshop.

The following table summarizes the responses based on scores ranging from 1 for strongly agree to 5 for strongly disagree

Evaluation Question	**Average Response**
The Training Session activities were well organized	4.5
Was informative and useful to my "mapping" work	4.5
Novel (i.e. "new" information was presented)	4.6
Met my expectations	4.25
Would consider attending another similar training session	4.0

It was specifically noted that the opportunity to work on the exercises individually allowed the group to proceed according to their experience and abilities. Some individuals were able to accomplish more work than others, but all participants were seen to make progress and advance their knowledge and understanding of the available resources.

Section 3: Conclusion

The Mini-Workshop provided an excellent opportunity to make use of existing capacity building material in a shorter time period than designed.

The evaluation documented that participants were satisfied with the training.

Section 4: Acknowledgements

The ACZISC Secretariat would like to acknowledge the GeoConnections Program for its contribution to Phase 1 of COINAtlantic development and implementation.

The collaborators who assisted in the development of the original training material were essential in having the material available for this training.

The BoFEP organizing committee did and excellent job of finding an appropriate room and the necessary computers for the training. They are thanked for their excellent marketing of the mini-workshop during the Plenary sessions. Through their efforts the room was full with intelligent and interested participants.

Appendix 1: Participants

Martha Baldwin
Jeremy Broome
Danielle Cassarini
Gail Chmura
Romeo DaRecke
Chris Feurt
Chantal Gagnon
Ben LeMieux
Melissa Nevin
Casey O'Laughlin
David Robichaud
Susan Rolston
Andy Sharpe
Amber Silver
Jackie Spry
Bill Whitman

Presentation and assistance provided by:

Paul Boudreau
Nadine Gauvine
Melissa Landry
Christine Tilburg

Appendix 2: COINAtlantic Search Utility Exercise 1 – The Basics

The COINAtlantic Utility is a free on-line utility that allows users to search for and access environmental information for Atlantic Canada.

Go to http://coinatlantic.ca to begin.

You will notice on the COINAtlantic home page there are support features at the bottom of the page in the form of a COINAtlantic Facebook group, a four-minute introductory video and a two page quickstart tutorial.

The following activity is a chance for users to get familiar with the basic features of the COINAtlantic Search Utility.

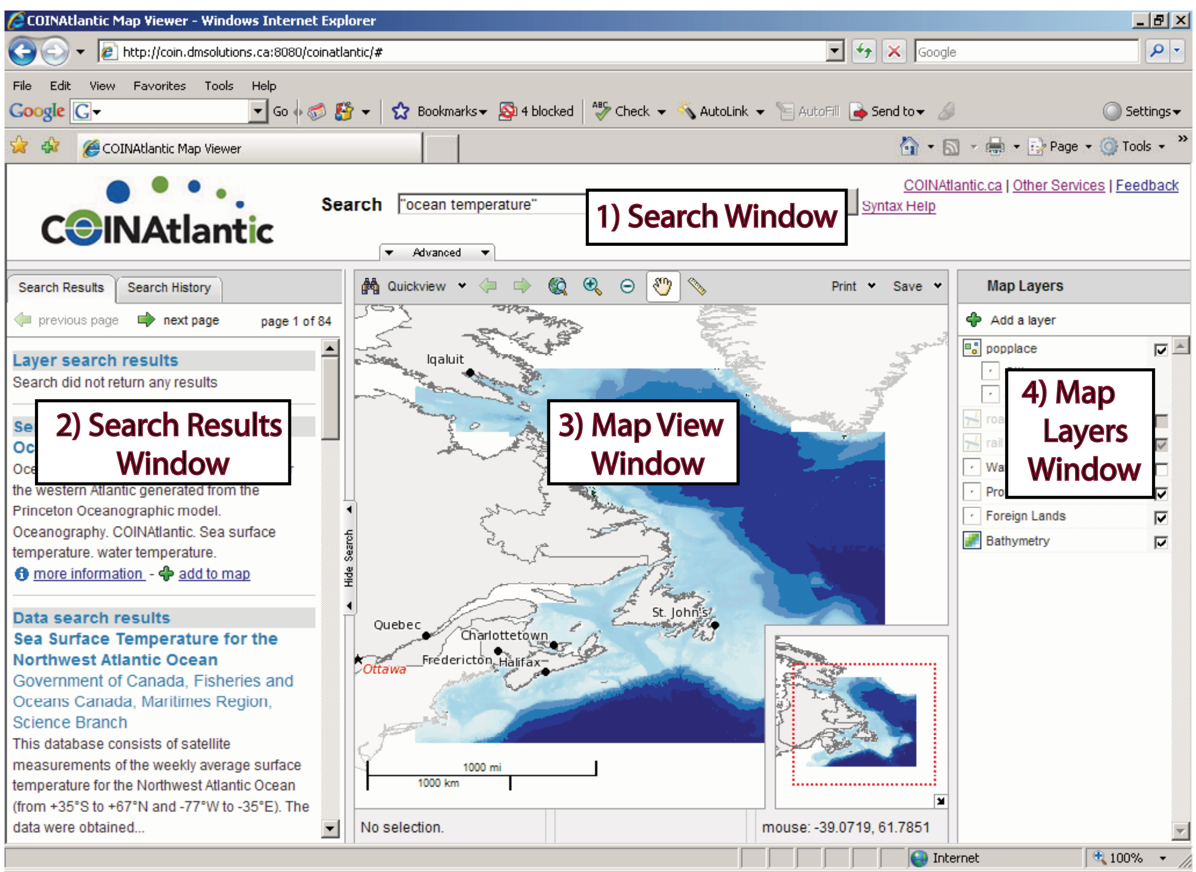
All highlighted sections of this text were taken directly from the quickstart tutorial on the COINAtlantic website.

Step 1) To access this site, please type COINAtlantic into your search engine or type: http://coinatlantic.ca/ into your web browser's address bar.

Step 2) To get to the search utility, click once on the map image in the middle of the page.

The search utility page will have four windows:

1. Search window across the top
2. Search Results window down the left hand side
3. Map View window in the middle
4. Map Layer window down the right hand side



With any search utility, it is important how you query a subject. Some queries will return lots of information and others will return none. If the Utility successfully finds information sources that contain the word or phrase, it will present these sources in the Search Results window on the left hand side. For each source of information that is found, a title, a short description and a number of highlighted links will be displayed. Note that the source described may be a publication, a database or a map.

Step 3) In the “Search Window”, type in ocean temperature (without quotation marks) and then click Submit. In your “Search Results Window”, take note of how many pages of information were gathered (upper right corner of Search Results Window).

Step 4) Now type in “ocean temperature” (with quotation marks) and note how many pages of information were gathered.

Step 5) To find out why entering the same words, but in a different manner and to help out with future searches, you can click on “Syntax Help” to the right of the Submit button.

What can we find?

Step 7) In the Search window, type in “currents” and click Submit.

Step 8) Move the cursor through the Search Results Window. Do you notice anything in the Map View window?

When the cursor is placed on any part of a description in the Search Results window, a pink square will be shown in the Map View window to represent the geographic area covered by that entry. Entries for information from small, site-specific sources will be represented by small squares centered over the site. Entries for larger regional or national sources will be represented by large squares that may cover the full Map View window. Note that some sources do not have the necessary information to be presented in this manner and so no pink square will be displayed.

If the search finds a large number of sources, there may be more than one page of results. In this case, the “next page” link at the top of the Search Results window will be highlighted. By clicking on this link, one can advance through the pages in the results.

Each entry in the Search Results window will have a link at the bottom to “more information.” This link will open an external web page with additional background information on that entry. This is helpful to understand the data entry and to evaluate whether this information is useful.

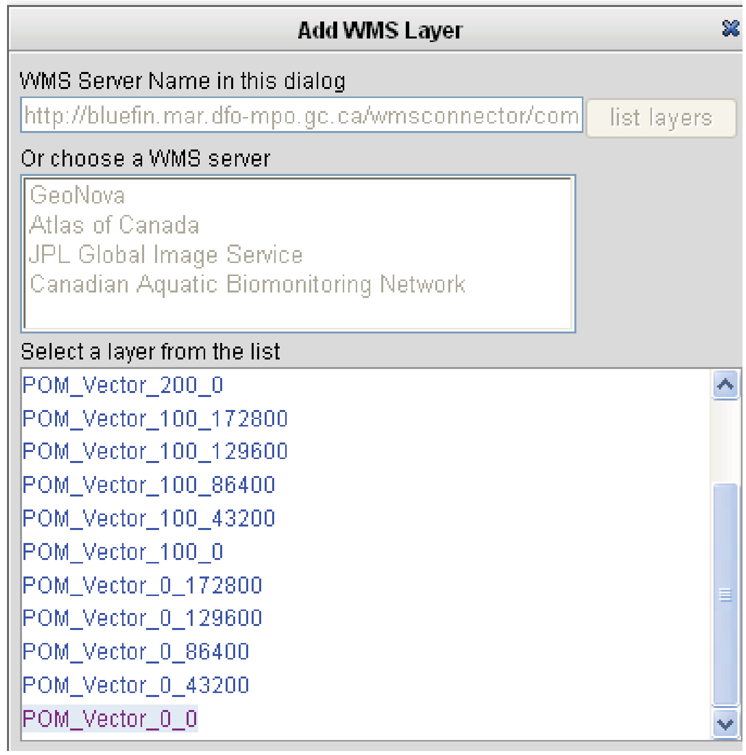
Depending on the information available for the entry, there may be two additional links presented at the bottom of the description: 1) access link and 2) add to map.

The “access link” opens a new web page that provides additional information relating to this entry. For some entries there maybe multiple “access link” links. Each will open a separate web page with additional background information. This may be useful in evaluating the usefulness of this data source.

Step 9) Move you cursor over the various results and click on different “more information” and “access link” links. When you are finished, close the various Browser windows so that you can see the Search Utility again.

Adding information to our map

Step 10) In the “Currents for the Western Atlantic” results (it should be the first result) in the Search Results window, you will notice “add to map.” Click on this link and the following box should appear:



Step 11) Scroll down and select "POM_Vector_0_0." This is a map layer for modeled ocean surface currents. You will notice that "POM_Vector_0_0" has now been added as a layer in your Map Layers window on the far right side of the screen.

Step 12) You can close the "Add WMS Layer" box by clicking the "x" in it's upper right corner.

NOTE: A comparable process can be done searching for the word "multibeam" and selecting an area of interest from the list.

Navigating in the Map View Window:

Step 13) Along the top of the Map View window, you will find several tools to help look at the map data. Slowly move your cursor over the icons to find button names.

The "zoom in" tool is used to zoom into a geographic area of interest by clicking and dragging a box over the map. With this tool selected, click above and to the left of the area of interest, hold down the mouse button and drag down and to the right. An indicator box will be displayed to show the area that is being selected. When the box covers the area of interest, release the mouse button. The map window will then be regenerated for just the geographic area selected.

Step 14) Use the "zoom in" tool to select your home province and then use it again to select a smaller area near where you live.

By clicking once on the "zoom out" icon, the map will be regenerated to display a slightly bigger geographic area. NOTE: if the area displayed in the map is not the one desired, you can reset the window to a map of the Atlantic Provinces by clicking once on the map reset icon at the top of the Map View window. You can then attempt to use the zoom in tool to select the area of interest.

Step 15) Click once on the "zoom out" tool see if you can notice a difference in the appearance of your map. Now click once on the "Initial Map View" icon to reset the map view to Atlantic Canada.

Step 16) Select "Pan Mode" place your cursor inside the Map View window (your cursor will change to a hand when inside the Map View window). The "Pan Mode" tool is useful for repositioning the map within your Map View window without changing the zoom level.

Step 17) Left click your mouse and drag your cursor within the Map View area and release the mouse button.

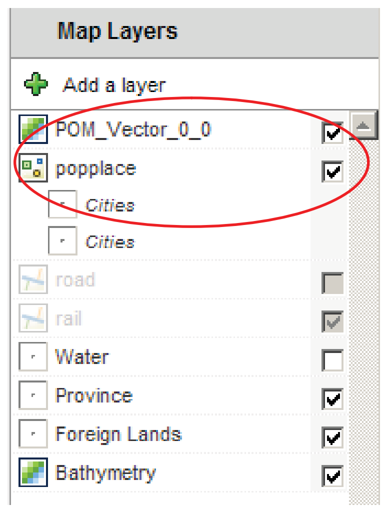
Step 18) Select "Initial Map View" (on Map View Tool Bar) to go to original map view.

Map Layers

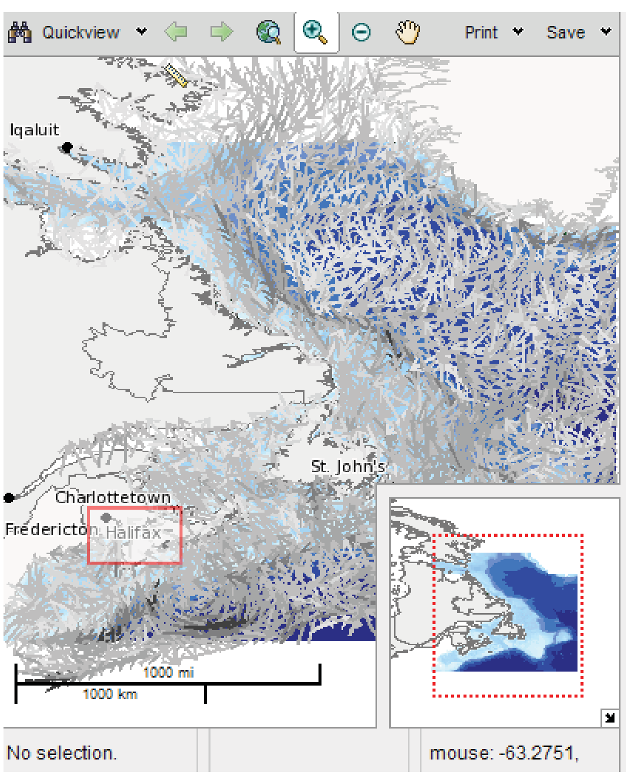
To work with the map layers that have been added to the Map View window, one uses the Map Layers window to the right of the screen. All map layers that have been added to the map will be displayed in the list on the right hand side in the Map Layers window. Each map layer is listed with a short title and a check box to the right hand side. If there is a check mark displayed in the box, the layer will be displayed in the Map View Window. By clicking on the check mark box, the check mark will disappear and the map will be redrawn without that layer being displayed.

IMPORTANT NOTE: The map information provided is "open source" and their may be some problems encountered by the user. The textual name for the layer is provided by the source of the information and may not be very helpful to the user. It is possible that spatial data from two different sources may not align correctly. Users are advised to use the "more information" and "access link" links to access additional information that may be useful in evaluating any information displayed.

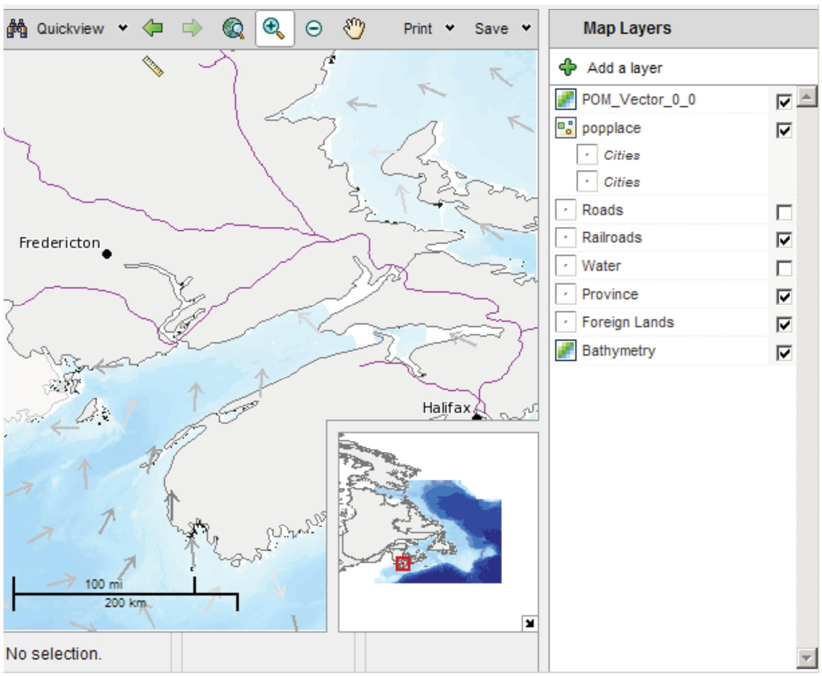
When the cursor is placed over the text name of the layer in the Map Layers window, their will be a small X displayed to the left of the checkbox. By clicking on the X, the layer will be removed from Map Layers window.



Step 19) Look at the Map Layers window and notice which layers are turned on (checkmark in box) and also note the "Roads" and "Railroads" layers are grayed out. This is because these layers are zoomed out too far.

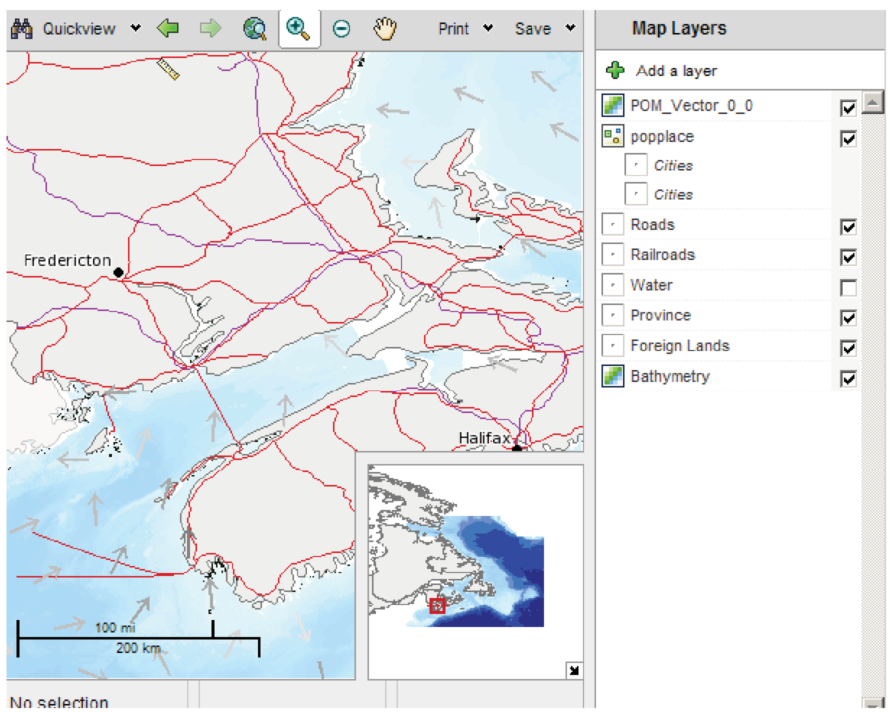


Step 20) Select the "zoom in" tool in the Map View window and start your selection north of Fredericton and end it southeast of Halifax.



When the picture regenerates, the "Railroads" and "Roads" layers are now active in the Map Layers window. The railroads appear on the map, but the roads do not appear because that layer is not turned "on."

Step 21) Click on the checkbox for the "Roads" layer to turn this layer "on." When the Map View regenerates, the roads should now appear on your map.



Removing a Layer:

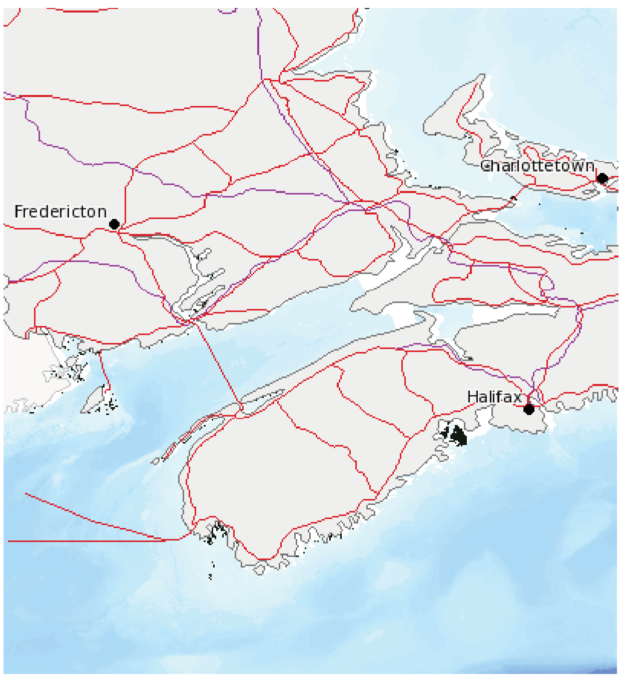
Step 22) Move your cursor over the "POM_Vector_0_0" layer and click on the "x" between the layer name and the checkbox and answer "OK" to the dialogue box to remove the layer.

After the Map View regenerates, the arrows in the water will disappear and the "POM_Vector_0_0" layer has been removed.

Printing and/or Saving your Work

Once a map has been generated in the Map View window with the proper geographic area and the desired map layers selected, an image of the map can be generated by clicking once on "Print" in the Map View window tool bar.

By clicking on "Save", the Utility will save the map image as a .tif file that can be inserted into a word processing document or it can be saved as a URL in the Browser's list of "Favorites" and/or e-mailed to a colleague.



Map saved as a .tif file and then inserted into this document.

Step 23) Save your work.

**Please note that this is a very basic tutorial and other examples of how to use the COINAtlantic Search Utility can found in the COINAtlantic Facebook group, the COINAtlantic Help folder http://www.marinebiodiversity.ca/COINAtlantic/map-utility/help-files.

Appendix 3: Exercise 2 – COINAtlantic Search Utility – Creating a Map for your Local Area

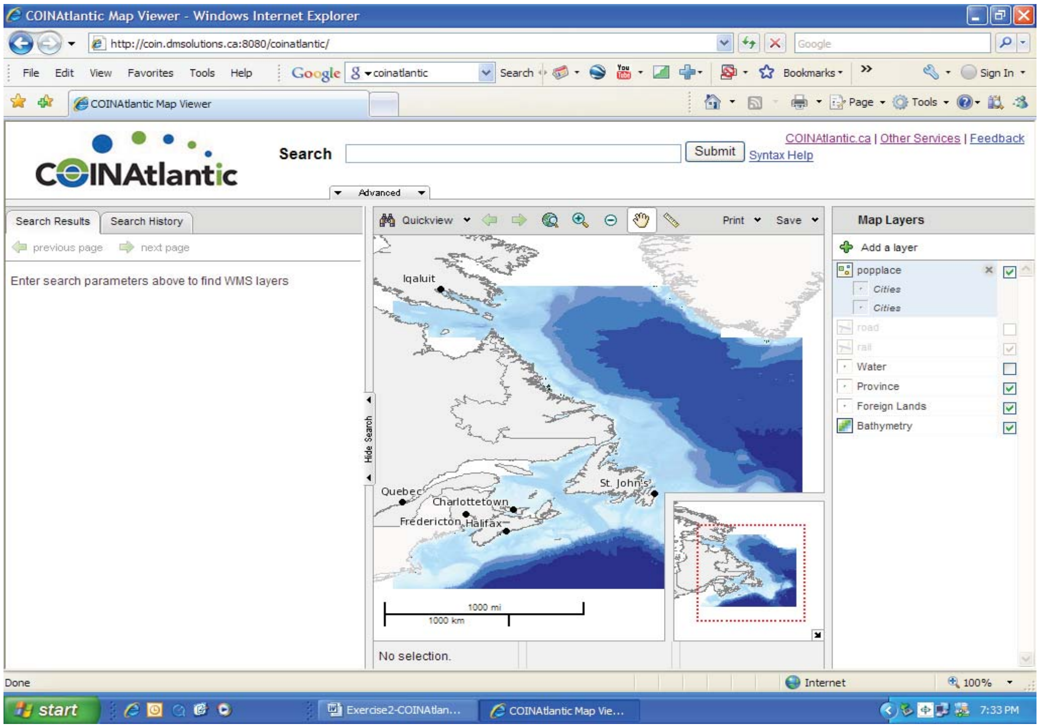
During this exercise, we will use the COINAtlantic Map Viewer to create a map from Atlas of Canada data. First, we will delete existing map layers, then add the desired map layers from the Atlas of Canada and reorganize the layers so they are ordered for best viewing. We will save the map as a TIFF image so it can be inserted into a word document.

This exercise is designed to re-emphasize some of the basic skills learned in Exercise 1.

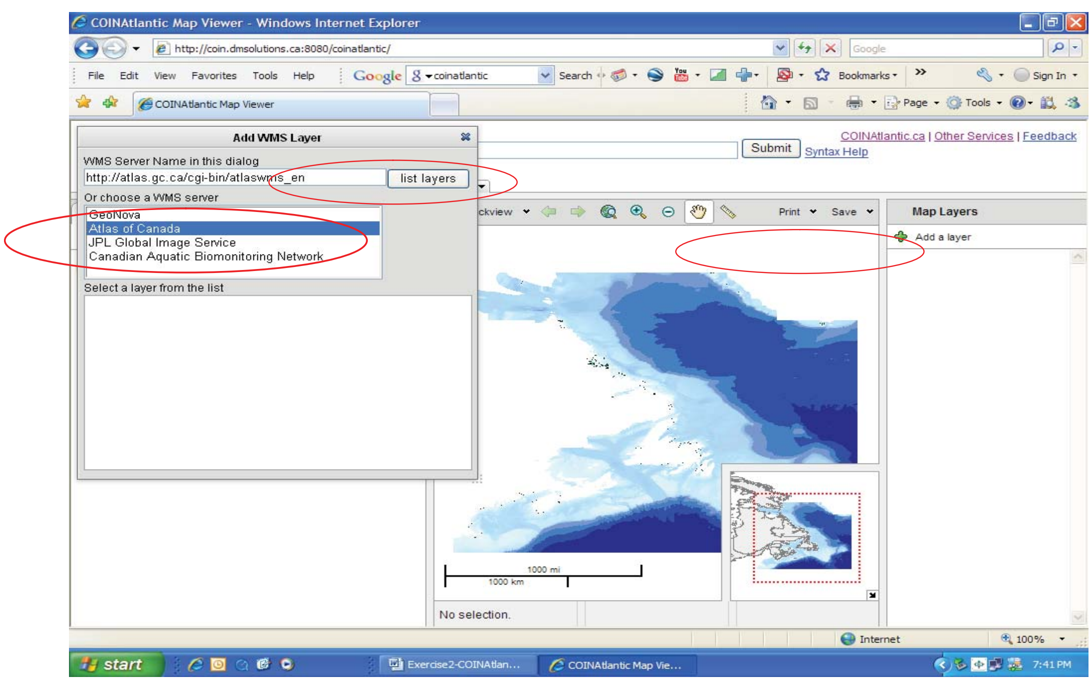
Step 1) In your web browser, go to http://coinatlantic.ca/ and click once on the map in the centre of the page. This should take you to the COINAtlantic Map Viewer page.

Step 2) a. We will not need any of the layers listed in the Map Layers window. Delete all existing layers by clicking on the "x" that appears between the layer name and the layer checkbox when you place your cursor on a map layer name.

b. Click "OK" to prompt asking to remove each layer.
c. After last layer is removed, a "setLayers failure" message will appear. Click "OK."



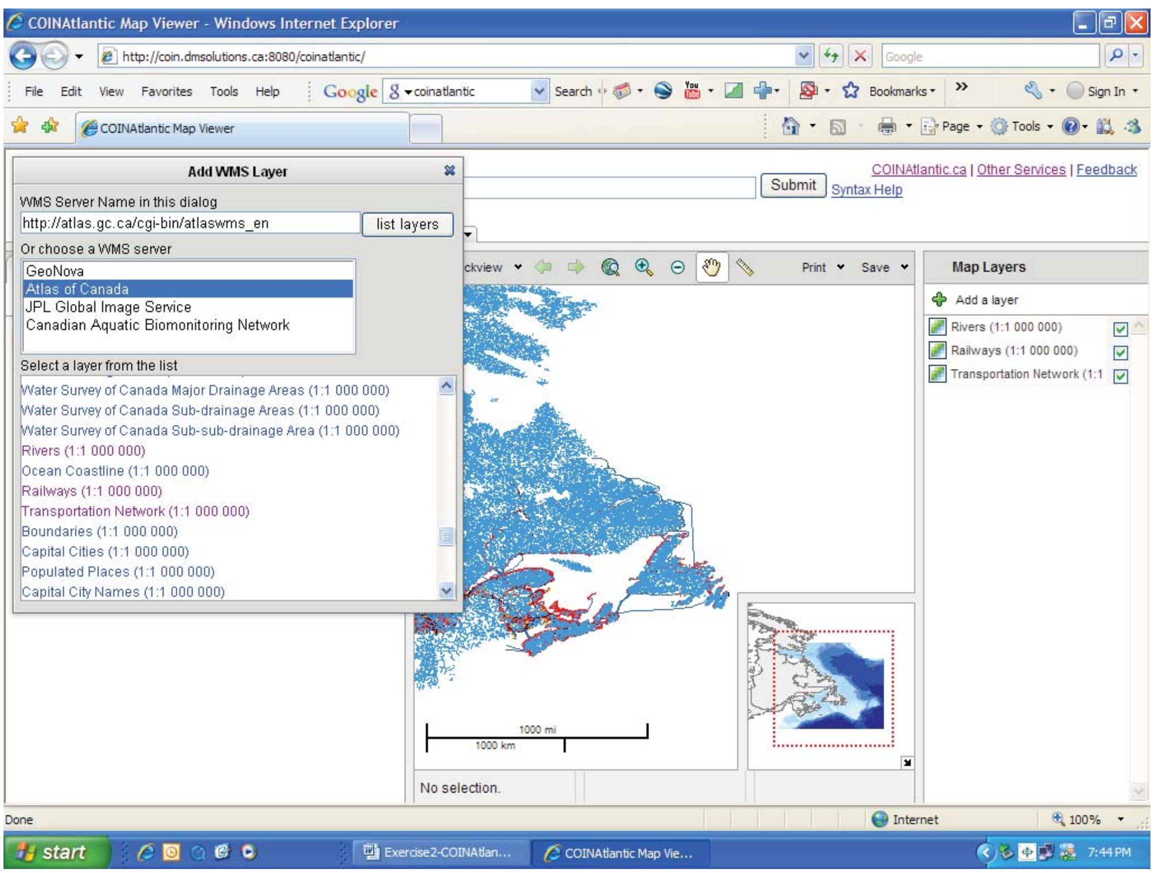
Step 3) In the Map Layers window (on right side of page), select "Add a layer." In the new window that opens up, select "Atlas of Canada" (it will highlight in blue) and then click on "list layers." This will populate the bottom of the pop-up window with a list of layers that you will select from.



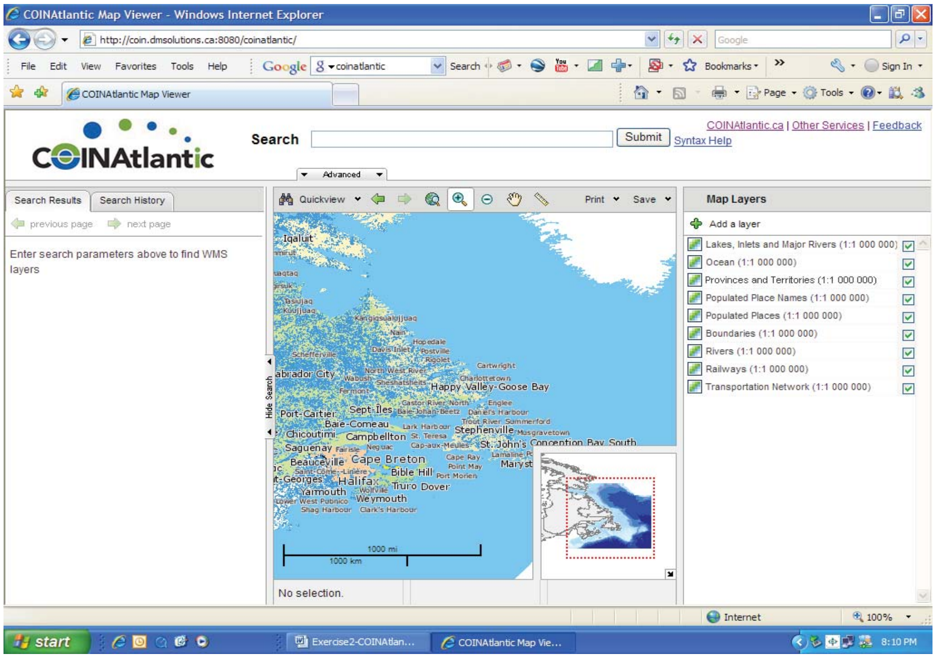
Step 4) Scroll through the list of layer names. The numbers after many of the layers are the scale of the map the layers are from. For our purpose we will use the map scale that has the most detail (in the data listed here) and select data layers with a 1:1 000 000 scale.

Step 5) Select the following layers by clicking on the layer name once. After selecting a layer it should be added into the Map Layers window (right side of screen). The image below has added three of the required nine layers.

Transportation Network (1:1 000 000)
Railways (1:1 000 000)
Rivers (1:1 000 000)
Boundaries (1:1 000 000)
Populated Places (1:1 000 000)
Populated Place Names (1:1 000 000)
Provinces and Territories (1:1 000 000)
Ocean (1:1 000 000)
Lakes, Inlets and Major Rivers (1:1 000 000)

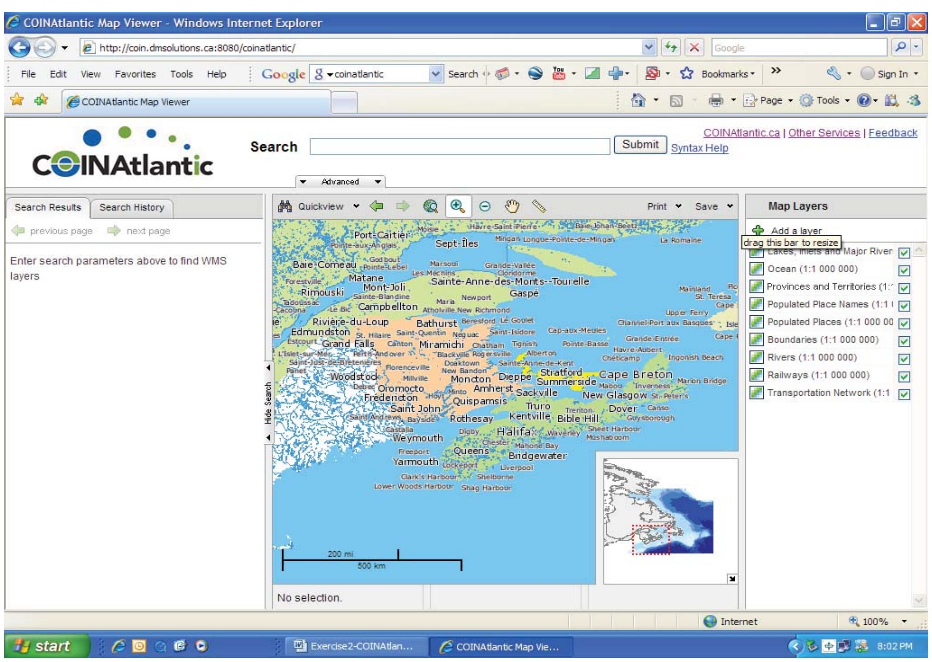


Step 6) Close the "Add WMS Layer" box and your screen. In the image below, the Map View window and the Map Layers window have been resized by clicking and dragging the boundaries of each window.



Step 7) Click on the "zoom in" tool on the tool bar in the Map View window and zoom into an area that includes: New Brunswick, Nova Scotia and Prince Edward Island. Look at the layer names in the Map Layers window and then look at the data displayed in the Map View window. You will notice that several layers are not displaying their data including:

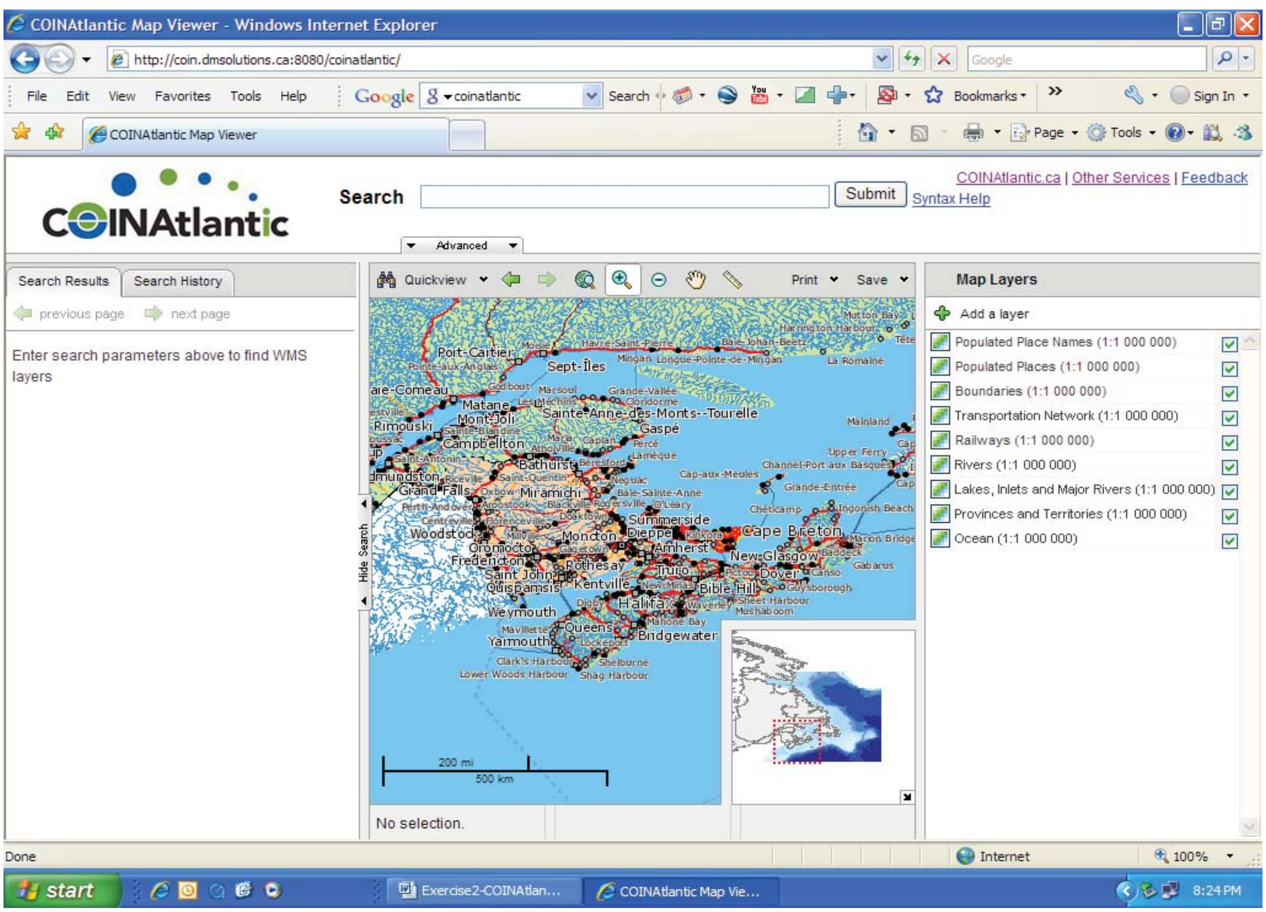
Railways (1:1 000 000)
Rivers (1:1 000 000)
Boundaries (1:1 000 000)
Populated Places (1:1 000 000)



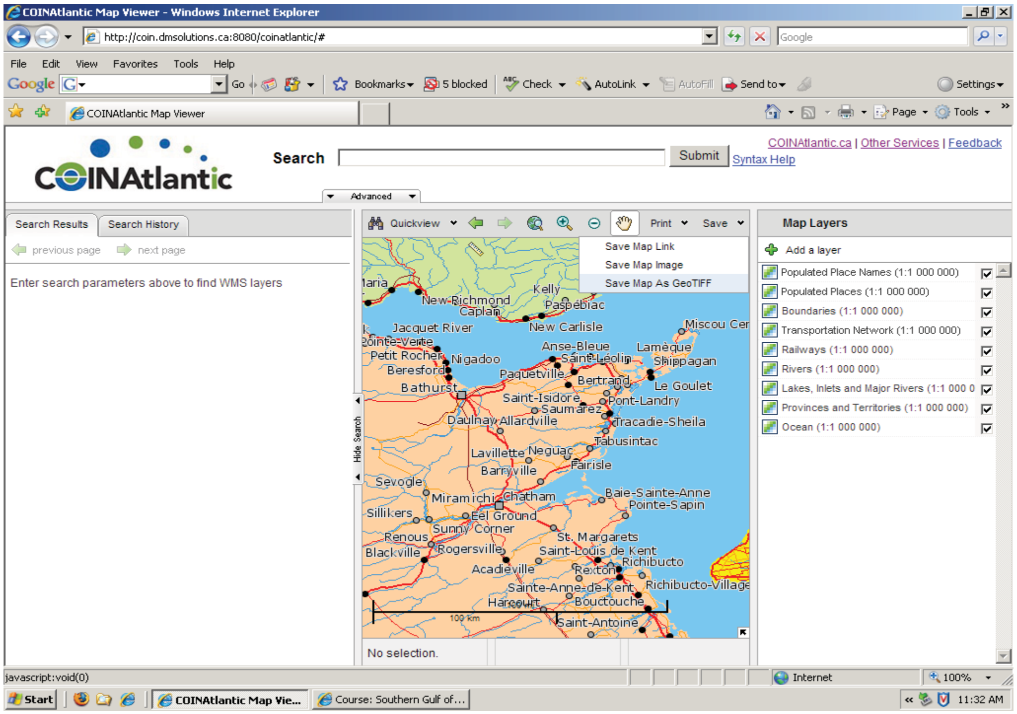
NOTE: When developing a map with several layers and different types of data (area, line, text and point data), it is important to consider the order in which the layers need to be organized so the data will display correctly. Area data will block out line data that is below it, making it necessary to position area data layers at the bottom of the layer profile. Line data is above area data, then point data and text data in the top layers. This is a general statement and may not apply to every mapping situation.

Step 8) Rearrange the map layers into the following order in your Map Layers Window. Layers can be rearranged by clicking on the layer name and dragging it up or down and releasing the mouse when the layer is in the correct location.

Populated Place Names (1:1 000 000)	text data
Populated Places (1:1 000 000)	point data
Boundaries (1:1 000 000)	line data
Transportation Network (1:1 000 000)	line data
Railways (1:1 000 000)	line data
Rivers (1:1 000 000)	line data
Lakes, Inlets and Major Rivers (1:1 000 000)	area data
Provinces and Territories (1:1 000 000)	area data
Ocean (1:1 000 000)	area data

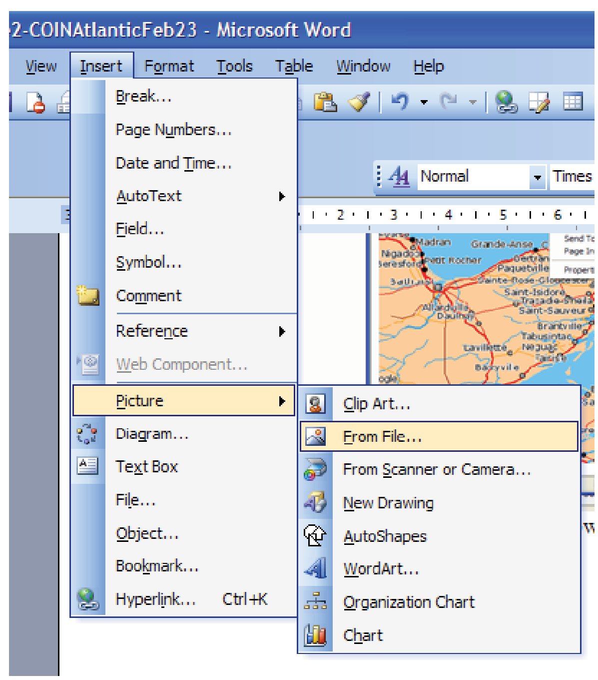


Step 9) Zoom into a local area of interest and select Save / Save as GeoTIFF. It may take a few moments to save. Save and name file. Close after "download is complete."



Step 10) If image does not save properly, your can then do Save / Save Map Image. The image will reappear and then you can right-click on image and select "Save picture as…." Save file in appropriate directory and name it with a .gif extension.

Step 11) In MSWord, place cursor where the picture can be inserted into the body of the text. Select Insert/ Picture/From file…. Find stored location of map on the computer.



The following map was created during the above exercise.

USE OF GIS FOR DECISION SUPPORT IN COASTAL ZONE MANAGEMENT IN THE SOUTHWESTERN NEW BRUNSWICK PORTION OF THE BAY OF FUNDY

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Introduction

The Coastal Ocean and Ecosystem Research Section at the St. Andrews Biological Station, in collaboration with colleagues at the Bedford Institute of Oceanography, has been involved in the application of GIS (geographic information system) technology to issues in the southwestern New Brunswick (SWNB) area of the lower Bay of Fundy since 2001, with an emphasis on issues related to salmon aquaculture. In this report, we summarize our group's GIS-related activities to date. A more detailed report can be found in Chang et al. (2008).

Infectious Salmon Anemia Management in the Salmon Farming Industry of SWNB

Our first involvement in using GIS was related to the management of the disease infectious salmon anemia (ISA) in salmon farms in SWNB. In 2001, we were approached by the New Brunswick government to provide advice on the potential fish health risk resulting from the approval of some new farms in the southern Grand Manan Island area. Prior to 2001, there were seven farms in this area: six farms were odd year-class farms and one farm was even year-class. In 2001, five new odd year-class farms were approved in this area. Previously, the one even year-class farm was relatively isolated from the other farms, but the addition of the new farms would decrease the separation distances between farms.

Previous Norwegian and Scottish experience with ISA suggested that water-borne disease spread was an important risk factor, and that the highest risk was at the scale of one tidal excursion around infected farms. In Norway, circular control zones were established around infected farms; these zones had a radius of at least one tidal excursion, with a minimum radius of 5 km. Similar zones were used in Scotland. If 5-km radius circular zones around farms were used in SWNB, this would suggest a high potential for water-borne transport of disease among farms.

Our approach to this issue was to use a tidal circulation model that had been developed for the Gulf of Maine–Bay of Fundy area (Greenberg et al. 2005) and customize it for the specific area of interest (the SWNB salmon farming area). We used the model to predict the tidal excursion area of each farm. We then used GIS software (MapInfo) to determine the overlaps of each tidal excursion area with other farm sites. Details of the methodology have been previously reported (see Chang et al. 2005a).

Figure 1 shows the model-derived tidal excursion areas of all farms in the southern Grand Manan Island area before and after the new farms were added in 2001. The maps show that in 2000, the even year-class farm was somewhat isolated from the other farms, but the addition of the new farms in 2001 reduced the degree of isolation. Also, prior to 2001, the White Head Island farms were isolated from the other southern Grand Manan Island farms, but the addition of the new farms meant that the White Head Island farms were no longer completely isolated.

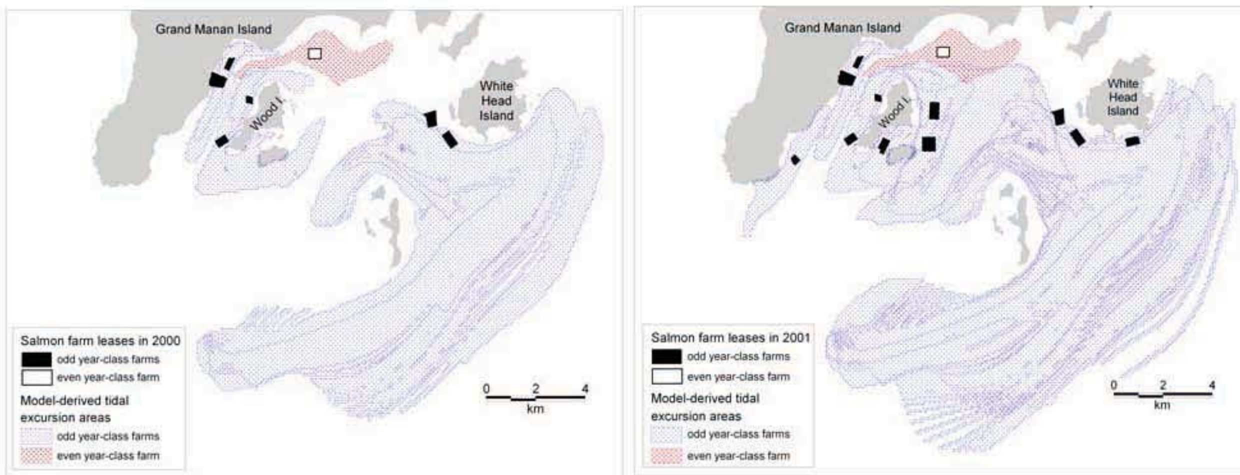

Figure 1. Model-derived tidal excursion areas of salmon farms in the southern Grand Manan Island area, 2000 (left) and 2001 (right)

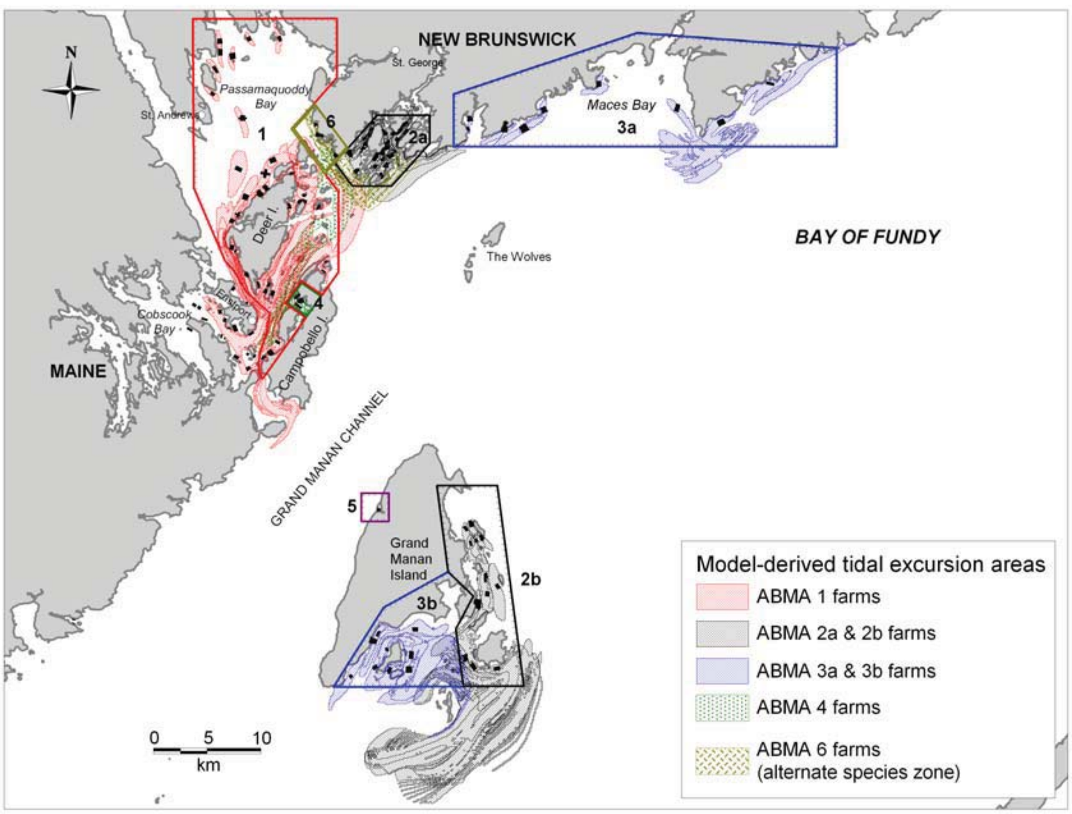

Figure 2. Map of SWNB showing finfish farms in 2006 (small black polygons), Aquaculture Bay Management Areas (ABMAs) implemented starting in 2006 (thick colored outlines), and model-derived tidal excursion areas of all farms (shaded colored polygons). Information on farm locations and ABMAs provided by the New Brunswick Department of Agriculture and Aquaculture. From Chang et al. (2007)

Development of a New Aquaculture Bay Management Area Structure for SWNB

In 2000–2001, the province and industry introduced an Aquaculture Bay Management Area (ABMA) framework comprised of 22 ABMAs. Within each ABMA, all farms were to become single year-class farms, with all farms in the same ABMA having the same year-class of fish and common management standards and practices. One of the main reasons for implementing ABMAs was to address the ISA problem; however, ISA continued to be a problem for the industry in the early 2000s. One factor may have been that the framework had too many ABMAs. Another factor may have been that farms were on a two-year rotation system, which allowed for some market fish to be held over on a farm when the next year-class of smolts was introduced.

A major criterion used in the establishment of management areas in Norway and Scotland was that there should be few or no overlaps of tidal excursion areas of farms in one management area with farms located in other management areas. For SWNB, in the 2000–2001 ABMA framework, the model-derived tidal excursion areas of 20 of the 94 farms overlapped with farm sites located in other ABMAs (Chang et al. 2007). This indicates a considerable amount of water movement between ABMAs.

Our tidal excursion data was an important consideration in the process which resulted in a new ABMA framework which was implemented starting in 2006. This new framework has five large ABMAs which contain the majority of farms, plus a few smaller ABMAs for the few remaining farms (Figure 2). Farms are now on a three-year rotation system, with mandatory fallowing between successive year-classes. In this framework there are only four cases where the tidal excursion of a farm in one ABMA overlaps with a farm site(s) located in a different ABMA, indicating that there is relatively little water movement between ABMAs (Chang et al. 2007). The SWNB industry has now been free of ISA for more than two years.

We also looked at overlaps between the new ABMAs and the most important fishing activities occurring in SWNB (Chang et al. 2007). Geo-referenced commercial catch data (to the nearest minute of latitude and longitude) were available for most of the important fisheries in SWNB, except for the lobster fishery. Considerable fishing activity occurs within the ABMA boundaries (Figure 3), especially for those fisheries that occur mainly near the coast, such as sea scallops, herring weirs, and sea urchins. Groundfish and herring seine fisheries occur mainly in offshore areas, with only a small percentage of the catches occurring within the ABMAs.

For lobsters, for which we had no geo-referenced catch data, we looked at the bottom subtrate type, as a predictor of the suitability of an area for juveniles (Chang et al. 2007). Shallow cobble/gravel subtrates are considered to be the preferred habitat for juvenile lobsters. Our analysis showed that 78% of the cobble/gravel habitat in depths <60 m occurs within the ABMAs (Figure 4), suggesting a high potential for interaction between salmon aquaculture and juvenile lobster habitat.

Open Ocean Aquaculture Potential, Based on a Preliminary Analysis of Marine Resource Use in the Bay of Fundy

Open ocean aquaculture is defined as fish culture in exposed or offshore areas. The interest in open ocean aquaculture is due to the shortage of new sites for aquaculture development in nearshore or protected areas; there is also the preception that open ocean sites would have fewer user conflict issues. We undertook a GIS resource study to look at the potential for open ocean aquaculture in the Bay of Fundy (Chang et al. 2005b). In this preliminary analysis, we collected readily available information on resources and activities in the Bay of Fundy, as well as the suitability of such areas for raising fish. The main information sources were: Fisheries and Oceans Canada; Canadian Coast Guard; New Brunswick Department of Agriculture and Aquaculture; Eastern Charlotte Waterways Inc.; Buzeta et al. (2003); Graham et al. (2002); MacKay et al. (1978-1979); Lacroix and Knox (2005).

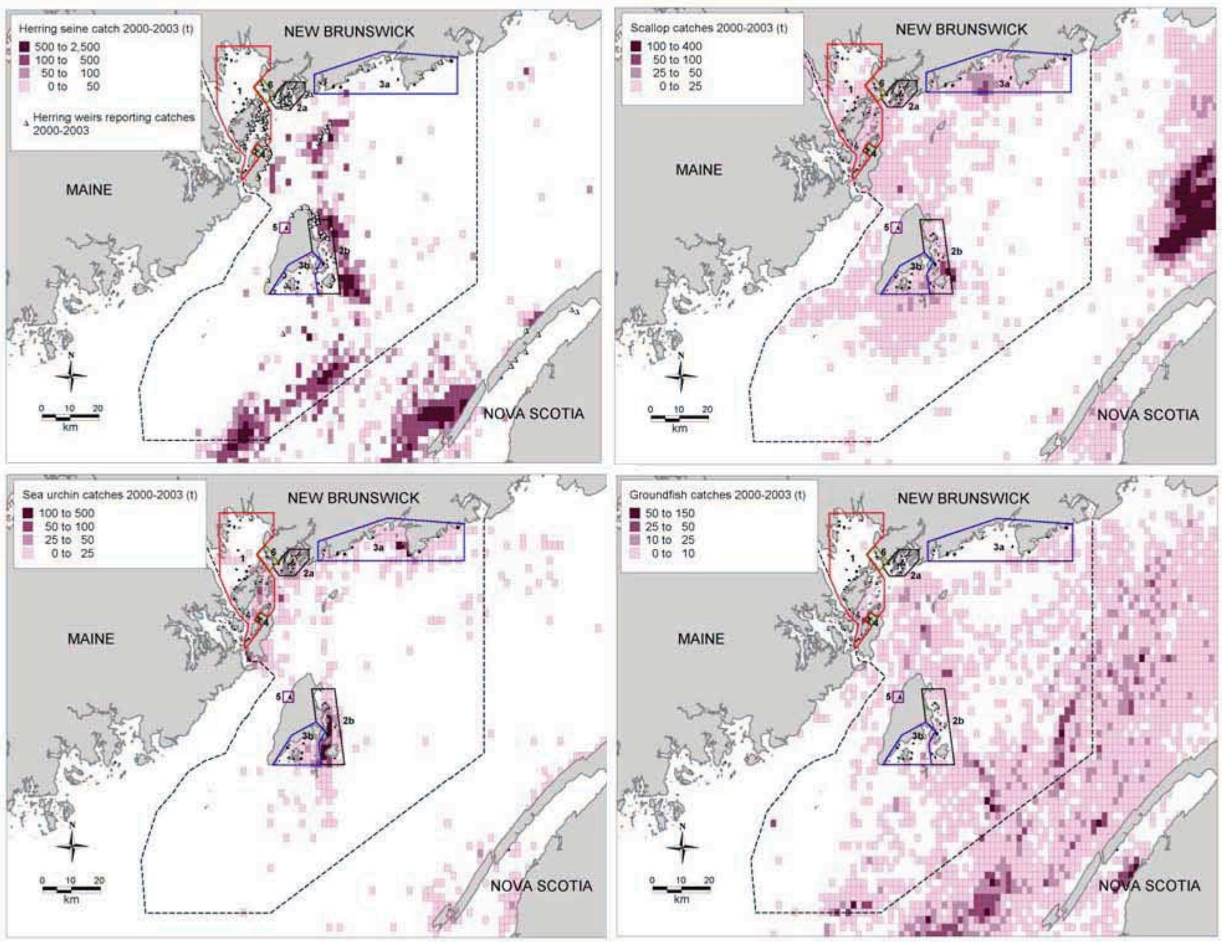

Figure 3. Aquaculture Bay Management Areas (solid lines) and catches of herring, sea scallops, sea urchins, and groundfish for 2000-2003. The dotted line defines the SWNB area. Data for U.S.A. waters are incomplete. Data source for catch data: Fisheries and Oceans Canada. From Chang et al. (2007).

We overlayed data on various activities and issues, including all reported fishing areas, spawning areas of commercial species, major shipping lanes and anchorages, aquaculture sites, cetacean areas, seal haul-outs, and important bird areas. We also included areas with high currents and areas susceptible to <0°C seawater temperatures; these would be considered unsuitable for salmon farming. The initial analysis indicated that there were no areas in the Bay of Fundy where there were no potential conflicts (Figure 5). If we eliminated less productive fishing areas and historic (but not current) spawning areas, some potential areas for offshore aquaculture are indicated (Figure 6). However, it is essential that further work be done to confirm if these potential sites are free of conflicts. It is especially important to confirm areas of fishing activities, especially considering that the most productive fishing areas can often change between years. Furthermore, we know that some important activities, such as lobster fishing and critical habitats for the endangered stocks of inner Bay of Fundy salmon, were not adequately included in our analysis due to lack of data.

We must emphasize that the analyses presented are our first efforts in this direction. It must also be noted that the presence of an overlap in the GIS analysis does not necessarily mean that there is a conflict or problem. Similarly, as noted above, the absence of an overlap does not necessarily mean that there are no conflicts. This work has proven to be an effective communications tool for decision makers and clients.

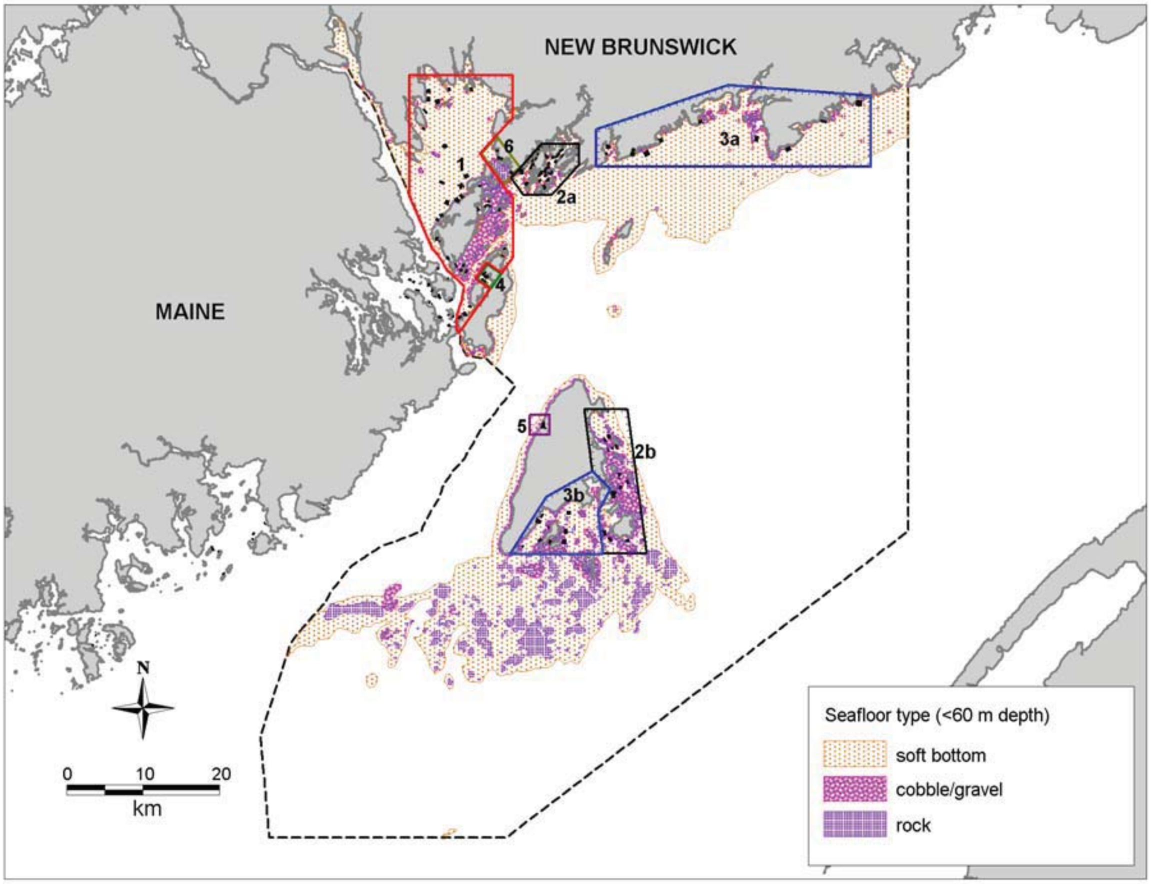

Figure 4. Aquaculture Bay Management Areas (solid lines) and seafloor habitats for depths less than 60 m. The seafloor types are an indication of juvenile lobster habitat. The dotted line defines the SWNB area. Seafloor classification by P. Lawton and R. Singh. From Chang et al. (2007).

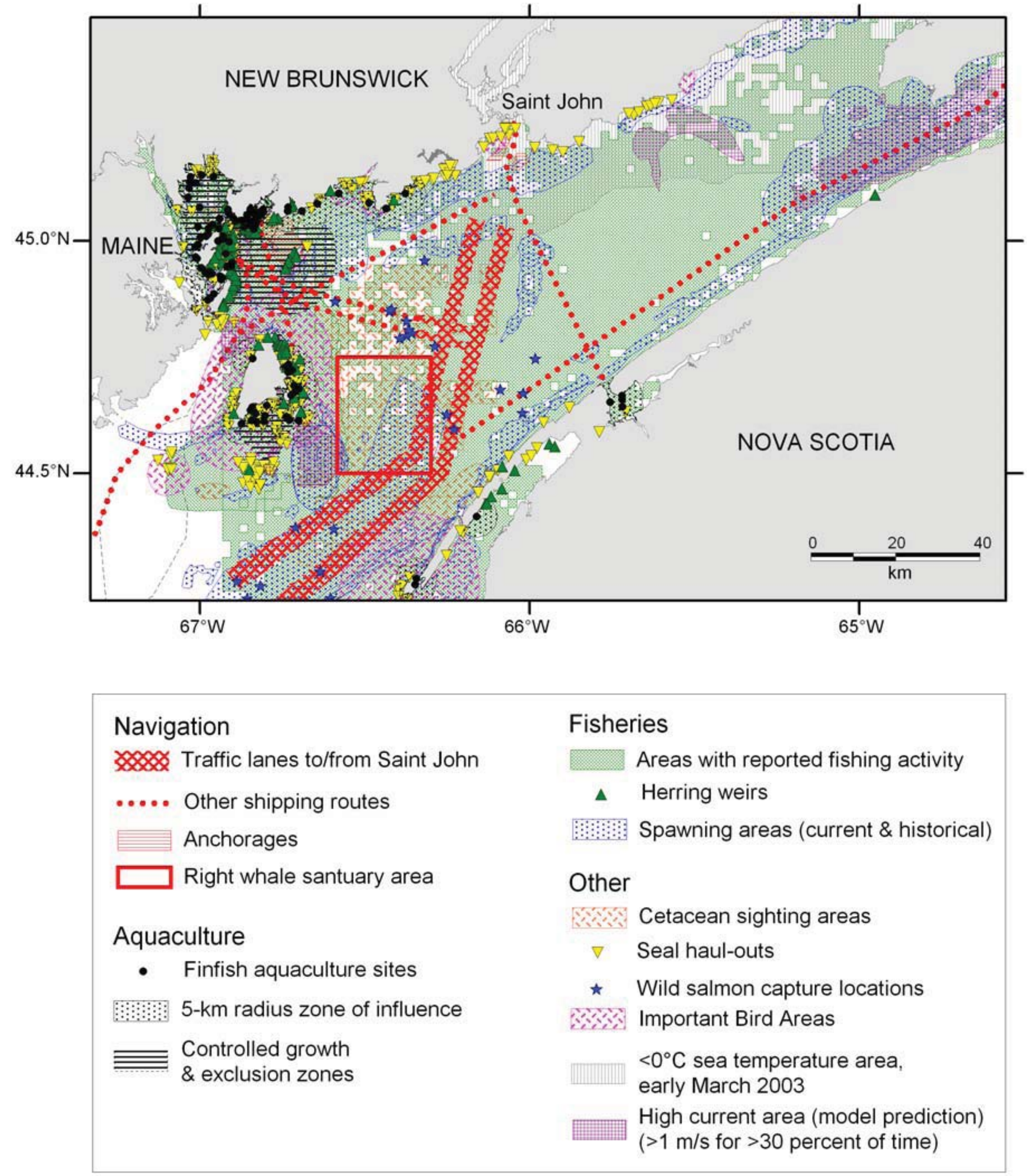

Figure 5. Geographic overlaps of activities and issues in the Bay of Fundy. Modified from Chang et al. (2005b)

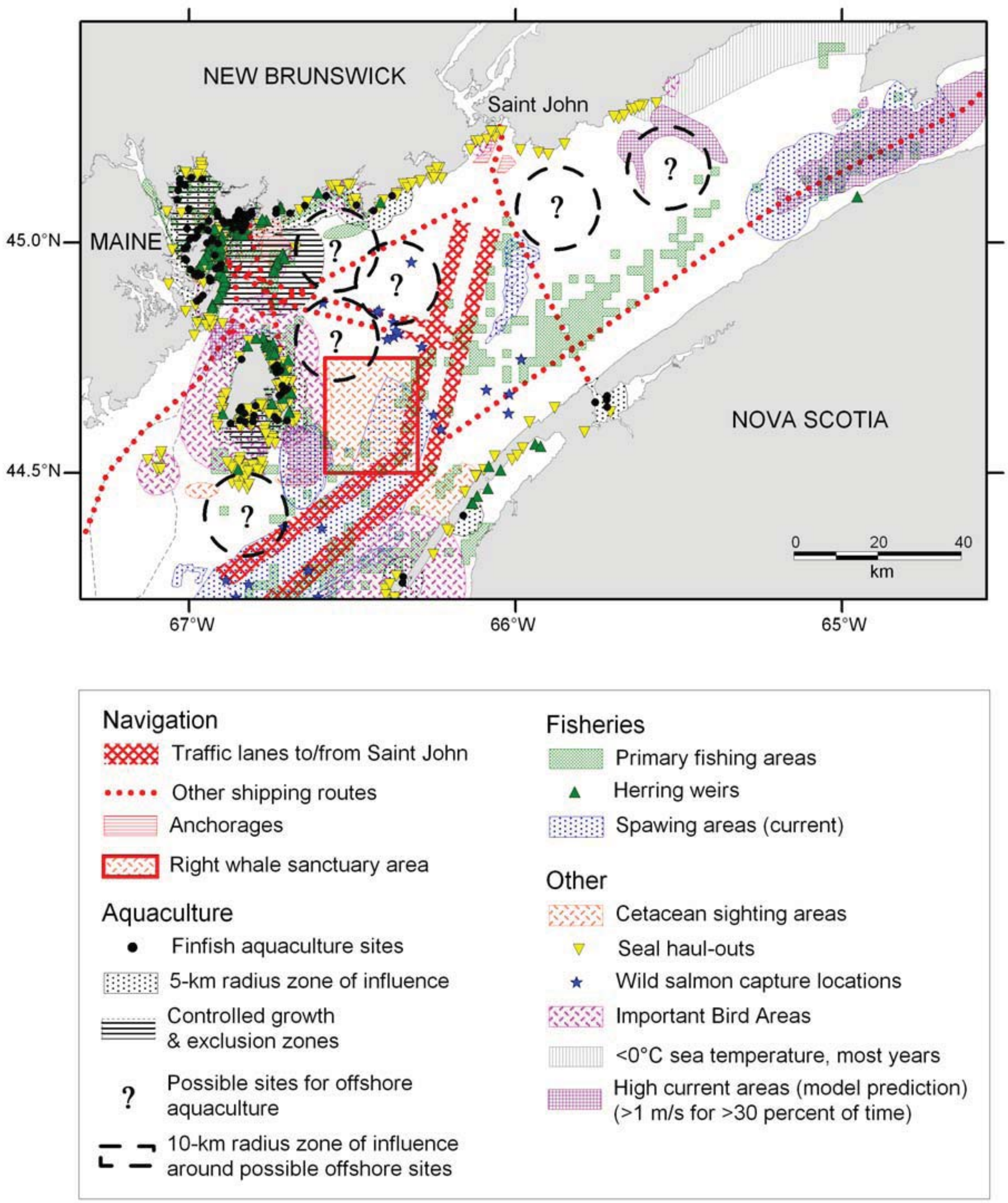

Figure 6. Potential locations for offshore aquaculture in the Bay of Fundy, based on preliminary analyses. Further analysis is required to confirm the suitability of any of the indicated potential offshore aquaculture sites. Modified from Chang et al. (2005b).

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The 9th BoFEP Bay of Fundy Science Workshop

"Protecting the Watersheds and Estuaries of the Bay of Fundy: Issues, Science and Management"

Date: October 2011

Proposed Location: New Brunswick (Saint John or Moncton)

Proposed Major Topics:

Advances in understanding macro-tidal estuaries
Conservation of estuarine fishes
Coordinating monitoring programs – from the watershed to the coast
Cross-border issues and cooperation watershed issues
Estuarine issues – education and public awareness
Estuarine restoration
Freshwater-saltwater ecotoxicology
Fundy watersheds – research case studies
Information and knowleedge – use and influence
Species at risk in Fundy watersheds and estuaries
Strengthening estuarine protection for Fundy watersheds
Tidal power development in macro-tidal estuaries – Fundy and beyond

Other topics for sessions are welcomed and encouraged

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