Protecting the Watersheds and Estuaries of the Bay of Fundy: Issues, Science and Management

Proceedings of the 9th BoFEP Bay of Fundy Science Workshop,
Saint John, New Brunswick
27–30 September 2011

Editors

T. Vickers, J. A. Percy, P. G. Wells and S. J. Rolston

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Preface

The 9th BoFEP Bay of Fundy Science Workshop was held in Saint John, New Brunswick, Canada on September 27–29, 2011. The Workshop, titled *Protecting the Watersheds and Estuaries of the Bay of Fundy: Issues, Science and Management*, provided a timely meeting and collaboration of stakeholders who were actively engaged in improving our understanding and management of ecological resources in the Bay of Fundy. Presentations were divided into nine themes, which included Intertidal Biodiversity & Ecology, Human Impacts: Tidal Power/Climate Change/Aquaculture, Salt Marsh/Mudflat Dynamics & Restoration, Managing Coastal & Marine Information, Conservation & Ecology of Estuarine Fishes, Aquatic Health & Monitoring, Productivity of Anthropogenic Structures in the Coastal Zone, Management Planning & Conservation, and Marine Protected Areas. The knowledge exchange was further augmented by the inclusion of twelve poster presentations that covered four contemporary themes; Ecology, Conservation, Fish & Fisheries and Information. The information exchanged and discussed brought new insights into ongoing scientific research and on the potential management repercussions of the findings. A mini-workshop titled 'Ecosystem Indicator Tools for the Gulf of Maine: A Hands-on Learning Experience' and a field trip to highlight the 'Marsh Creek Restoration Initiative' provided additional opportunities for participants to increase their topical knowledge and to share insights on management recommendations. Overall, the Workshop reaffirmed the commitment and dedication of a diverse array of stakeholders in enhancing and conserving the species, habitats, and ecological integrity of the Bay of Fundy.

Tim Vickers, Jon Percy, Peter Wells and Susan Rolston
Workshop Chairs and Editors, February 2012

Acknowledgements

The 9th BoFEP Bay of Fundy Science Workshop resulted from the collaborative efforts of numerous dedicated stakeholders, the most notable of which is the administrative resources of the BoFEP organization. The members of the Organizing Committee and the editors of these Proceedings, Peter Wells, Jon Percy and Susan Rolston, are each deserving of recognition of their tireless drive to make this event a success. New Brunswick's Minister of Environment, Hon. Margaret Ann-Blaney, not only provided the early financial assistance needed to secure the venue, but promoted the event within her Department resulting in increased representation from provincial regulators.

The exceptional efficiency by which the Workshop ran owed largely to the experience and poise of the session chairs. Enough cannot be said about the role these volunteers played in maintaining the precision of the schedule and the accuracy of the topic questions. Notable mention is made of the contribution of ACAP members Graeme Stewart-Robertson and Terry Cormier for their assistance in maintaining the computer and video imaging equipment, and Jean MacDonald for logistical support at the registration table.

Hats off to the plethora of presenters (oral and poster) who provided a wealth of new information on ongoing activities around the Bay of Fundy. Numerous comments were overheard about the professionalism and concise manner in which the materials were presented.

Guest speaker Jonathon Smith, from Blue Legacy International, delivered an energetic and pointed presentation on the increasing importance of science in an IT driven world. He encouraged the students in the room to maintain the resolve needed to protect and restore the marine and aquatic ecosystem of the planet. His passion and experience made for the perfect ending to an already successful event.

Lastly, I would like to thank ACAP staff member Crystal Colpitts for her impeccable attention to detail in all aspects of logistical support, ranging from participant registration, to evaluating the program, to ensuring all financial details were in order. Our lives were made much easier by her efforts.

Tim Vickers
9th BoFEP Bay of Fundy Science Workshop Chair

Workshop Organizers

Chair/Co-Chair

Tim Vickers, ACAP Saint John, Saint John, NB (Chair)
Peter Wells, BoFEP (Co-Chair)

Committee Members

Crystal Colpitts ~ ACAP Saint John, Saint John, NB
Simon Courtenay ~ Fisheries and Oceans Canada at the Canadian Rivers Institute, Fredericton, NB
Donna Curtis ~ University of New Brunswick, Frederictorn, NB
David Methven ~ Canadian Rivers Institute and University of New Brunswick, Saint John, NB
Jon Percy ~ BoFEP and Sea Pen Communications, Granville Ferry, NS
Andrew Spring ~ Fundy Biosphere Reserve, Moncton, NB

Judges for Student Awards

Wayne Barchard
Michael Butler
Patricia Hinch
Jon Percy
Ashley Sprague
Peter Wells
Maxine Westhead

BoFEP Environmental Stewardship Award Committee

Rodrigo Menafra, Chair
Michael Butler
Patricia Hinch

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Awards Presented at the Workshop

BoFEP Environmental Stewardship Award 2011

Stephen Hawboldt

The BoFEP Environmental Stewardship Award 2011 was present to Stephen Hawboldt in recognition of his vision, energy and dedication toward healthy watersheds and wetlands around the Bay of Fundy. For the past two decades, as Executive Director of the Clean Annapolis River Project, Steve Hawboldt has been the pre-eminent voice for environmental conservation and stewardship throughout the Annapolis Valley and adjacent areas of the Bay of Fundy. His inspiring leadership, formidable networking and management skills, and his infectious enthusiasm have sparked a host of environmental success stories throughout the region. He has always been adept at bringing the right partners to the table and encouraging them to work together to develop win-win solutions. He has long been, and continues in retirement to be, a forceful voice for environmental reason and responsibility in the Fundy region. 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.

BoFEP Chair, Peter Wells (l) presenting Stephen Hawboldt (r) with the BoFEP Environmental Stewardship Award 2011.

Best Undergraduate Student Paper Presentation

Melissa Herbert of Mount Allison University for:
Diurnal and Nocturnal Foraging Behaviour of Staging Semipalmated Sandpipers in the Upper Bay of Fundy
Melissa A. Hebert[1], Jenna T. Quinn[1] and Diana J. Hamilton[1]
[1]Mount Allison University, Sackville, NB

Best Graduate Student Paper Presentation

Andrew Taylor of Mount Allison University for:
Movement Patterns and Habitat use of Atlantic Sturgeon, *Acipenser oxyrinchus*,
from the Saint John River, New Brunswick, Canada
Andrew D. Taylor[1] and M.K. Litvak[1]
[1]Mount Allison University, Sackville, NB

Best Undergraduate Student Poster

Alison Bijman of Saint Mary's University for:
The Influence of Tidal Creek Networks on Wetland Vegetation Colonization in a Macro-tidal System
Alison Bijman,[1,2] J. Lundholm,[1] and T. Bowron[2]
1Environmental Studies Program & Dept. of Biology, Saint Mary's University, Halifax, NS
[2]CBWES Inc., Halifax, NS

Best Graduate Student Poster

Betsy Barber of UNB, Saint John for:
Predation Effects on Juvenile Invertebrates in Two Rocky Subtidal Communities
Betsy L. Barber[1] and Heather L. Hunt[1]
[1]University of New Brunswick, Saint John, NB

(L-R) Andrew Taylor, Melissa Herbert, Alison Bijman (Betsy Barber absent). Congratulations to the award winners and to all the students for their enthusiastic participation and the high calibre of their presentations.

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/

ACAP Saint John

ACAP Saint John is a multi-stakeholder enivronmental non-governmental organization with an enviable reputation of delivering sound third-party advice on contentious environmental issues in southern New Brunswick. ACAP's competitive advantages are founded on the exceptional leveraging of financial assets through multi-sectorial stakeholder engagement, which are augmented by a well-established and constantly managed information network. ACAP Saint John aspires to incorporate forward thinking and innovative facets of sustainable development into all of their community centric initiatives.

To learn more about ACAP Saint John, visit: http://www.acapsj.com/

Opening Remarks and Keynote Address

OPENING REMARKS

SUSTAINING THE BAY OF FUNDY, ITS WATERSHED, ESTUARIES AND COASTAL WATERS, NOW AND INTO THE FUTURE

Peter G. Wells

Bay of Fundy Ecosystem Partnership (BoFEP), and Faculty of Management (Marine Affairs Program and School for Resource and Environmental Studies) and International Ocean Institute, Dalhousie University, Halifax Canada (oceans2@ns.sympatico.ca)

On behalf of BoFEP, welcome to the 9th BoFEP Bay of Fundy Science Workshop, being held this year at the Delta Brunswick Hotel, Saint John, NB, and co-hosted by ACAP-Saint John and BoFEP. I thank Tim Vickers and ACAP-Saint John for their leadership in organizing the meeting over the past year. A number of people on the organizing committee deserve our thanks for their considerable work and assistance, especially Ms. Crystal Colpitts (Logistics) and Dr. Jon Percy (Program). We are also very grateful to the other workshop sponsors for their financial assistance; this has helped make the workshop possible during these economically challenging times.

Each of the BoFEP Science Workshops has had a different theme since the first workshop in 1996 (Percy et al. 1997), hence they have considered many topics about the Bay's habitats, living resources and ecological integrity. The workshops were inspired by a collective desire to manage the Bay as a whole ecosystem, to study specific questions such as protecting migratory bird habitat and conserving endangered species such as salmon and right whales, and to meet periodically to exchange Fundy information and inspire new research. The past three workshops, in 2004 (Cornwallis, NS), 2006 (St. Andrews, NB) and 2009 (Wolfville, NS), covered "The changing bay over the past 400 years", "Challenges in environmental management" and "Resource development and its implications", respectively (see www.bofep.org/publications for the Proceedings of these meetings and previous ones). This year, we are addressing "Protecting the Watersheds and Estuaries", focusing on the intimate linkages between the land and its many watersheds, the estuaries, and the Bay's coastal waters. Saint John is a particularly appropriate setting for such a theme, given the large Saint John River watershed and estuary, the work of UNBSJ's Rivers Institute and ACAP-Saint John on the river and local tributaries (e.g. Marsh Creek), the historic industrialized city and port, and the enormous oceanographic influence of the river's discharge on the Bay of Fundy and Gulf of Maine (Beardsley et al. 1997).

We have an excellent program for this year's workshop, thanks to all of the contributors. The Program covers a range of topics, from the ecology of intertidal areas, to the biology and ecology of estuarine and coastal fish, and to management topics such as information management needs, planning and conservation, and the role of marine protected areas (MPAs). However, some important topics are not covered this year. These include education and outreach, the different historical and societal perspectives of marine conservation, and the significance of cumulative effects of different stressors on the various ecosystems of the Bay. Given the importance of engaging members of coastal communities more actively and addressing their concerns, such topics should receive dedicated attention at future forums and workshops.

Workshops are gathering places for colleagues, old friends and new acquaintances. While in Saint John, it is important to use the workshop to meet and discuss, to strengthen networks and partnerships, and to think about new research and management initiatives. Your views and engagement in the workshop programs are vital to ensure that we are tackling subjects vital to the longer term sustainability of the Bay's ecosystems, i.e. habitats, biodiversity and productivity.

Current marine environmental research, the published literature (primary and grey), media reports, and observations of community groups around the Bay show continuing concerns about the Bay's health and ecological integrity. These include climate change, living and non-living resource extraction, and increasing industrialization (see recent BoFEP, GOMC and RARGOM publications; Pesch and Wells 2004; Burt and Wells 2010). Significant environmental concerns include the impacts of expanded salmon aquaculture on both sides of the Bay; tidal power development in both the upper and lower Bay, and its potential impact on species and ecological processes, as well as the challenges of conducting meaningful monitoring prior to approved development; the risks of oil spills in the Bay and greater Gulf and our state of preparedness to deal with them; and the implications of seasonal toxic algal blooms and year-round sewage pollution to shellfish fisheries and human health.

The Bay has already been significantly changed over the past 400 years (see Proceedings of past workshops). It is important to know whether proposed new developments and cumulative stress will tip the bay's ecosystems and resources beyond the point of recovery. Our biggest scientific challenge is to measure the resiliency of the Bay, assuming its current condition as a baseline.

A comprehensive, legally recognized management plan and program is needed for the Bay of Fundy. This would ensure coordination and cooperation between the various players as they act on the above concerns and others. A management plan was promised at the final session of the GOMC Gulf of Maine Summit in Fall 2004, to be promulgated under Canada's *Oceans Act* (King and Mackenzie 2005, pp. 15–16), but it has yet to appear. Despite the delay, ocean managers realize that the Bay of Fundy's sustainable future requires such a comprehensive plan and program, in the spirit of Large Marine Ecosystems (LMEs, USA), Large Ocean Management Areas (LOMAs, Canada), and the principles of precaution, ecosystem-based management and integrated coastal and ocean management. This plan should be given priority by responsible government departments, and groups such as GOMC. As well, the crucial role of coastal municipalities and municipal planners regarding coastal land use and its sustainable development should be considered in such a plan. Indeed, this role is addressed in the workshop session on "management, planning, and conservation" (see Session H, this Proceedings; also see Sprague and Graham 2011, BoFEP website).

Over the past 16 years (1995- to date), our team at BoFEP and members of BoFEP's various working groups have addressed some of the Bay of Fundy issues, and the science and management needs in an objective and non-advocative manner. This has been accomplished through a combination of research coordinated by the working groups, the biennial workshops, and Fundy related communications (Web site, fact sheets and newsletter). BoFEP's 15th Anniversary is in 2012. In preparation for that, we are launching the BoFEP strategic plan in October (BoFEP 2011). As well, over the past three years we have become more focussed on selected projects dealing with land based activities/pollution, its impact on coastal waters, and solutions involving coastal communities, municipal planners and First Nations (Wells et al. 2011). At all times, we are open to a wider input and viewpoints into BoFEP's operation and future work, as well as to suggestions for additional funding opportunities for our programs.

Several on-going and important Bay of Fundy-related events require everyone's engagement. The New 7 Wonders of Nature Competition is still open (www.MyFundy.com), with the Bay of Fundy being the only Canadian entry; it needs your votes and those of individuals in your network. This competition is producing really important publicity for the Bay, so be sure to vote and encourage others to vote! Second, 2011 is the centenary of the establishment of Canada's Parks Service (Parks Canada), in 1911; visit and celebrate Fundy and Kejimkujik National Parks in particular, and support efforts by Parks Canada to establish a National Marine Conservation Area soon in the Bay. Thirdly, we should be aware of the upcoming Rio+20 Conference on Environment and Sustainable Development, June 2012, and contribute to Canadian initiatives on key coastal and ocean issues at this meeting.

Finally, a new initiative of the GOMC (Gulf of Maine Council on the Marine Environment) is underway for assessing the state of the marine environment in the GOM (see www.gulfofmaine.org/stateofthegulf). BoFEP has contributed to this initiative by preparing a theme paper (Wells 2010), by reviewing theme papers in preparation, and by researching the use and influence of the first set of papers (Soomai et al., this Proceedings). The Council and the funding department (DFO 2011) are looking for topics for future theme papers. This is an opportunity for everyone to engage in a project that is integrating scientific information, ecosystem indicators and monitoring data, communication needs, policy making, and management action on the Bay of Fundy and greater Gulf of Maine.

In particular, the GOMC is seeking input from everyone into the revised Emerging Issues theme paper for 2012 (see Wells 2010). There are many new issues to consider, in the context of the Bay of Fundy, its watersheds, and the greater GOM. The following are a few for consideration: micro-plastics in the ocean; legacy underwater munitions; dams, reservoirs, and flow regulation (Prowse et al. 2004); the future of the endangered inner Bay of Fundy salmon; environmental aspects of tidal energy (addressed at this workshop); cumulative effects of aquaculture (salmon farming) on fisheries, such as lobster in St. Mary's Bay, NS; pharmaceuticals and personal care products – their ecotoxicology in the Bay and its watersheds; climate change and its impacts (e.g., Are the Bay of Fundy and GOM becoming more acidic?); the control of invasive species, such as crabs and tunicates; harmful algal blooms – their status in the Bay?; the intersection/interface of coastal oceanography and human health; the risks associated with oil spills and other hydrocarbon inputs; and the need to continue to document Fundy's marine biodiversity through programs such as the Census of Marine Life. There are undoubtedly other emerging issues (e.g., Sprague and Graham 2011 and the views of municipal planners). We hope to hear about them from you.

The above briefly describes our activities and some of the challenges facing the Bay of Fundy. On behalf of BoFEP, I wish everyone a very enjoyable and informative workshop in Saint John and many years of productive work on the Bay of Fundy, its watersheds and its estuaries.

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KEYNOTE ADDRESS

THE MARSH CREEK RESTORATION INITIATIVE

Tim Vickers

Executive Director, ACAP Saint John (acapsj@rogers.com)

The Marsh Creek watershed is a 4,000 hectare landscape that defines the eastern sections of the City of Saint John in the province of New Brunswick, Canada. The watershed embodies six tributaries that each spring to life in scenic and forested hillsides before descending into a myriad of commercial, industrial and residential developments as they flow towards their terminus in the world-renowned Bay of Fundy.

This expansive feature bears a rich and enviable history of having provided a wealth of resources to a young and developing port of Saint John. The clean and abundant water that was used for drinking, washing and boating throughout the City also supported healthy populations of trout, salmon, eels and mackerel that provided sustenance to many residents. The expansive marsh flats were dyked and developed for agriculture with local features such as Haymarket Square still paying tribute to their importance. While only ghostly remnants of the wooden fishing wharves jut out from its banks, the folklore surrounding Marsh Creek's most famous export still abound; the legendary *Marco Polo*, the fastest ship in the world of its time, which was reputed to owe its speed to the bending of its keel on the muddy bottom of Marsh Creek where it was built and launched in 1851. There is no doubt that Marsh Creek was a fundamental part of the successful establishment and growth of Canada's oldest incorporated city.

Unfortunately, the characteristics that made Marsh Creek an early attraction to settlers also made it an attractive location upon which to export the less desirable by-products of an urban environment. Residential, commercial and municipal wastewater outfalls were directed into the lower sections of the creek, resulting in the creation of several kilometres of toxic and foul smelling flows that exist to this day. Industrial operations with little environmental containment leached dangerous chemicals into the stream and the riparian areas that contained it. Oils, tars, antifreezes and perhaps most concerning, thousands of litres of the carcinogenic wood preservative creosote still rise from the sediments on warm summers days, posing a ongoing threat to fish, wildlife and even human visitors.

Most surprisingly, and disappointing, was the practice of developing large commercial properties in the expansive marsh flats located five kilometers upstream of the Bay of Fundy. This region, labelled by early settlers as the Great Marsh, is located below the level of high tides in the Bay of Fundy and therefore subject to extensive flooding. Attempts to alleviate the flooding involved the creation of a causeway with simplistic flood gates across the mouth of Marsh Creek. While this artificial barrier has helped alleviate (but not stop) the flooding, it has also posed an impediment to the migration runs of anadromous fishes such as alewives and smelt that could benefit from the upstream spawning habitats in Marsh Creek. In summary, neglect, short-sightedness and a lack of urban planning has degraded Marsh Creek from a once vital and integral community asset, into an embarrassing socioeconomic and environmental liability.

Fortunately, ACAP Saint John has identified an unprecedented and visionary opportunity to not only revitalise Marsh Creek into a valuable community asset, but to position it as the central landscape feature in Saint John's long term growth strategy. Moreover, we believe that this contemporary watershed revitalisation titled "The Marsh Creek Restoration Initiative (MCRI)" represents the most ambitious sustainable development project ever proposed for Atlantic Canada.

The MCRI is founded on two overarching principles; first, enhance Marsh Creek's natural features to benefit the community and secondly utilise its existing blue corridors as a framework for a multi-jurisdictional active transportation route. Specifically, ACAP Saint John proposes to enhance the physical and ecological integrity of Marsh Creek's wetlands to increase the total volumetric capacity of the watershed to store and mitigate the release of stormwater runoff. These enhanced wetland features will also serve to improve the aesthetic appearance of our region while creating the impetus for new eco-tourism opportunities such as nature photography and adventure racing. The expanded aquatic habitat will simultaneously serve as exceptional habitat for amphibians, reptiles, fish, mammals and all manner of resident and migratory birds. This blue web of six tributaries, eighteen lakes and countless wetlands will become the link between the terrestrial world through which Marsh Creek flows and the expansive marine environment of the Bay of Fundy and the Atlantic Ocean. The nature of this proposed watershed transformation also creates exceptional opportunities for research on the re-establishment of fish communities in a Gulf of Maine tributary.

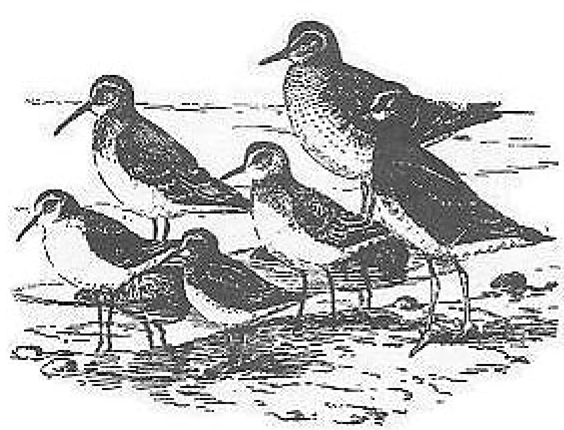
The active transportation route will provide the means by which the greater Saint John community can directly immerse itself in the wonders of this urban watershed. New and much needed walking and cycling opportunities will place tens of thousands of residents and tourists amidst ecological treasures, embellished with a rich learning environment created by effective and visually pleasing interpretive panels and education hubs. Marsh Creek, being the geographic centre of the region, will naturally provide opportunities to interconnect with other key features such as the shopping district, Rockwood Park (one of the largest municipal parks in Canada), and the well-established and highly valued Harbour Passage walking trail. This active transportation route will be the link between the major residential and commercial centres of greater Saint John.

It has been oft stated that when it comes to delivering on a truly exceptional and innovative vision that timing is everything. In the case of the Marsh Creek watershed and the greater Saint John community, the time to act is now. The MCRI is poised to capitalise on the positive momentum building in our community. Harbour Cleanup will see the end of wastewater discharges into Marsh Creek by 2013 thereby opening a new window of cleaner and safer water. The City of Saint John has boldly embraced the merits of a revitalised Marsh Creek by incorporating it into their newly minted Municipal Plan. And most importantly, the community has clearly provided their support for this vision by way of constant and consistent messaging provided through dozens of media and public presentations. The MCRI is more than just the enhancement of Marsh Creek; it is Saint John's watershed legacy.

Session A

INTERTIDAL BIODIVERSITY AND ECOLOGY

Chair: Gerhard Pohle, Huntsman Marine Science Centre, St. Andrew's, New Brunswick



MONITORING MARINE BIODIVERSITY: TESTING THE EFFECTS OF THE SUBSTRATE OF A SITE ON RECRUITMENT IN COBBLE-FILLED COLLECTORS

Lauren Ellis, Rémy Rochette, and Heather L. Hunt

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Insufficient resources are allocated to studying marine environments and associated biodiversity. A biodiversity monitoring tool (hereafter collector) targeting organisms inhabiting shallow subtidal areas of cobble substrate is being tested at sites in the southwest Bay of Fundy, Canada, to standardize its protocol to facilitate monitoring and conservation efforts. The main objective of this study is to determine if the substrate on which the collector is deployed affects the community structure or species abundances found inside it, which in turn will indicate whether future collector deployments should be preceded by substrate surveys. In July 2009 we deployed ten collectors at each of six different sites (1600–5400 m^2), two in each of three geographic areas (270–1400 km^2) and recovered these three months later; within each area, the bottom of one site was predominantly cobble while the other was fine-sediment. The two sites within each area were in close proximity to one another (240–730 m) to keep larval supply as similar as possible. Two of the three areas were recently identified by DFO as Ecologically and Biologically Significant Areas. Preliminary results show that the substrate upon which collectors were deployed has a pronounced effect on the community structure found within it, with differences between fine-sediment and hard bottom sites being related both to what species are present as well as their abundances.

VARIABILITY IN TAXONOMIC DIVERSITY OF EPIFAUNA AT TWO SPATIAL SCALES IN THE SHALLOW ROCKY SUB-TIDAL ZONE OF THE SOUTHWESTERN BAY OF FUNDY

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As human activities are causing unprecedented declines in marine organisms and associated ecosystem goods and services, it is critical to develop management strategies that enable the sustained use of our oceans. Recently, federal programs have shifted towards an ecosystem-based approach to management with the principle objective of preserving biodiversity. However, with lack of suitable monitoring to provide standardized empirical assessment of biodiversity patterns, further management is impeded. Cobble-filled passive larval collectors are being investigated as a method to assess the epibenthos of shallow rocky-bottom habitats as settlement and recruitment patterns are linked to community structure. Our project will contribute to the development of this monitoring tool and program first by providing quantitative data on patterns of biodiversity in four study areas in the southwestern Bay of Fundy (each containing three nested sites), including three proposed Ecologically and Biologically Significant Areas. We will also contrast variability in biodiversity at two spatial scales (between areas and between sites within areas), which will help to refine the scope of future collector deployments (e.g., how many sites per area). Preliminary data on taxonomic diversity will be presented here from five collectors in three nested sites in each of the four study areas. Other applications to be investigated include: (1) use of biological trait analysis to determine if spatial patterns in communities are the same whether based on taxonomic or functional criteria, and (2) assessment of spatial patterns of biodiversity using different levels of taxonomic resolution to support cost-benefit (time/resolution) analyses for future sampling efforts.

MERCURY METHYLATION AND DEMETHYLATION BY THE POLYCHAETE WORM *NEREIS DIVERSICOLOR* IN INTERTIDAL MUDFLATS

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Introduction

Power generation and gold mining have lead to increasing concentrations of mercury (Hg) in the global atmosphere. Mercury can migrate towards polar regions via the 'grasshopper effect' and is found at elevated concentrations in remote ecosystems (O'Driscoll et al. 2004). Methylmercury (MeHg) is an endocrine disrupter, a neurotoxin and is the most toxic Hg species, because it is able to cross the blood-brain barrier. MeHg is bioaccumulated in organisms, biomagnified through trophic levels and can therefore cause acute toxic effects in higher organisms. It is the uptake of MeHg at the base of the food chain that determines the rate of biomagnification and eventual toxicity of Hg to higher organisms. Therefore, quantifying the fundamental processes that control the methylation rates of Hg at the base of the food web are critical to understanding the biomagnification and toxicity of Hg to birds and fish in aquatic ecosystems.

'Biological Mercury Hotspots' have been identified in South-East Canada because of elevated concentrations of Hg detected in birds and fish inhabiting inland freshwater wetland sites (Evers et al. 2007). While much is known about the processes affecting Hg speciation in freshwater wetlands, very little is known about the biogeochemical factors affecting Hg methylation and demethylation in coastal environments. The Minas Basin of the Bay of Fundy, Nova Scotia has the world's highest tidal amplitude giving rise to mudflats that extend several kilometers from the shore at low tide. Mudflats and wetlands of the Minas Basin are designated as internationally significant under the Ramsar convention due to their importance as feeding areas for migratory birds such as Semipalmated Sandpipers (*Calidris pusilla*). Therefore the mudflats of the Minas Basin are an excellent model ecosystem for studying the Hg dynamics at the base of the coastal food chain.

Some areas of mudflats in the Minas Basin contain elevated concentrations of MeHg, due to the availability of organic matter and to the reduction of Fe^{3+} and/or SO_4^{2-} during anerobic respiration by sediment-inhabiting microorganisms (Sunderland et al. 2006). The polychaete worm *Nereis diversicolor*, which are abundant in many of these areas of the mudflats, live in permanent U- or Y-shaped burrows which they ventilate and oxygenate with fresh seawater, increasing the sediment-water interface by up to three times and producing a redox chemocline. They have a flexible feeding strategy enabling them to feed on organic detritus and phytoplankton (i) suspended in the water column (filter feeding) or, (ii) in surface sediments (deposit feeding) (Smith et al. 1996; Scaps 2002).

Because *N. diversicolor* can affect the physiochemical parameters of its habitat through burrow formation and changing redox chemistry, they can be considered ecosystem engineers (Aberson et al. 2011) and therefore may affect the bioavailability and chemical speciation of contaminants in intertidal mudflats (Cardoso et al.

2008). We carried out a laboratory experiment to determine the impact of *N. diversicolor* on the speciation of Hg in the mudflats of the Minas Basin.

Methods

Sediments were collected from four intertidal mudflats in Southern Bight of the Minas Basin, Bay of Fundy at: Wolfville, NS (MeHg: 569 pg g^{-1}, Hg: 25.2 ng g^{-1}), Windsor, NS (MeHg: 546 pg g^{-1}, Hg: 26.2 ng g^{-1}), Hantsport, NS (MeHg: 358 pg g^{-1}, Hg: 26.1 ng g^{-1}) and Kingsport, NS (MeHg: 448 pg g^{-1}, Hg: 7.86 ng g^{-1}). Both Wolfville and Windsor sediment samples contained oxic and anoxic sediment, Hantsport sediment was completely oxic and Kingsport sediment was completely anoxic. Seawater (MeHg: 19.2 pg L^{-1}, Hg: 0.469 ng L^{-1}) was collected from Wolfville harbour. *Nereis diversicolor* (MeHg: 5820 pg g^{-1}, Hg: 103 ng g^{-1}) were hand-collected from Wolfville in the same location as the sediment was collected.

Sediments from all four sites (300 g dry weight) were weighed into 800 ml HDPE containers (40 containers, 10 per sediment type). Containers were then kept in environment chambers at 10 ˚C under a 16:8 light:dark cycle. Seawater was used to top up the level in each container to the 800 ml mark. Before addition of the worms, water in the containers was bubbled continuously with air for 24 hours.

Ten *N. diversicolor* (0.15 g, SD = 0.05, n = 200) per container were added to half of the vessels containing the sediments. This gave five replicates of each treatment: worm-inhabited and worm-free sediment. These were left for a total of 28 days with air bubbling continuously in every vessel. Every seven days the water overlying the sediment was siphoned off and replaced with fresh seawater.

After 14 and 28 days, sediment samples were taken in each microcosm. A sample was taken from the sediment surface and small sediment cores (diameter =1.5 cm, length = 9 cm) were taken directly below this surface sample. In worm-inhabited Windsor and Wolfville sediments where the oxygenated burrow linings were clearly visible, a small sample of these burrow linings were taken from the cores.

After 28 days the microcosms were inverted and sediment sorted to find and count the worms (those missing were presumed dead). Methylmercury (MeHg) and inorganic mercury (Hg(II)) was determined in sediment and worm tissue samples by alkaline digestion, ethylation purge and trap GC-CVAFS (Gas Chromatograph – Cold Vapour Atomic Fluorescence Spectrophotometer) following U.S. EPA method 1630 (U.S. EPA 2001).

Results and Discussion

N. diversicolor survived reasonably well in the sediments and although there was approximately a 20% mortality reported in all treatments this was likely due to the difficulties in finding worms in the sediment after the incubation rather than mortality occurring. Worms incubated in the Wolfville and Windsor sediment gained weight (2.15 % and 4.16 % respectively) but worms lost weight considerably (14.1 % and 20.7 % respectively) in the Hantsport and Kingsport treatments. In all treatments the concentration of MeHg and Hg(II) in the tissues of the worms was greater after the 28 day incubation compared to the concentrations before addition. The %MeHg however, was similar after incubation in all treatments compared to before addition to the sediments.

Generally speaking, the worms did not affect the speciation of Hg in the completely oxic (light colored) Hantsport sediment and completely anoxic (dark colored) Kingsport sediment. There was no visible sign that the worms affected the redox conditions of either of these sediments and there were no burrows made visible by a change in color of the sediment (Figure 1). It can therefore be concluded that either; (i) in sediment that has very high or very low Eh, *N. diversicolor* does not affect the speciation of Hg, or (ii) that in the Hantsport or Kingsport sediments there was insufficient available food for the polychaetes and they therefore did not feed or interact with the sediments.

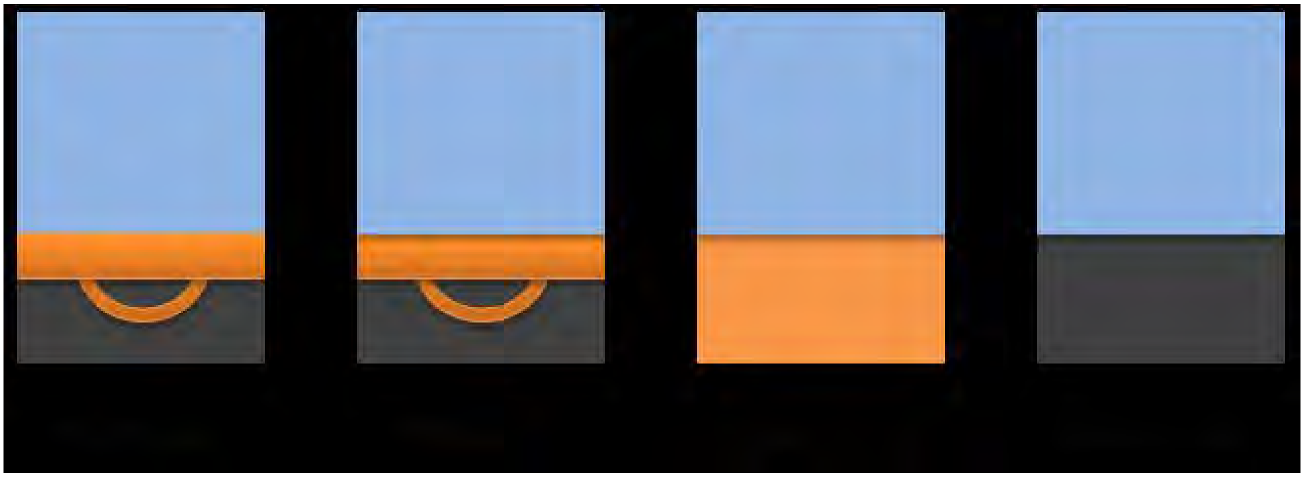

Figure 1. Schematic representation of sediments from Wolfville, Windsor, Hantsport and Kingsport after 28 days incubation with *Nereis diversicolor*. Black sediment represents anoxic sediment (reduced sulfur). Yellow sediment represents oxic sediment (oxidized sulfur).

In the sediments which contained both oxic and anoxic sediment (Wolfville and Windsor), an oxic/anoxic (light/dark) boundary quickly became established in the sediment despite the sediment being homogenized before addition to the microcosms. There were also visible burrows lined with oxic (light) sediment in the otherwise anoxic (dark) portion of the sediment (Figure 1). After both 14 and 28 days, there were elevated concentrations of Hg(II) in oxic burrow walls compared to bulk worm-inhabited and worm-free treatments. This was most likely due to an increase in the organically bound or microbially associated Hg as the activity of burrow ventilation increases organic carbon and microbial biomass (Saiz-Salinas and Francés-Zubillaga 1997).

The concentration of MeHg in worm-inhabited surface, bulk and burrow wall Windsor sediment samples was decreased after 14 days compared to the worm-free control treatment. However, after 28 days, MeHg concentration in the worm-inhabited surface, bulk and burrow wall sediments of Windsor sediment (and to a lesser extent Wolfville sediment) was increased compared to the worm-free control treatment. The reason for the difference in observations made after 14 days compared to 28 days may be related to the flexible feeding strategy of *N. diversicolor* (Scaps 2002) and can be explained by a shift in the feeding activity of the worms from filter feeding to deposit feeding.

During the first half of the experiment worms fed on the organic matter suspended in the sediment and water column by pumping fresh seawater into the burrow wall (Riisgård 1994), thereby ventilating the burrow wall and creating oxic conditions, which in turn resulted in Hg demethylation. In the second half of the experiment, the worms exhausted the supply of suspended organic matter and instead switched feeding strategy to the ingestion of sediment and assimilation of the organic matter associated with surface sediments (Reise 1979). Sediment passed through the anoxic gut of the worm and was deposited in the faeces both at the sediment surface and in burrow walls. The anoxic conditions in the polychaete gut may have favored Hg methylation either during passage through the gut or after deposition of faeces.

Conclusions and Environmental Relevance

The polychaete worm *N. diversicolor* contributes to both Hg methylation and demethylation, depending on the feeding strategy employed. When the availability of suspended phytoplankton and organic particles increases above a threshold, the polychaete switches from deposit feeding to filter feeding and therefore results in Hg demethylation rather than methylation.

When sediment cores are taken to determine the concentration of Hg and MeHg for environmental monitoring or risk assessment, the concentrations reported may not accurately reflect the environmentally relevant availability of Hg and MeHg. This is because the walls of polychaete worm burrows, which have more interaction with inhabiting organisms and the water column than the bulk sediment, may contain localized, elevated concentrations of MeHg and Hg(II). This research has important implications for Hg biogeochemical models and understanding Hg biomagnification in coastal ecosystems.

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WINTER POPULATION DYNAMICS OF THE INTERTIDAL AMPHIPOD, *COROPHIUM VOLUTATOR*

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Corophium volutator is a marine invertebrate, occupying u-shaped burrows in the intertidal mudflats throughout the Bay of Fundy. The life history of *C. volutator*, including its population dynamics, has been well-studied through the summer, but little is known about its population dynamics through winter. We know, indirectly through comparisons between annual samples, that *C. volutator* populations reach their lowest densities during the winter, but it is not known whether the decline in population density observed is continuous, or if it is punctuated by extreme abiotic stresses, such as cold weather events. We also lack any information of specific adaptations *C. volutator* may exhibit to survive the winter. Does it employ an avoidance strategy to avoid the cold (i.e., does it burrow deeper into the mud), or is it tolerant to freezing temperatures?

To address when *C. volutator* population densities change through winter, we sampled two focal mudflats (Grande Anse, NB, and Pecks Cove, NB), at 3-week intervals over two winters (2009–2010 and 2010–2011). We found that, when *C. volutator* population densities were above 2000 ind. m^{-2}, a linear decline in density was observed over both winters. However, if densities were below 2000 ind. m^{-2}, a decline could not be detected.

C. volutator may exhibit an avoidance strategy to cold temperatures, by burrowing deeper into the mud through winter. Depth selection of *C. volutator* in the mud has been measured in the summer, but no prior investigation has measured this in response to winter conditions. Our measurements of *C. volutator* depth selection indicate that it did not shift its burrow depth downward in response to winter, and that approximately 80% of the population is found in the top 1.5 cm of mud. We did observe a shift, in the proportion of individuals in mud cores, toward the surface, where temperatures were most variable and severe. It would appear that *C. volutator* survives the winter by being tolerant, and not through avoidance strategies.

We know that *C. volutator* is present in the mudflats in relatively high densities through the winter, and that those densities decline through the winter. We wanted to assess whether the declines in *C. volutator* population densities could be attributed to cold temperature. To measure the effect of cold, we performed a stress test in a lab using mud cores containing *C. volutator*, collected from the field. We measured *C. volutator* tolerance to freezing temperatures (-3,-8°C), over a two week period. We found that *C. volutator* was tolerant to freezing at both temperatures over short-term exposure (4 days), after which survivorship declined. Survivorship was higher in the -3°C treatment, than in the -8°C, after a longer exposure time.

These results enhance our understanding of an ecologically important species, *C. volutator*, over a period of time that has previously been understudied. We now have evidence that suggests that *C. volutator* population declines occur consistently through the winter, that *C. volutator* individuals do not avoid harsh conditions by burrowing deeper in the mud, and that they are tolerant to continuous short-term exposure to cold temperatures.

Best Undergraduate Oral Presentation

DIURNAL AND NOCTURNAL FORAGING BEHAVIOUR OF STAGING SEMIPALMATED SANDPIPERS IN THE UPPER BAY OF FUNDY

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Abstract

Each summer more than 70% of the world's population of Semipalmated Sandpipers (*Calidris pusilla*) utilizes upper Bay of Fundy mudflats as staging grounds; doubling their mass in only two weeks in preparation for their non-stop flight to South American wintering grounds. During this period effective foraging is critical to ensure adequate fat deposition. Diurnal and nocturnal foraging is known to occur in this species, but little research has been done on how foraging behaviours differ between day and night. Further, while feeding, Semipalmated Sandpipers typically peck and probe for invertebrates, primarily the amphipod *Corophium volutator*. However, sometimes birds also exhibit a different foraging method, skimming, in which the bill is run along the surface of the sediment, possibly to obtain alternate prey items. We used focal observations to compare Semipalmated Sandpipers foraging both day and night at two mudflats in the upper Bay of Fundy during summer 2010. We tested whether foraging rates and foraging modes used differed between day and night, and assessed the effect of a suite of factors (site, available prey, time of day, distance to shore, and conspecific density) on sandpiper foraging behaviour. We found that pecking was used primarily during the day and skimming was only observed at night. Factors such as time, site and distance from shore were found to be more influential to foraging behaviours than available prey. These results highlight the fact that nocturnal activities require further studies and should be considered for the conservation needs of this species.

Introduction

The upper Bay of Fundy is recognized by the Western Hemispheric Shorebird Reserve Network as a Site of Hemispheric Importance. Here, approximately 70% of the Semipalmated Sandpiper (*Calidris pusilla*) population (Hicklin 1987) uses intertidal mudflats for staging during their annual fall migration from the Arctic to South America. During this staging period, birds feed intensively on mudflat invertebrates, approximately doubling their weight before departing for the non-stop flight to South America.

Sandpipers foraging during the day in this region typically employ pecking and probing as their main feeding modes. However, previous work suggests that they can feed differently when needed. Skimming, a tactile feeding method which involves sandpipers maintaining contact between their bill and the top of the sediment while taking steps, and moving their head side-to-side, has been noted, probably in response to the absence of their most common prey item and superabundance of an alternate prey (ostracods) (MacDonald et al. 2012).

Much less is known about nocturnal foraging in this species, although it is common among other shorebirds (Robert and McNeil 1989). Because Semipalmated Sandpipers can use both visual and tactile cues to detect prey, a switch from visual foraging (such as pecking) during the day to tactile foraging (skimming or probing) at night could be predicted. To assess this, we quantified foraging behaviour using focal observations of Semipalmated Sandpipers foraging during both day and night in the upper Bay of Fundy. We also examined a suite of factors, including time, site, available prey, forager densities and site safety, to determine which best predicted the foraging activities of these birds.

Materials and Methods

We observed foraging sandpipers at Grande Anse, NB (Chignecto Bay) and Avonport, NS (Minas Basin) between 25 July and 25 August, 2010. Our daily observations were interspersed between the mudflats, during every low tide (day and night) from the time of the sandpipers' arrival until their departure.

We used binoculars or a night vision scope and infrared illuminator for day or night, respectively, to observe individual birds. When observing a bird we continuously dictated its foraging behaviours, for as long as possible, into a digital hand-held voice recorder, classifying each foraging attempt as pecking, probing, or skimming. Video data were also collected and used to determine duration of individual foraging attempts, as well as density of foragers. Distance that birds were foraging from shore was noted using a handheld GPS. Availability of potential food items was also assessed though collection and processing (see Hamilton et al. 2006) of sediment cores from areas in which birds were foraging. We also collected two surface sediment samples to determine the available biolfilm (as a potential prey item) near where birds were feeding (see Coulthard and Hamilton 2011 for methodology).

Results

We observed a total of 155 birds during the day (79 at Grande Anse; 76 at Avonport) and 38 birds at night (14 at Grande Anse; 24 at Avonport). During these observations skimming was only noted at night. Foraging rate (foraging attempts per minute) was approximately two times higher during the day than at night at both sites (Table 1), primarily because an individual skimming event at night took much more time than an individual peck or probe. Overall foraging rates also differed between the sites, with more rapid foraging at Grande Anse (Table 1). This was driven primarily by an increased pecking rate at that site (ANOVA, $F_{(1,191)} = 53.17$, $p < 0.001$).

	Avonport		Grande Anse	
	Day	**Night**	**Day**	**Night**
Mean	55.46	35.21	80.46	38.31
St. Dev.	18.52	22.36	22.89	15.27

Table 1. Foraging rate (attempts/min.) for Semipalmated Sandpipers foraging at the different site-time combinations [GA day (n = 79), GA night (n = 14), Avonport day (n = 76), Avonport night (n = 24)] in the upper Bay of Fundy during summer 2010.

	Avonport		Grande Anse	
	Day	**Night**	**Day**	**Night**
Mean	43.82	52.68	60.73	47.27
St. Dev.	13.1	18.18	12.2	11.64

Table 2. Proportion of time devoted to foraging (%) for Semipalmated Sandpipers foraging at the different site-time combinations [GA day (n = 79), GA night (n = 14), Avonport day (n = 76), Avonport night (n = 24)] in the upper Bay of Fundy during summer 2010.

Proportion of time devoted to foraging was greater during the day than at night at Grande Anse (ANOVA, $F_{(1,188)}=18.75$, $p=0.01$), but there was no significant difference at Avonport (ANOVA, $F_{(1,188)}=18.75$, $p=0.06$) (Table 2). Less time was spent pecking at night (ANOVA, $F_{(1,191)} = 113.324$, $p < 0.001$), and skimming was used significantly more at night (ANOVA, $F_{(1,191)} = 318.624$, $p < 0.001$). Overall, birds spent more time pecking at Grande Anse (ANOVA, $F_{(1,191)} = 54.64$, $p < 0.001$) and more time probing at Avonport (ANOVA, $F_{(1,191)} = 54.64$, $p < 0.001$).

Peck rate and the proportion of time devoted to pecking were best predicted by models containing time of day (greater during day), distance to shore (positive correlation), and biomass of the amphipod *Corophium volutator*, an important prey item (positive correlation) (multiple regression with the AIC model selection technique, peck rate: $F_{(4,157)} = 62.4$, $p <0.001$, proportion of time devoted to pecking: $F_{(5,156)} = 44.7$, $p <0.001$). Additionally, there was a negative correlation between proportion of time devoted to pecking and bird density in the best model. Unlike pecking, the best model for skim rate and proportion of time devoted to skimming included only time, with more skimming at night (skim rate: $F_{(1,160)} = 583.7$, $p <0.001$, proportion of time devoted to skimming: $F_{(1,160)} = 337.6$, $p <0.001$).

Discussion

In our study, Semipalmated Sandpipers fed extensively at night. They switched from mainly using a visual foraging mode (pecking) during the day to a more tactile foraging mode at night (skimming). Although foraging rates were significantly lower at night than during the day, which on the surface suggests that sandpipers foraged less at night, overall foraging time was more similar. Manseau and Ferron (1991) found a decrease in foraging rate for these birds at their study site. We found that birds pecked more slowly at night, even after excluding time spent skimming, suggesting that this visual means of foraging may be more difficult at night. Perhaps as a result of this, we noted a clear shift from visual to tactile foraging modes from day to night, with tactile skimming only observed at night. This change in behaviour probably explains the similarity between day and night in total time spent foraging. Although the frequency of individual foraging actions declined at night, skimming, which is a more continuous activity than pecking or probing, took up substantially more time for each individual event. Thus, night foraging, although involving a different technique, is an important activity for these birds.

Although overall day versus night trends were consistent between the two mudflats, there were also substantial spatial differences that led to differences in foraging behaviours, specifically pecking and probing. This is not surprising, as Grande Anse and Avonport are in separate arms of the upper Bay of Fundy, each covering different areas, with different sediment characteristic, different threats of predators, different available prey, and multiple other factors that have been known to affect foraging.

Time of day was the strongest individual predictor of foraging behaviour, but other factors also contributed to the best multiple regression models for peck rate and proportion of time spent pecking. Pecking increased with distance from shore. Distance to shore can be used as an index of site safety (Sprague et al. 2008; Beauchamp 2010) as the further the birds are from shore the further they are from where predators, such as Peregrine Falcons (*Falco peregrinus*) and Merlins (*Falco columbarius*), may launch attacks. This allows the birds to forage more and devote less time to vigilance behaviours (Beauchamp 2010). Peck rate and proportion of time devoted to pecking also increased with *C. volutator* biomass. This is not surprising because pecking is used by Semipalmated Sandpipers to capture *C. volutator* as the tide recedes (Beauchamp 2005). As biomass of available *C. volutator* increases it makes sense that pecking would increase because this visual behaviour would be best suited for targeting epifauna (Sutherland et al. 2000), like *C. volutator*, that crawl on top of the sediment. Finally, increasing density of foraging birds was negatively correlated with proportion of time devoted to pecking, perhaps because increased foraging depletes available prey through indirect competition between foraging individuals in an area

(Beauchamp 2007). This could result in less pecking if the birds switch to alternate foraging modes to search for alternate prey.

In conclusion, we found that Semipalmated Sandpipers fed extensively at night by using different foraging behaviours compared to day feeding. Combined with previous observations of use of skimming during the day to target certain prey items (MacDonald et al. 2012), this provides evidence of foraging flexibility that could help this species to respond to future changes in this critical ecosystem. The use of focal observations has allowed us to fill gaps in knowledge for this species as well as to broaden our understanding of their foraging activities during a critical part of their annual cycle. Further studies considering not only foraging rates and time devoted to foraging modes, but foraging success, prey items consumed, biomass and nutritional values of these prey items compared between day and night would allow us to more accurately determine the importance of nocturnal foraging for Semipalmated Sandpipers during their time in the upper Bay of Fundy.

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AN OVERVIEW OF FOOD HABITS AND FORAGING BEHAVIOUR OF SEMIPALMATED SANDPIPERS IN THE UPPER BAY OF FUNDY: IS COROPHIUM STILL THE KEY?

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Semipalmated Sandpipers (*Calidris pusilla*) use the upper Bay of Fundy, Canada, as an important staging area during their annual fall migration. Their main prey in this area has historically been thought to be the mudflat-dwelling amphipod *Corophium volutator*, and fluctuations in its abundance have raised questions about the food supply for these birds.

To address these questions, we conducted a series of studies from 2006–2010 that examined diet, prey availability and quality, and diurnal and nocturnal foraging activities of Semipalmated Sandpipers feeding on mudflats in this region. Specifically, we first videotaped foraging birds to record behaviour relative to prey availability during day and night. After each recording session, sediment samples were collected from the area in which birds were foraging. These samples were later sieved, and invertebrates sorted into taxonomic groups, counted, and weighed and measured where appropriate. Additional samples were collected to estimate biofilm abundance (based on Chlorophyll *a* concentration). We also captured birds in both Chignecto Bay and Minas Basin using a Fundy pull trap, weighed them, and collected small samples of blood from a subset of birds weighing > 35 g. Blood was then separated into plasma and red blood cells, and plasma analysed for stable isotope values of ^{15}N and ^{13}C, as a means of estimating diet in both arms of the Bay of Fundy. Heavy birds were used because the turnover of plasma is very rapid, so selecting birds that had already gained substantial weight ensured that results reflected food consumption while birds were in the region. Invertebrate samples were also collected from the foraging areas and submitted for isotope analyses. Results, when combined using mixing models, provided an estimate of diet for these birds. Finally, we assessed the quality of the various prey items by analyzing fatty acid concentrations in a range of possible prey items. *Corophium* is known to be a high quality prey item, and our objective was to see how other possible prey compared with it.

Results suggest that birds are more flexible in behaviour and diet than previously thought. Sandpipers foraged actively at night by skimming the surface of the mud rather than the typical daytime pecking and probing. Skimming during the day was limited to one mudflat in one year where *Corophium* was essentially absent, but where ostracods were very abundant. In that year we found a highly significant positive relationship between skimming and ostracod abundance (MacDonald et al. 2012). In a subsequent year in which ostracods and *Corophium* were roughly equally available in terms of biomass, no daytime skimming was noted, suggesting that the use of alternate foraging behaviour was based on necessity when the preferred prey was absent and an alternative was available. Isotopic analysis of blood plasma suggests that diets varied between years and locations, with consistent evidence that birds foraging in the Minas Basin fed at a higher trophic level than those in Chignecto Bay (Quinn 2011). Although *Corophium* was always present in the diet, it was not necessarily dominant, and somewhat tied to availability. Alternate foods such as polychaetes and surface biofilm were a regular part of the diet, though ostracods were unimportant. We suggest that biofilm was obtained as by-catch during nighttime skimming; there is no evidence to suggest that birds targeted it. Biochemical profiles indicate that polychaetes are a suitable alternate prey, with levels of polyunsaturated fatty acids not significantly lower than *Corophium*. Conversely, biofilm and ostracods appear to be inferior prey items, with extremely low levels of all fatty acids measured (Quinn 2011). Thus, while the foraging flexibility observed in migrating Semipalmated

Sandpipers suggests they can respond to a changing prey base, different prey may not be entirely interchangeable with respect to efficient weight gain and preparation for migration. Diet in this species is clearly much broader than previously thought, though it is not clear whether this is a change from previous years, or has just now been detected by using different methods. Additional work is required to understand the effects of varying diets on weight gain in Semipalmated Sandpipers foraging in this region. This will help us to predict how future changes in the prey base will affect preparation of birds for migration, and potentially their use of this area.

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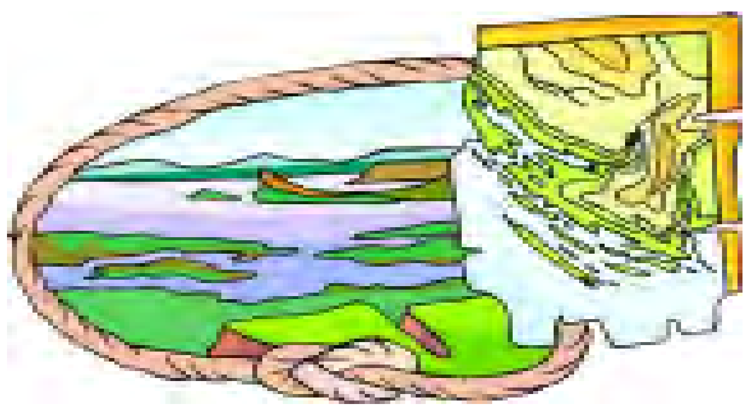
Session B

HUMAN IMPACTS: TIDAL POWER/ CLIMATE CHANGE/AQUACULTURE

Chair: Peter Fenety, St. Andrews, New Brunswick



GAPS, CHALLENGES AND OPPORTUNITIES FOR RESEARCHING THE ENVIRONMENTAL IMPACTS OF TIDAL ENERGY IN THE BAY OF FUNDY

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With the growing demand for renewable energy, there is increasing interest in tidal in-stream energy technologies to harness the considerable tidal energy resources of the Bay of Fundy. However, there are still many uncertainties that will need to be addressed regarding the potential near and far-field effects of tidal in-stream devices on Fundy's marine, coastal and estuarine habitats and species. The next few years will see large-scale demonstration projects in the Minas Passage at the FORCE (Fundy Ocean Research Centre for Energy) test facility (four technologies) and in Cobscook Bay, Maine, as well as community-scale projects off Brier Island, Nova Scotia. With these projects comes a vital opportunity for ground-breaking research and monitoring to address some of the environmental knowledge gaps. However, the powerful and dynamic conditions in Fundy and the diversity and emergent, experimental nature of technology designs pose significant and unique challenges for research and monitoring that will need to be overcome. In 2010, the Fundy Energy Research Network (FERN), an independent organization, was formed to foster collaboration, capacity and information exchange among the multi-institutional Fundy tidal energy research community to address the uncertainties and challenges. This presentation will examine the key knowledge gaps, and challenges and opportunities for research, on the potential environmental impacts of tidal energy development in the Bay of Fundy.

POTENTIAL FAR FIELD EFFECTS OF TIDAL ENERGY EXTRACTION ON INTERTIDAL ECOSYSTEMS IN THE BAY OF FUNDY

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With a resurgence of interest in the installation of tidal power devices in the Minas Passage of the Bay of Fundy, there is an increased need to understand the potential far field effects of tidal energy extraction. This is particularly important within sensitive intertidal ecosystems such as tidal flats and salt marshes. Sediments are the primary determinants of biological activity in the Upper Bay of Fundy. This presentation will focus on providing an overview of potential effects of changes in tidal energy or tidal range and associated changes in hydrodynamic forces, the structure and location of biotic communities and rates of sedimentation and erosion. These changes are most likely to be felt within intertidal communities at the upper reaches of the tidal reference frame. Since the processes of sedimentation and erosion are spatially and temporally variable, field data are required over a range of suspended sediment concentrations, current velocities, water depths, topographies, biotic communities (e.g., vegetation and benthos) and wind wave energy. Results will be presented from field studies within the Upper Bay that have been conducted from 2009–2011 and preliminary hydrodynamics modeling exercises. Since the magnitude of the change in intertidal areas is currently unknown and may or may not occur within a range of natural variability it will be vital to model these processes over a range of environmental conditions.

SHOREZONE CHARACTERIZATION FOR CLIMATE CHANGE ADAPTATION IN THE BAY OF FUNDY

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Human settlement in environments as dynamic as the coastal zone will inevitably lead to conflict between the natural variability of the coastal environment and the economic, social and cultural activities taking place within it. In order to mitigate potential negative impacts (e.g., loss of life and infrastructure), managers and planners need to better understand coastal processes and dynamics. This requires up-to-date shore zone characterization including built structures and a solid understanding of the boundaries of coastal processes and historical rates of coastal change. A dynamic segmentation model was developed within ArcGIS to delineate and characterize the backshore, foreshore and nearshore zones within the Southern Bight of the Minas Basin, Bay of Fundy, Canada. This was populated with data collected during shoreline surveys using a YUMA tablet and any available aerial imagery for the region. Segments were catalogued using a customized decision key to characterize the shoreline. Areas of the coast were assessed for shoreline stability and presence or absence of a cliff (consolidated and unconsolidated). Due to the extensive foreshore areas of saltmarsh that occurred seaward of the MHW line traditionally used to define the shoreline, the edge of marsh was used to delineate shoreline change over time. These data were merged with a LiDAR elevation survey and surficial geology to provide a comprehensive overview of coastal characteristics to serve as the foundation for coastal vulnerability assessments.

THE APPLICATION OF AIRBORNE AND GROUND-BASED LASER SCANNING TO COASTLINE ANALYSIS (FLOOD RISK AND EROSION) AROUND THE BAY OF FUNDY

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The Applied Geomatics Research Group has been conducting research into the application of airborne LiDAR for flood risk mapping for three coastal communities within the Bay of Fundy: Yarmouth, Wolfville-Windsor, and Amherst. The high resolution elevation models (DEM) derived from LiDAR have been used to construct flood inundation maps for these communities. The approach has been to use a past "benchmark" storm to assess the model and then apply relative sea-level rise expected from climate change to determine areas vulnerable to coastal flooding. Other depictions involve projecting storm surge levels on predicted spring high tide levels for these communities. Communities in the upper parts of the Bay are protected from rising sea-levels by dykes where flood inundation maps have been predicted for both overtopping and breaching scenarios. The return period, or risk of these high water events occurring was assessed by analyzing water level time-series data from tide gauges at Yarmouth and Saint John. Ground-based LiDAR has been used to monitor coastal erosion at Mavillette Beach by surveying the dune, glacial till bank, and bedrock cliff in the fall of 2010 and spring of 2011. This technique allows for detailed 3-D change analysis of the coastline over a single storm season. The system has also been used to survey breaches in the dyke at Fort Beausejour with researchers from Mount Allison. The data were integrated with previous airborne LiDAR to form a baseline in order to monitor morphological change in the system resulting from the breaches and salt marsh restoration.

SPATIAL AND TEMPORAL ANALYSIS OF STORM SURGE FLOODING OF DYKELANDS IN THE BAY OF FUNDY

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Over the next century, the Upper Bay of Fundy will likely experience an increase in sea level and frequency of storm events. The predicted one meter sea level rise will place the dyke protected low lying areas and associated infrastructure at significant risk. The purpose of this research is to analyze the spatial and temporal variability in storm surge flooding within dykelands in the Upper Bay of Fundy to assist with planning and emergency management decisions. In addition, we analyze the relative importance of variables (e.g., type and number of water control structures, surface roughness, creek networks, subsidence and dyke design, tidal stage) in determining the rate and extent of coastal flooding within these regions. TUFLOW, a hydrodynamic model was used with SMS 10.0 and ArcGIS to simulate flooding parameters over a multi-resolution grid generated from LiDAR data. Surface roughness was expressed as a Manning's n coefficient and varied seasonally depending on vegetation growth. Initial results indicate that timing with respect to tidal stage (e.g., length of time dyke overtopped) and internal channel complexity exerted the most influence on the duration, velocity and extent of the flooding event. Drainage was influenced most strongly by the spatial arrangement of aboiteaux structures, amount of precipitation, surface cover and spatial configuration of the dyked marshbody. At the projected rate of sea level rise, the current elevations of the existing dykes are insufficient to protect low lying areas behind the dykes including major transportation corridors, wastewater treatment facilities, and coastal towns.

TEMPORAL AND GEOGRAPHIC TRENDS IN ANNUAL ENVIRONMENTAL MONITORING RESULTS AT SALMON FARMS IN SOUTHWESTERN NEW BRUNSWICK, BAY OF FUNDY, 2002–2010

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Abstact

Monitoring of sediments under salmon farms in southwestern New Brunswick (SWNB) was first conducted in 1992 and 1993, and has been conducted annually since 1995. Sediment sulfide concentrations have been measured as part of the monitoring program since 2002, and this has been the sole parameter used to rate each farm's environmental performance since 2006. This study examined temporal and geographic trends in sediment sulfide concentrations from the annual monitoring at salmon farms in SWNB from 2002-2010. There has been an overall trend toward improved ratings over this period. Probable factors for the improved ratings include the implementation in 2006 of a new Aquaculture Bay Management Area (ABMA) framework, including mandatory fallowing between successive year-classes, together with the introduction of a performance-based standards (PBS) approach to determining production levels. These practices were intended to facilitate improved environmental and fish health conditions at farms. Maps of the geographic distribution of ratings indicate that some areas, such as Passamaquoddy Bay and the Létang area, were more likely to include farms with Anoxic or Hypoxic ratings, while in Maces Bay and Grand Manan Island, ratings were mostly Oxic.

Introduction

Finfish aquaculture has been conducted in the southwestern New Brunswick (SWNB) portion of the Bay of Fundy since 1978. In 2010, there were 95 approved finfish leases in SWNB, of which 54 were growing Atlantic salmon (*Salmo salar*), 4 were growing other finfish species, and the rest were fallow. Salmon production in SWNB in 2009 was estimated as 24 000 t, while production of other finfish species was only 100 t (Statistics Canada 2010; NBDAAF 2010). Since 2006, farms in SWNB have been organized into a framework of Aquaculture Bay Management Areas (ABMAs), as shown in Figure 1. Under this ABMA framework, farms must be single-year-class operations, stocking every three years, with mandatory fallowing of farms and ABMAs between successive crops.

A history of environmental monitoring of finfish farms in SWNB can be found in Chang and Page (2011). The first industry-wide environmental monitoring of finfish farms in SWNB was in 1991 and 1992. Annual monitoring of sediments under all farms with approvals to operate has been conducted since 1995. During 1991–1992 and 1995–2001, ratings were qualitative: farms were rated as having low, moderate, or high impacts (see Chang and Page 2011 for details). A quantitative monitoring program, based on sediment geochemistry, was implemented starting in 2002. From 2002–2005, ratings were based on redox potential and sulfide concentrations in sediment samples. In 2002 and 2003, all samples were taken directly under the fish cages, while in 2004 and 2005, some samples were taken directly under the cages and some under the cage edges. Since 2006, ratings have been based solely on sulfide concentrations in sediment samples taken under cage edges (NBDENV 2006, 2011); redox potential results were found to be highly variable and unreliable. Triplicate samples are taken at the edges of two or more cages per farm, depending on the size of the farm. Sediment samples have been mostly taken by divers using core samplers, except at a few deep sites where surface-deployed grabs have been used. The change in sample locations from directly under cages to under cage edges was made primarily for diver safety reasons and also because surface-deployed grabs are unable to collect samples directly under cages.

Sulfide concentration categories and the associated effects on marine sediments are shown in Table 1 (based on NBDENV 2006). A Performance Based Standards (PBS) approach was implemented in 2006 for the regulation of environmental quality. Under the PBS approach, farms with elevated sulfide concentrations can be required to implement mitigation and remediation measures, including additional monitoring. In addition, the number of fish approved for stocking at a farm is related to the environmental performance. The annual monitoring (known as Tier 1) is intended to estimate the intensity of impact on sediments, but not the area of impact.

This report examines temporal and spatial trends in the sediment sulfide monitoring data collected at SWNB salmon farms since 2002. Average sediment sulfide concentrations at each farm from the annual Tier 1 monitoring were obtained from NBDENV (2011).

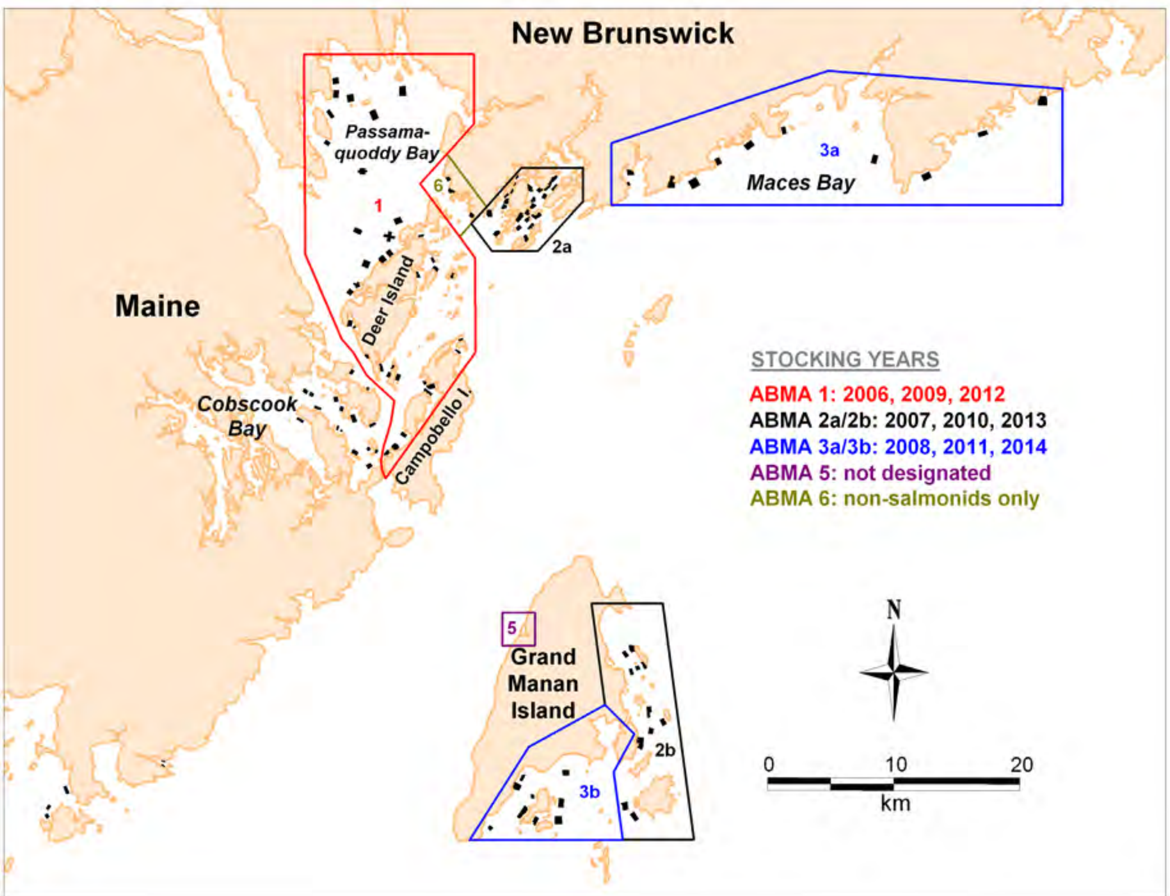


Figure 1. Map of the southwestern New Brunswick area and adjacent Maine, showing finfish leases (small black polygons) and Aquaculture Bay Management Areas (ABMAs; indicated by colored outlines) in 2010.

Site Classification	Sediment Sulphide Concentration (μM)	Effects on Marine Sediements
Oxic A	< 750	Low effects
Oxic B	750–1,500	Low effects
Hypoxic A	1,500–3,000	May be causing adverse effects
Hypoxic B	3,000–4,500	Likely causing adverse effects
Hypoxic C	4,500–6,000	Causing adverse effects
Anoxic	> 6,000	Causing severe damage

Table 1. Site ratings based on sediment sulfide concentrations, used in the SWNB environmental monitoring program (frm NBDENV 2006).

% of Monitored Farms	2002	2003	2004	2005	2006	2007	2008	2009	2010
Hypoxic A	18.9	17.6	20.7	19.2	14.1	5.8	15.9	20.4	20.4
Hypoxic B	6.7	9.9	5.7	6.8	1.4	2.9	3.1	0.0	0.0
Hypoxic C	2.2	11.0	2.3	4.1	4.2	1.4	3.1	0.0	1.9
Hypoxic Total	*27.8*	*38.5*	*28.7*	*30.1*	*19.7*	*10.1*	*22.2*	*20.4*	*22.2*
Anoxic	1.1	3.3	0.0	4.1	4.2	1.4	0.0	2.0	1.9
Hypoxic & Anoxic Total	*28.9*	*41.8*	*28.7*	*34.2*	*23.9*	*11.6*	*22.2*	*22.4*	*24.1*

Table 2. Percentages of monitored salmon farms in SWNB with Hypoxic and Anoxic sediment sulfide ratings, 2002-2010. Data source: NBDENV (2011).

Temporal Trends

Interannual trends in environmental ratings based on sediment sulfide concentrations are shown in Figure 2. The percentages of Hypoxic+Anoxic rated farms ranged from 11.6–41.8%, with an overall trend of decreasing percentages over time (Table 2). The lowest number of Hypoxic+Anoxic farms (and highest number of Oxic farms) was in 2006–2008, when there was the highest number of farms holding no fish at the time of monitoring.

Geographic Trends

Maps showing environmental ratings, based on average sediment sulfide concentrations in Tier 1 monitoring at salmon farms in SWNB in 2002–2010, are shown in Figure 3. Hypoxic and Anoxic ratings were most commonly found in northern Passamaquoddy Bay (northern part of ABMA 1) and around Deer and Campobello Islands (southern part of ABMA 1) and in the Létang area (ABMA 2a), as shown in Figure 4. Hypoxic and Anoxic ratings were uncommon in the eastern and southern Grand Manan Island areas (ABMAs 2b and 3b) and in the Maces Bay area (most of ABMA 3a).

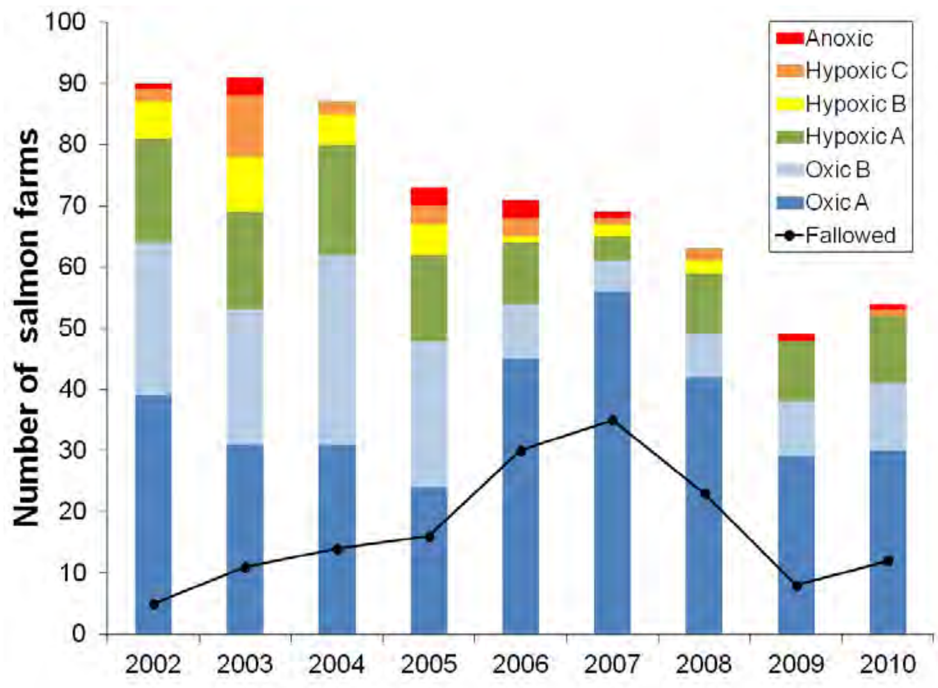
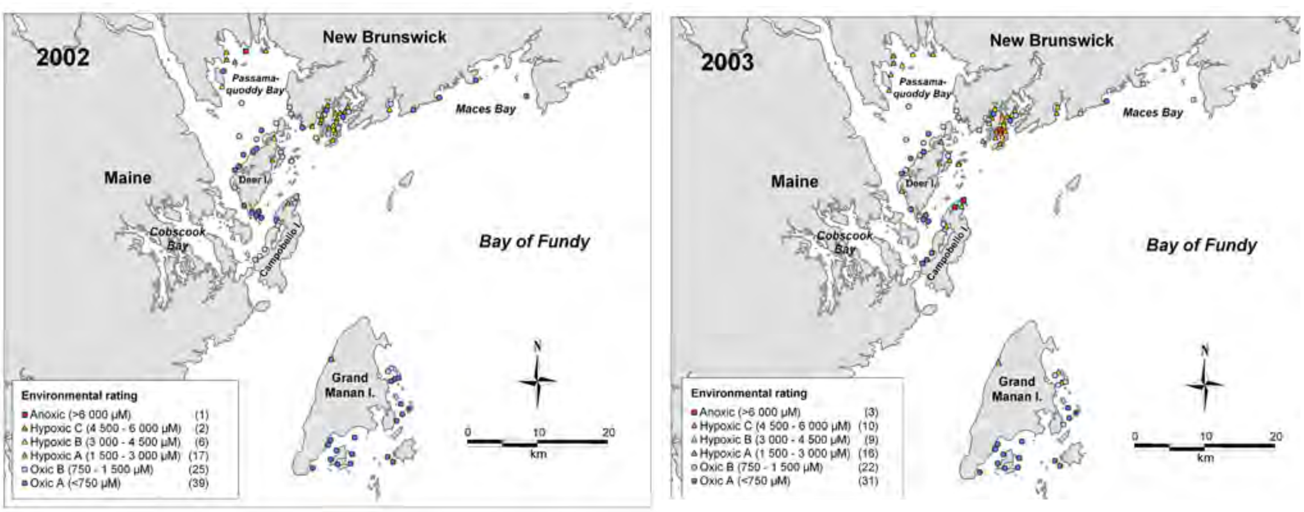
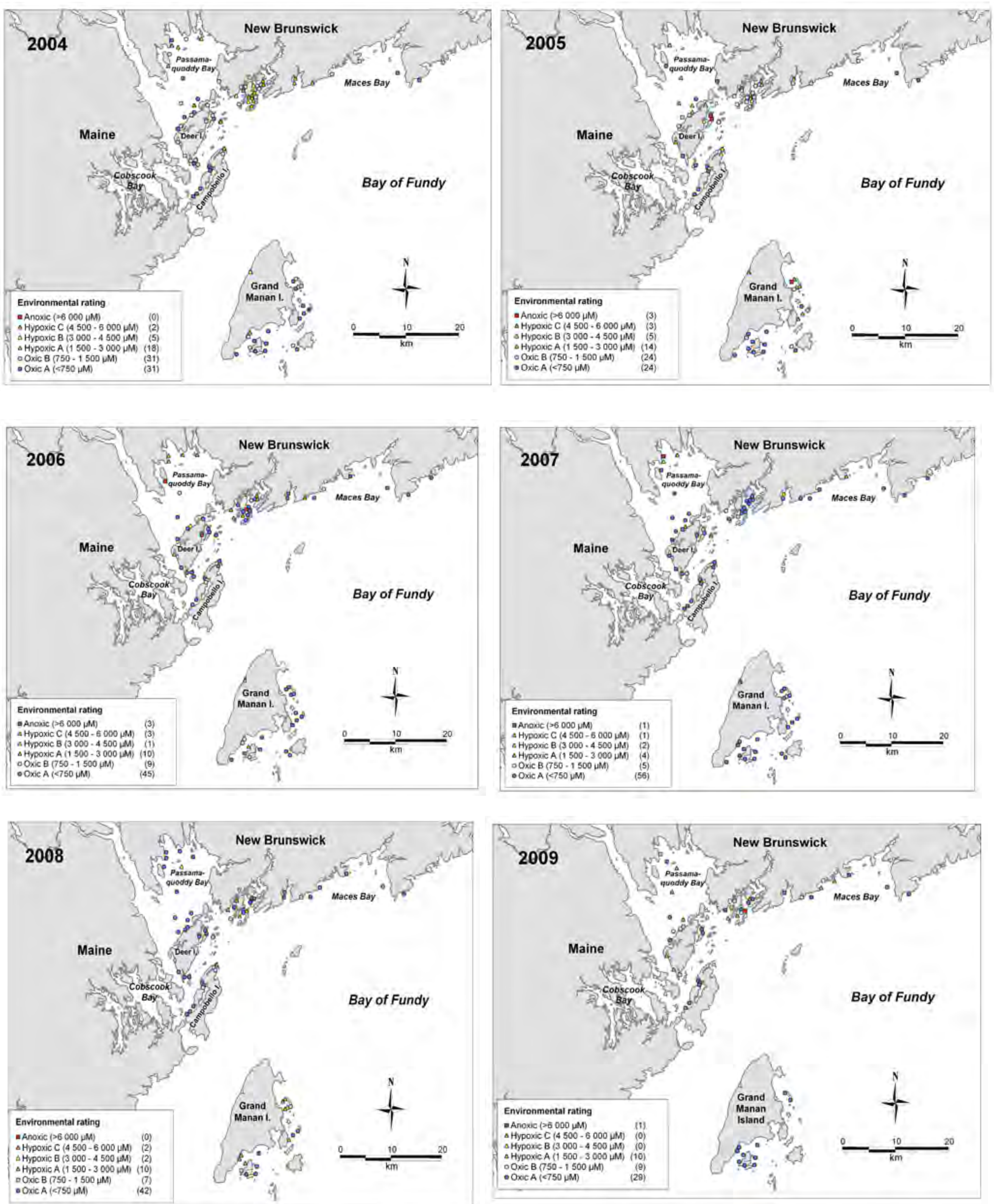


Figure 2. Environmental ratings at salmon farms in SWNB by year, based on Tier 1 sediment sulfide concentrations. "Fallowed" indicates farms that had no fish at the time of monitoring.




2004
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Deer I.
Cobscook Bay
Campobello I.
Bay of Fundy
Grand Manan I.
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (0)
Hypoxic C (4 500 - 6 000 µM) (2)
Hypoxic B (3 000 - 4 500 µM) (5)
Hypoxic A (1 500 - 3 000 µM) (18)
Oxic B (750 - 1 500 µM) (31)
Oxic A (<750 µM) (31)
2005
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Deer I.
Cobscook Bay
Campobello I.
Bay of Fundy
Grand Manan I.
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (3)
Hypoxic C (4 500 - 6 000 µM) (3)
Hypoxic B (3 000 - 4 500 µM) (5)
Hypoxic A (1 500 - 3 000 µM) (14)
Oxic B (750 - 1 500 µM) (24)
Oxic A (<750 µM) (24)
2006
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Deer I.
Cobscook Bay
Campobello I.
Bay of Fundy
Grand Manan I.
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (3)
Hypoxic C (4 500 - 6 000 µM) (3)
Hypoxic B (3 000 - 4 500 µM) (1)
Hypoxic A (1 500 - 3 000 µM) (10)
Oxic B (750 - 1 500 µM) (9)
Oxic A (<750 µM) (45)
2007
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Deer I.
Cobscook Bay
Campobello I.
Bay of Fundy
Grand Manan I.
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (1)
Hypoxic C (4 500 - 6 000 µM) (1)
Hypoxic B (3 000 - 4 500 µM) (2)
Hypoxic A (1 500 - 3 000 µM) (4)
Oxic B (750 - 1 500 µM) (5)
Oxic A (<750 µM) (56)
2008
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Deer I.
Cobscook Bay
Campobello I.
Bay of Fundy
Grand Manan I.
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (0)
Hypoxic C (4 500 - 6 000 µM) (2)
Hypoxic B (3 000 - 4 500 µM) (2)
Hypoxic A (1 500 - 3 000 µM) (10)
Oxic B (750 - 1 500 µM) (7)
Oxic A (<750 µM) (42)
2009
New Brunswick
Passama-quoddy Bay
Maces Bay
Maine
Cobscook Bay
Bay of Fundy
Grand Manan Island
N
0 10 20
km
Environmental rating
Anoxic (>6 000 µM) (1)
Hypoxic C (4 500 - 6 000 µM) (0)
Hypoxic B (3 000 - 4 500 µM) (0)
Hypoxic A (1 500 - 3 000 µM) (10)
Oxic B (750 - 1 500 µM) (9)
Oxic A (<750 µM) (29)

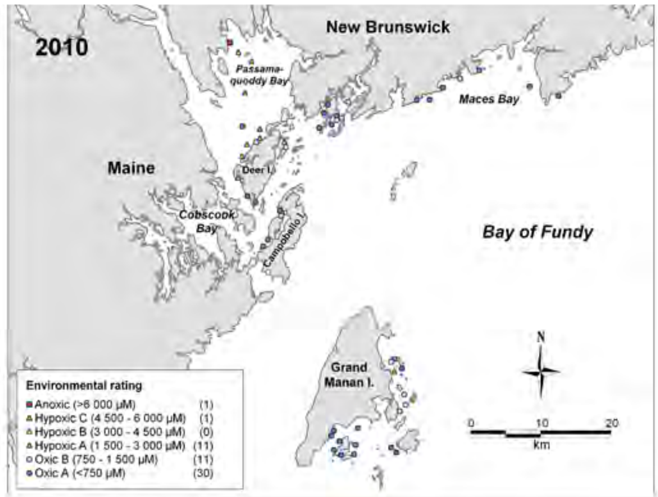


Figure 3. Maps showing environmental ratings based on sediment sulfide concentrations in Tier 1 monitoring of salmon farms in SWNB, 2002–2010.

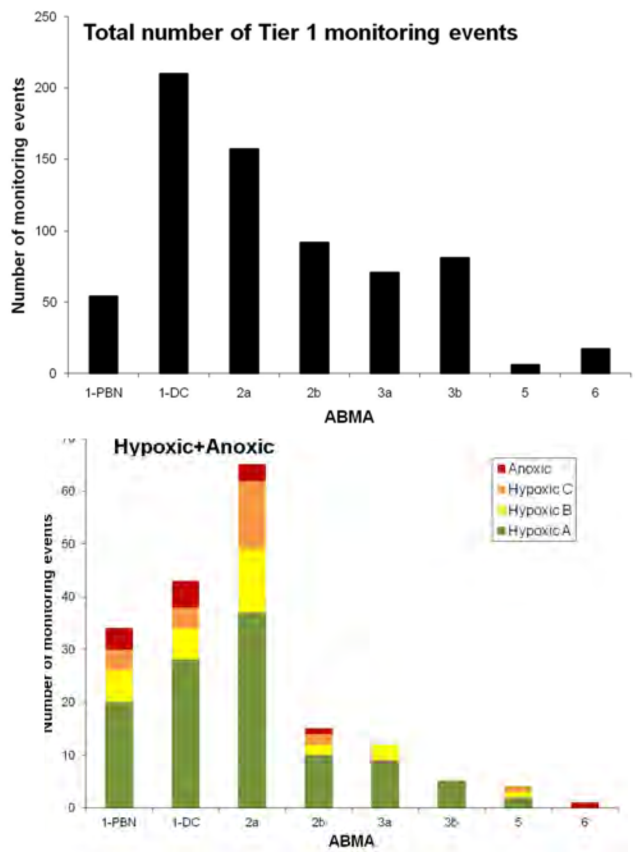


Figure 4. Total number of Tier 1 monitoring events during 2002–2010 (top) and the number of Hypoxic+Anoxic events (bottom), by Aquaculture Bay Management Area (ABMA). ABMA 1 has been sub-divided into ABMA 1-PBN (northern Passamaquoddy Bay) and ABMA 1-DC (Deer and Campobello Islands).

Discussion

The analyses presented in this report are based on the results of the annual environmental monitoring program, which monitors sediment geochemistry in the immediate vicinity of each farm. These results indicate that sediment conditions at the majority of farms are Oxic. The total area of all finfish farm leases in SWNB is only 1.4 % of the total nearshore environment (from the coastline to 50 m depth). Since only 12–42% of monitored farms in any year have received Hypoxic+Anoxic ratings and many other farm leases are not monitored due to inactivity, the results suggest that a very small area—<0.5% of the SWNB nearshore marine environment—is adversely affected by near-field organic deposition from salmon farms.

Some factors that may have contributed to the trend of improving environmental ratings over time include the implementation in 2006 of the ABMA framework, with single-year-class farming and mandatory fallowing between crops, and implementation of the PBS approach. There is also the possibility that the small changes in the sampling locations could have been a factor: during 2002–2005, some or all samples were taken under cages, while since 2006, all samples have been taken under the cage edges.

Another study has examined the annual Tier 1 monitoring data to determine if certain parameters associated with farms can be used to predict the intensity of benthic impacts, as measured in the annual sediment sulfide monitoring. It was found that some factors, especially fish biomass at the time of monitoring, average current speed (as predicted by a model), and farm age show significant relationships with sediment sulfide concentrations in most or all years. Some of these factors can help to explain the geographic trends in environmental ratings. For example, elevated sulfide concentrations were common in ABMA 1, where current speeds were mostly low, and in ABMA 2a which had a predominance of older farms (Chang and Page 2011). However, the relationships between sulfide concentrations and the various parameters show wide variability, and no one factor can be used to predict sediment sulfide concentrations under farms (Chang and Page 2011).

Models have also been used to predict benthic impacts of salmon farms. One example is DEPOMOD, a commercially available model, originally developed to predict impacts of salmon farms in Scotland (Cromey et al. 2002). DEPOMOD predicts the organic carbon deposition rate at fish farms, based on feeding rates, waste particle sinking rates, current speeds, and water depths. A study comparing DEPOMOD predictions with actual sediment data collected at farms in SWNB is currently underway.

Acknowledgements

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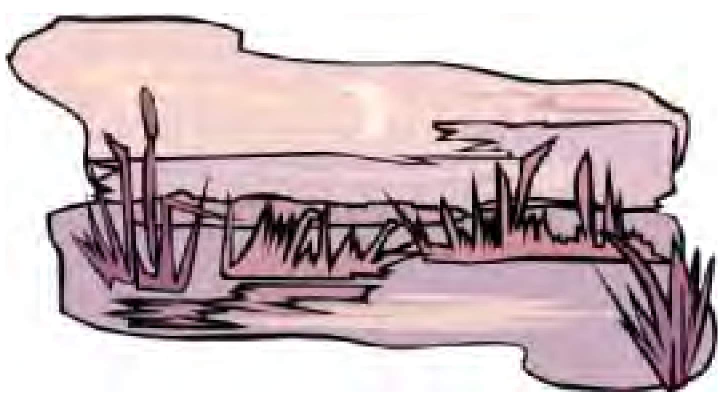
Session C

SALT MARSH/MUDFLAT DYNAMICS AND RESTORATION

Chair: Jeff Ollerhead, Department of Geography and Environment, Mount Allison University, Sackville, New Brunswick



VARIATION IN HYDROLOGICAL PROCESSES OVER THE SPRING–NEAP CYCLE IN A HIGH INTERTIDAL SALT MARSH CREEK (BAY OF FUNDY, NOVA SCOTIA)

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The potential extraction of energy from a macrotidal system (e.g., the Bay of Fundy) by tidal power installations will influence sediment dynamics to a degree which is currently unknown, and alterations to intertidal systems could occur that are beyond the natural range of variability. This research considers acoustic Doppler velocimeter (ADV) and optical backscatter (OBS) data from a sheltered salt marsh tidal creek in the Minas Basin, for analysis tidal characteristics over the spring-neap cycle in a macrotidal environment. Changes in energy between over-marsh and channel-restricted tides are identified through variations in current velocity, turbulence, suspended sediment concentration and deposited sediment. Velocity variations are on the order of ~1 - 10 $cm{\cdot}s^{-1}$ in the tidal creek, with a slight ebb dominance on over-marsh tides and distinct flood dominance on channel-restricted tides. Topographic thresholding by the marsh surface is demonstrated by increased turbulence and velocity peaks that repeatedly occur above the bankfull level (4.5 m CGVD28). High suspended sediment concentration (up to 3500 $mg{\cdot}l^{-1}$) indicates meteorological influence on the availability of suspended sediment to the tidal creek, associated with a weak hurricane in the region. Sediment deposition was extensive and showed a wide range of values (55 – 328 $g{\cdot}m^{-2}$). In general, over-marsh tides possess more energy and offer more sediment for deposition, whereas channel-restricted tides demonstrate low energy and lower amounts of deposition.

SEDIMENTARY DYNAMICS WITHIN A HYPERTIDAL SALT MARSH AND TIDAL CREEK SYSTEM

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A resurgence of interest in tidal power development has raised the question regarding the consequences of removing energy from the tidal environment, particularly far field changes in sedimentation. The overall rationale is to better understand the change in sediment dynamics that has the potential to occur with tidal energy extraction. As the biological components are controlled by the dynamics of the marsh and creek system, a change in sediment dynamics could potentially impact the biological components of the marsh.

The purpose of this honour's research was to evaluate the factors affecting sediment deposition in the tidal creek and on the marsh surface. The objectives were to measure flow velocity, suspended sediment concentration and deposition, including the amount transported and deposited in flocculated form; and to compare the results within a tidal creek and adjacent salt marsh in the Upper Bay of Fundy. The study area was located in Starr's Point, Nova Scotia. There were four plots at the study area including three plots on the marsh and one plot in the creek. A meteorological weather station was stationed on site to collect precipitation, wind direction, wind speed, atmospheric pressure and temperature data.

Flow velocity on the marsh was measured with three acoustic Doppler velocimeters (ADVs) each measuring specific velocity at one area 15 cm above the bed on the high marsh and 10 cm above the bed on the low marsh at 16 Hz. Flow velocity in the creek was measured with one acoustic Doppler current profiler (ADCP), measuring a profile of the water column in the creek. Suspended sediment concentration was measured on the marsh with two OBS (optical backscatter) instruments which were co-located with ADVs. Suspended sediment concentration in the creek was measured with an RBR instrument measuring turbidity and also with a water sampler taking 250 ml water samples at 30 minute intervals during high tide when the creek was inundated. Sediment deposition was measured with surface mounted sediment traps both in the creek and on the marsh. The filters with sediment were weighed dry to obtain the net deposition of sediment at each plot. Disaggregated grain size analysis was performed on the Coulter Multisizer^{tm} 3 grain size spectra to determine the amount deposited in flocculated form (Kranck and Milligan 1979). The impact of vegetation was measured by taking a representative sample of vegetation for each plot on the last day of each of three experiments during which the data were collected and vertical biomass was determined by cutting the vegetation at 2.5 cm sections and weighing it dry (Neumeier 2005).

All data were collected during spring tides, in the creek and on the marsh simultaneously to compare with distance to creek. Experiments were all done during spring tides for all tides to be over bankfull level where data could be collected on the marsh surface.

Previous research has shown that spring tides result in more deposition than neap tides in this area. Inundation time was found to affect sediment deposition on the marsh, as longer inundation times led to more deposition. Inundation time was less of a factor in the creek where there was little variance in the inundation time between tides. Flocculation of sediments was also anticipated to be the reason for this.

There was found to be more deposition in the creek than on the marsh. This was likely associated with higher flocculation in the creek; and it was also associated with higher suspended sediment availability and longer inundation times. The creek received an average of seven times more sediment deposition than the marsh surface. The average deposition on the marsh surface was 54.8 g/m^2 and the average deposition in the creek was 357.6

g/m^2. When dividing deposition by plots, it was seen that there was consistently less deposition with increasing distance from the creek. This was consistent for all tides for which data was analysed.

The ADCP data were also able to be used as an approximation for suspended sediment concentration because of its use of signal strength to count the particles in the water to measure the speed of the particles and therefore the speed of the water. On higher tides, low signal strengths were identified just after high tide on the ebb, suggesting that sediment is settling. On lower tides, there was not the same clearing of sediment on the ebb, potentially suggesting re-suspension of sediment, which is the period of the tide that has been associated with more erosion (Voulgaris and Meyers 2004).

Most of the factors evaluated did have an effect on sediment deposition. The velocity affected the whole system, both the creek and the marsh together. Higher velocities on the marsh were recorded and therefore there was less deposition on the marsh and more sediment available in the creek. High turbulence was shown to have an effect on the marsh by preventing the particles from settling, as low turbulence has been studied to promote particle settling (Christiansen et al. 2000), therefore also creating more availability in the creek. Vegetation was found to promote particle settling, as more vegetation and a higher ratio of living vegetation to dead vegetation lead to more sediment deposition.

The implications which are involved are that the dynamics and habitat of the salt marsh and tidal creek have the potential to change with a change in energy. The results of this research will provide empirical data for sediment transport models currently being developed in the region to assess the potential effects of energy extraction due to tidal power.

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A CONCEPTUAL MODEL FOR DETERMINING COASTAL VULNERABILITY IN A MACROTIDAL ENVIRONMENT

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This research aimed to produce a globally applicable framework in order to assess vulnerability in a macrotidal environment by constructing a consistent and comprehensive conceptual model. In climate change assessments, vulnerability is a term that requires adequate definition, in order to avoid misunderstanding; especially in interdisciplinary research concerning vulnerability and adaptation. The framework for the model begins by clearly defining vulnerability in the context of the specified system (biophysical, socio-economic), type of hazard (erosion, sea level rise, storm surge) and time (short vs. long term exposure). Within the literature, the most common factors or variables utilized in coastal vulnerability assessments include coastal slope, coastal geology, dominant wind/wave direction, fetch, width of foreshore and the presence of barriers/obstacles. However, in a macrotidal environment, such as the Bay of Fundy, Nova Scotia, the driving force behind the dynamic influence of these variables is the changing tide level. In the short term, impacts from hazard events such as storm surges will be hindered or amplified depending on the tide level at landfall. In the long term, the large energy flows characteristics of a macrotidal range will influence exposure to erosion. This conceptual model, specifically oriented to define coastal vulnerability for the Bay of Fundy, is particularly important due to the dynamic complexity of the influencing factors and their relationship with changing tide level.

A BAY OF FUNDY SALT MARSH RESTORATION AT AULAC, NB—THE FIRST YEAR

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The purpose of this presentation is to report on the progress of a salt marsh restoration at a site near Aulac, NB in the Cumberland Basin. Cumberland Basin is a 118 km^2 turbid estuary with a semi-diurnal tidal range of 10 to 13 m. The fetch ranges from 5 to 20 km and the water has a high suspended sediment concentration (mean > 300 mg/L). The project was designed in 2009–2010 and implemented in 2010. Three openings were cut in an existing dyke at the site in October 2010. As a result of this action, two different agricultural fields are now being regularly flooded with salt water from the Bay. Field data were collected prior to construction for a number of environmental variables (e.g., existing vegetation) and marker horizons were installed. Since the openings were constructed, they have been mapped using ground-based laser scanning (LiDAR), flows through one of the openings were measured using an acoustic Doppler current profiler (ADCP), and water levels both inside and outside of the restoration cells have been measured. In the summer of 2011, sediment deposition over the marker horizons was measured for the first time using cryogenic coring. Measured sediment depth and spatial patterns were then compared to predicted sediment depth and spatial patterns from the design process. Finally, the initial success of the project is assessed.

ECOLOGICAL RE-ENGINEERING OF A FRESHWATER IMPOUNDMENT FOR SALT MARSH RESTORATION IN A HYPERTIDAL SYSTEM

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This paper examined the vegetative, sedimentary, nekton and hydrologic response to ecological re-engineering of a freshwater impoundment in the Upper Bay of Fundy. The dyke was breached (2005) in five locations and one channel initiated to connect the river to the borrow pit behind the dyke. This triggered significant self-organization within the restoration site. Existing channels (e.g., borrow pit) were incorporated within the newly excavated and developing creek system, increasing hydraulic connectivity and fish habitat within the marsh. Vegetation colonization, primarily by *Spartina alterniflora*, was rapid with almost 100 per cent coverage by the end of the third year, with high marsh species present in increasing abundance by year five. The constructed channel experienced considerable morphological change in response to the increased tidal prism. In the year immediately following the breach, the surface of the marsh was unconsolidated and rates of change in surface elevation measured at RSET stations ranged considerable. By year three the rate of surface elevation change decreased to a more moderate but variable mean, implying subsurface consolidation. By year five, more subtle changes continued to be observed in the habitat structure (primary and secondary channel development, sediment and elevation) and the biological community (establishment of high marsh vegetation species, fish densities). This study represents the first comprehensive, quantitative analysis of ecological response to dyke breaching in a hypertidal ecosystem. These data will contribute to the development of long-term data sets of pre- and post-restoration, and reference marsh conditions, and has improved our ability to design subsequent restoration projects.

THE USE OF LOW ALTITUDE AERIAL PHOTOGRAPHY: EXAMINING SURFACE COVER CHANGES ON A NEWLY RESTORED TIDAL MARSH

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This research examines the role that surface morphology and drainage networks have on the natural recovery of marsh vegetation within a macro-tidal restoration site. Previous works examining salt marsh vegetation recovery have shown that projects are most successful when: (1) there is no restriction on the dispersal ability of target species near the restoration site, and, (2) there is a disturbance to remove non-target species within the restoration area. Restoration of tidal flow to a 13 ha section of fallow agricultural dykeland along the St. Croix River (Hants County, NS) was undertaken in 2009. Rod Surface-Elevation Table measurements showed increase in the sediment surface of up 23 cm one year following restoration. The high rate of sediment deposition resulted in the creation of a mudflat conditions over much of the site. High resolution, low-altitude geo-referenced aerial photography was employed to better understand factors influencing vegetation recovery and surface changes. Preliminary hydrogeomorphic analysis showed the reactivation of old agricultural ditches into the new drainage network. The vegetation survey showed the colonization of wetland species, such as *Polygonum hydropiper* and *Scirpus validus*, representing a change of vegetation dominance from pasture grasses to wetland species within the first year of restoration. Preliminary image classification of the orthophotos showed that exposed mud exceeded vegetated patches during the first growing season and that colonization of wetland species has primarily occurred near secondary drainage channels. These results suggest colonization occurred following the return of tidal waters and sediment deposition.

TIDAL CREEK HYDRAULIC GEOMETRY FOR SALT MARSH RESTORATION IN THE UPPER BAY OF FUNDY

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Salt marshes around the world have been seriously impacted by human activities and are in need of restoration more than ever in our changing climate. Shifts in environmental regulations, demographic, and economic structure in Nova Scotia have recently produced opportunities to restore these important habitats. However, successful restoration requires a better understanding of the characteristics of these systems than is available in our region at present. This research is intended to improve our understanding of the geometry of tidal creeks in the Bay of Fundy and their relationship to tidal prism using hydraulic geometry. Initially formulated in freshwater systems, hydraulic geometry correlates channel geometry with discharge using a power function and can be applied in tidal scenarios using tidal prism as a surrogate for discharge. The relationship between tidal prism and channel geometry has been well established in many parts of the world, however there is a lack of published exponent values and research on the topic for macro-tidal estuaries. Using ground surveys and high resolution digital terrain data for the Avon and Cornwallis estuaries this study provides exponent values for the region and examines the role of elevation and location in the tidal frame in channel geometry. Furthermore, the accuracy of the relationship is tested using representative creeks for the region and a model for salt marsh restoration in the region is developed.

COMPARISON OF GRAIN SIZE DETERMINATION USING COULTER LASER DIFFRACTION AND COULTER ELECTRICAL SENSING ZONE METHOD FOR SALT MARSH RESTORATION MONITORING

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One of the indicators of success of a salt marsh restoration project is if the site is trending towards conditions present at a reference site. Grain size statistics can be used to assess whether a restoring salt marsh is trending towards conditions experienced at the reference site. The grain size spectrum of a sample location is influenced by source material and velocity of current. If the grain size spectrum is incorrectly identified, it can alter the assessment of the success of a salt marsh restoration project. The grain size statistics can give indications of other soil characteristics such as porosity, bulk density and can be used to identify the hydrodynamic transport processes within the marsh surface. Advanced analysis of the grain size spectrum can indicate source material. The purpose of this project is to explore the differences and limitations of using a Coulter LS 200 (Laser Diffraction Method) as compared to using a Coulter Counter Multisizer 3 (Coulter Electrical Sensing Zone Method). It is hypothesized that the Laser Diffraction Method will overestimate the grain size spectrum as compared to the Coulter Electrical Sensing Zone Method. The objectives of this research are to compare the grain size statistics (mean, median, mode, standard deviation, skewness and kurtosis) for each method, to investigate the use of disaggregated grain size analysis and to provide recommendations on the use of laser diffraction and Coulter multisizer for grain size analysis for salt marsh restoration.

The research was conducted on Cheverie Creek, Hants County, Nova Scotia a small macrotidal saltwater marsh which has been newly restored and associated reference site, Bass Creek, Hants County, Nova Scotia, in the Upper Bay of Fundy currently being monitored as a compensation project. Cheverie Creek experienced limited tidal activity due to a rock-filled causeway at the mouth of the creek and a small wooden culvert. This limited the amount of water coming through on each tide, which significantly limited fish travel and flooding of the marsh surface. From May 2002 to October 2004, research was conducted on the restoration site and reference site by the Ecology Action Center. In the summer and fall of 2005, monitoring was conducted by CB Wetlands & Environmental Specialists (CBWES) prior to culvert replacement. In the winter of 2005, the small wooden culvert was replaced with a new larger culvert which allowed increased fish travel and flooding of the marsh surface. CBWES has continued to monitor the restoration site and reference site with repeated sampling over the past six years (Bowron et al. 2009).

CBWES collected 21 cores from areas along the transect lines in the fall of 2008. Cores were analyzed within the Intertidal Coastal Sediment Transport (In_CoaST) Research Unit at Saint Mary's University in Halifax, Nova Scotia for water content, organic matter, bulk density and a subsample was removed for grain size analysis. Sub samples were dried at 65℃ and crushed using mortar and pestle. A portion of each sample was sent to Mount Allison Coastal Wetlands Institute in Sackville, New Brunswick for analysis using Coulter LS200. The residual subsample was retained for future analysis using the Coulter Counter Multisizer 3. The Laser Diffraction Method is based on the principle that particles of a given grain size will diffract light through a given angle. The Coulter Electrical Sensing Zone Method is based on the principle that as particles pass through an electrical field suspended in an electrolyte then the particle will displace its own volume of the electrolyte and cause a change in the electrical field. These changes are then counted as voltage pulses which are proportional to particle volume.

Samples were processed through the Coulter Counter Multisizer 3 by using the following method. The organic matter was removed by placing a small portion of the dried sediment into a 20 ml beaker. A 2.5 mL portion of 30% hydrogen peroxide was placed into each beaker. The sediment and hydrogen peroxide mixture was heated over a few hours to remove the hydrogen peroxide. In the lab, each beaker was filled with 1% NaCl electrolyte solution, sonified and processed through the Coulter Counter Multisizer 3. The 30 (measures from 0.779 to 27.1 μm) and the 200 (measures from 4.17 to 145 μm) micron aperture tubes were used for analysis to ensure a representative grain size spectra was produced for each sample. The resulting spectra were joined using MatLab, and Gradistat was used gather grain size statistics. The resulting grain size spectrums from both methods were compared to identify differences in interpretation of grain size spectrum for salt marsh restoration monitoring.

Preliminary results were gathered for 13 of the 21 samples collected. Large differences were found between the grain size statistics generated from the laser diffraction method and the Coulter electrical sensing zone method. The results of the absolute mean, median, mode, skewness and kurtosis for the laser diffraction method were over estimated as compared to the results from the Coulter electrical sensing zone method. The absolute standard deviation was the only statistic that was similar between the two methods. There is a trend emerging from the data which shows that if the laser diffraction data is divided by four, then it is approximately equal to the results from the Coulter electrical sensing zone method. This however cannot be proven until further analysis is performed.

The preliminary results have confirmed the hypothesis that laser diffraction method will overestimate the grain size as compared to electrical sensing zone method. Further analysis will need to be conducted before any firm conclusions can be drawn and recommendations made as to which method is more suitable for grain size analysis for salt marsh restoration.

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Session D

MANAGING COASTAL AND MARINE INFORMATION

Chair: Michael Butler, International Ocean Institute–Canada, Dalhousie University, Halifax, Nova Scotia

ATLAS IN THE CLOUDS: NEW METHODS OF ENVIRONMENTAL KNOWLEDGE DISSEMINATION IN THE AGE OF SOCIAL MEDIA

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In 2006, four urban watershed management plans were researched and composed by ACAP Saint John, resulting in new directions forged in environmental decision making within the City of Saint John, and have served as the basis for countless new initiatives and as background research for several environmental impact assessment (EIA) documents, private and public engineering studies and municipal sustainability toolkits. Perhaps their greatest success resulted from the Marsh Creek Watershed Management Plan which has become the primary impetus for the creation of the Marsh Creek Restoration Initiative, now recognized as the most ambitious sustainable development proposal in Atlantic Canadian history and adopted by stakeholders across the region as a key component of growth strategies such as PlanSJ, Saint John's new municipal plan.

Despite all these successes, it has transpired that since these plans' development, Saint John has seen the most intense period of development in recent memory and many of the threats or challenges documented in these plans have either been addressed, been altered or have never come to pass. As such, they found themselves in dire need of updating and enriching to include a greater array of watershed datasets such as those pertaining to wetlands and the use of new GIS tools and Internet dissemination. In this day and age, having an online component as a part of any project is a critical facet of its success as the demand for open, online information sources in the past five years has moved from being a mere luxury to a necessity of modern environmental work. As a result, ACAP Saint John has embarked on an in-depth set of revisions to these highly successful documents, while also creating new interactive tools to facilitate even greater dissemination within Greater Saint John and the Province of New Brunswick. These tools and management frameworks are to be made readily accessible to every segment of the population and therefore could be easily adopted by other watershed groups and municipalities across the province and the region.

The up-to-date management plans and research datasets collected within each watershed are being designed to not only be written into traditional reports, but to be fundamentally based on a new Web-based format that is readily accessible by the community at large. Each element of the final watershed management plan is to be presented on a Web mapping interface, allowing users to interface with a spatial representation of the collected data and see first-hand the interactions between their community and the natural world. The linking of photos, video and datasets to geo-located reference points bridges the gap between what is measured on the ground and what is presented to the public, and a colour-coded system of iconography has been developed to allow rapid recognition of the threats facing each of the four major watersheds. The nature of this innovative interactive tool requires significant information and communication technologies (ICT) development and will be reviewed thoroughly by staff, stakeholders and advisory personnel prior to public release. The goal of this new method of report delivery is to disseminate information so as to encourage others to participate in the decision-making process associated with managing the future of our watersheds. The core mandate of this initiative has been to leverage ACAP Saint John's well established, and rapidly growing, social media networks to engage otherwise out-of-touch segments of society directly into environmental management processes, furthering the coalescence of scientific research and the public realm.

ORGANIZING VISIBILITY ON THE INTERNET THROUGH COINATLANTIC

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Abstract

In 2002 the University of California at Berkley estimated there was 167 terabytes (i.e. 167 x 1012 bytes) of information on the World Wide Web. The amount of information had at least tripled since their initial study in 1999. How does an organization make its information visible and available to others in this vast expanse? The Atlantic Coastal Zone Information Steering Committee (ACZISC) has been responding to this challenge for coastal and ocean information since 1992 when it published its first Database Directory. The ACZISC through its Coastal and Ocean Information Network – Atlantic (COINAtlantic) initiative is now exploiting the power of the Internet search to increase the visibility of an organization's information. The COINAtlantic GeoContent Generator (CGG) is a free, on-line, and simple-to-use utility that allows users to generate information about their data, project, organization or publication that is tied automatically to a geospatial polygon of their choice and published on-line in a way that will be found quickly by Google. The ACZISC is offering the use of this tool to any organization along with an initial consultation, training in the use of the CGG and follow up support through the new COINAtlantic Internet Visibility Initiative (CIVI). This paper will describe how three components of the COINAtlantic spatial data infrastructure, the CGG, the CIVI, and the COINAtlantic Search Utility (CSU), can benefit organizations and show how these users fit into the broader chain of information access from provider to user.

Introduction

The Atlantic Coastal Zone Information Steering Committee (ACZISC) was established in 1992 to foster cooperation in Atlantic Canada with regards to integrated coastal and ocean management (ICOM) and the sharing of the spatial data and information needed for good management. Its members represent governments at both the federal and provincial levels and organizations which have a mandate for, and can contribute to, the development, coordination and implementation of ICOM in Atlantic Canada.

In 2002, the University of California at Berkley (UCB) estimated there was 167 terabytes (i.e. 167 x 1012 bytes) of information on the World Wide Web. The amount of information had at least tripled since their initial study in 1999 (Lyman and Varian 2003). de Kunder (2011), using models and the size of search engine indices, estimated the size of the indexed Internet to be 19.19 billion pages on 14 July 2011. The UCB study and de Kunder's model demonstrate that there is an overwhelming amount of information possibly available from the Internet and the amount is growing rapidly. Butler et al. (2010) demonstrate that for the ICOM community of practice, it is essential to consider spatial data infrastructure that build on information from many sources. Sherin et al. (2011) described the challenge faced by coastal and ocean managers as the "billion URL challenge". A major part of the ACZISC's response to the "billion URL challenge" has been the Coastal and Ocean Information Network – Atlantic (COINAtlantic), a network of data providers and users. COINAtlantic is not a metadata catalogue, a data warehouse, or a sophisticated GIS system. It is a network of 1) people willing and interested in providing access to their information; 2) publication of information on the Internet using appropriate standards; and 3) on-line tools and procedures to facilitate the finding and accessing of available information. Two COINAtlantic tools that help ACZISC members and other users navigate and promote themselves and their information for ICOM on the Internet are the COINAtlantic GeoContent Generator (CGG), and the newly introduced COINAtlantic Internet Visibility Initiative (CIVI) described in more detail below.

COINAtlantic

Sherin et al. (2010) and Sherin (2007) have outlined the history, general structure and objectives of COINAtlantic. Figure 1 shows the five links in the COINAtlantic chain of information access. Together, the five links provide a spatial data infrastructure for discovering, accessing, and visualizing data and information on the Internet. Link 1 consists of data providing organizations maintaining well-managed silos of information accessible to the Internet in Web mapping services (WMS) or Google Earth KML file format. Link 2 consists of comprehensive up-to-data standard metadata embedded in the WMS and KML files. Link 3 is indexing the metadata by Internet search engines such as Google and Bing. Link 4 is finding these metadata products for relevant geospatial information sources using standard Internet searches and displaying and manipulating the information in a geospatial search utility application like the CSU described later in this paper. Link 5 is to view, overlay and process the geospatial data using the CSU or other Web-based application.

An ACZISC workshop was held in spring 2010 to review progress on COINAtlantic and to develop a strategy for future development of a geospatial search function (ACZISC 2010). The workshop clearly identified the need to implement geospatial searching of all Internet sources of information relevant to ICOM not just what was in the (GeoConnections Discovery Portal (GDP) or other metadata databases. Recent developments by the Open Geospatial Consortium (OGC), Google and others suggest that the technology for carrying out such an extensive search is now available.

Since April 2010, COINAtlantic has been focusing on two aspects of this strategy: 1) contributing Internet discoverable geospatial metadata, and 2) geospatial search to exclude information not in the area of interest.

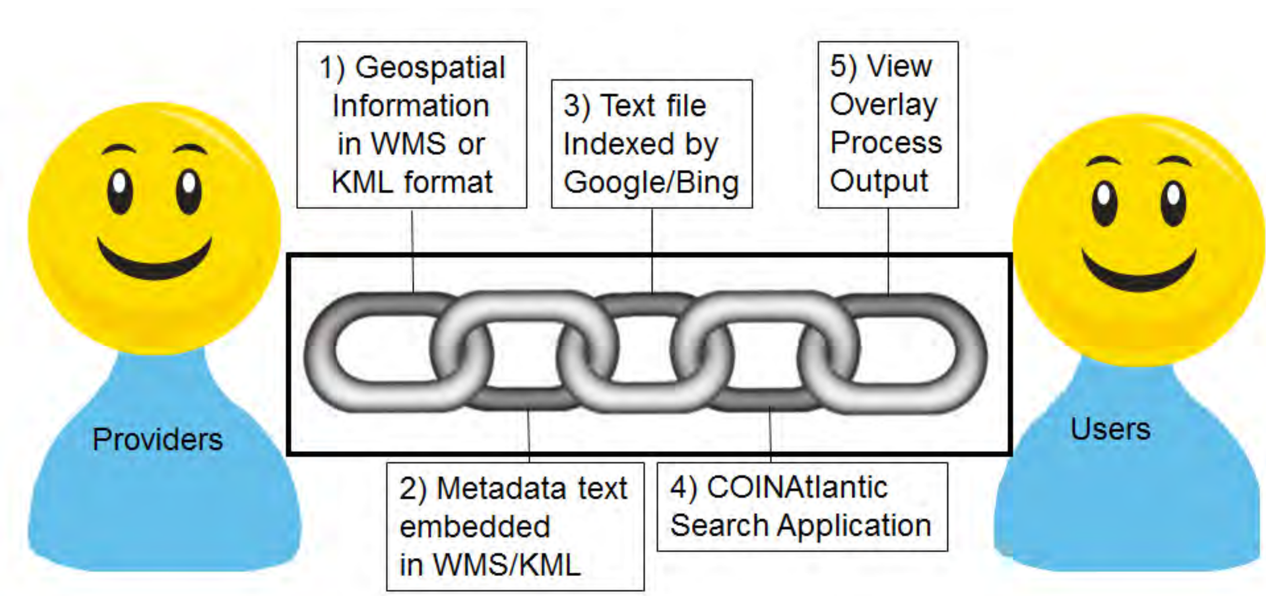

Figure 1. The COINAtlantic five link “Chain for Information Access”. Together, the five links provide a spatial data infrastructure for discovering, accessing, and visualizing data and information on the Internet.

COINAtlantic Geocontent Generator

A key piece of the COINAtlantic geospatial search strategy is facilitating the publication of text-based metadata that can be indexed and searched by Google and Bing. This metadata must also include geospatial information that describes the area of the globe of relevance to the data, information, organization, publication, etc. The CGG is an on-line application that has been developed and implemented to accomplish three key tasks: 1) provide an easy to use interface to facilitate the generation and publication of textual and geospatial information by non-GIS specialists; 2) publication of metadata in Web accessible folder that can be indexed by Google and Bing; and 3) generate and maintain a Google and Bing geositemaps to facilitate indexing. The CGG provides smaller organizations with the tools and supports to publish information on the Internet for their projects and publications.

Version 1 of the CGG was released in April 2011. It accomplished the three tasks described above using minimal mandatory fields for the textual component of the metadata. It was also delivered with a suite of KML polygon files delineating the boundaries of watersheds and estuaries in Atlantic Canada. The user can choose one of these existing KML polygon files to describe the geography of interest for the data, information, organization or publication the record is being created for. Alternatively, the user has two other options for describing the geography: 1) drawing the polygon freehand within the application; or 2) uploading an existing KML polygon file. An example of a KML polygon file is shown in Figure 2. COINAtlantic experience with this approach indicates these KML metadata files are discovered and appear in Google search results within two weeks.

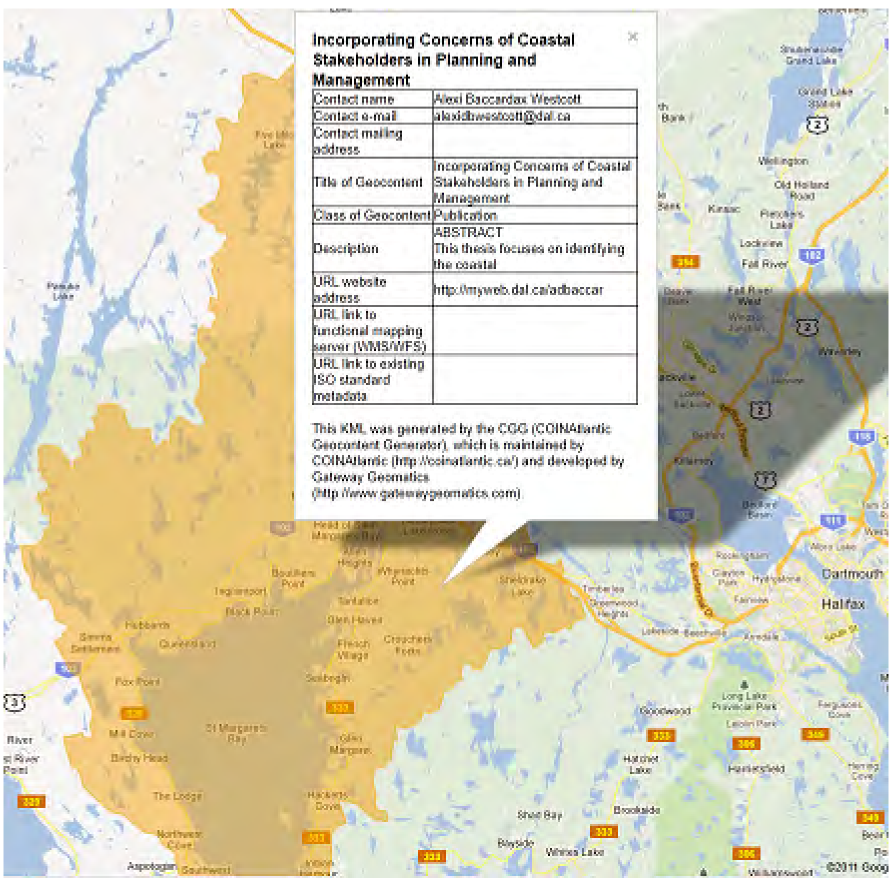

Figure 2. An example of a KML polygon and metadata generated by the CGG, discovered via a Google search and displayed using Google Maps. In this case a template polygon for the St. Margaret's Bay watershed and estuary in Nova Scotia was used to describe the geographic area of interest of a Master's thesis.

Version 2 of the CGG was released in October 2011 (http://coinatlantic.ca/cgg). Enhancements included: contextual help for the user, improved file management administration, editing capability for the KML file under construction, and KML file validation. The attribute metadata requirements will follow ISO 19115-2 standards (International Organization for Standardization standard for metadata) initially only for identification information, employing the spiral development methodology described by Habermann (2011).

COINAtlantic Internet Visibility Initiative

The CIVI aims to increase the visibility of geo-referenced information on the Internet. The idea for this Initiative developed from the successful first phase of the CGG in 2011. As part of the initiative the ACZISC Secretariat will provide participants with an initial consultation to determine which of their information/data holdings are suitable for use with the COINAtlantic Geocontent Generator. This will be followed by training in the use of the CGG and follow-up support. A tutorial explaining the use of the CGG is available on the ACZISC Web site (http://coinatlantic.ca/index.php/coinatlantic/geocontent-generator/456-cgg-tutorial) (ACZISC 2011). This tutorial along with direct support by the ACZISC Secretariat will help members and other interested associates to utilize the CGG to tie data, publications, Web sites, organization information, etc. to spatially-defined polygons, findable through Google or Bing text search and viewable through Google Maps or Google Earth.

COINAtlantic Search Utility

Since the release of Version 1 of the CSU, the COINAtlantic strategy has changed from the interrogation of a single (i.e., GDP) or even several metadata repositories (i.e., GDP, GeoNova, GeoNB, and NASA's Global Change Master Directory) to the use of Google searches of the Internet. COINAtlantic in collaboration with partners in New England developed a prototype CSU using this approach in 2010.

The development of an operational version of the CSU using Google searching began in July 2011. Although Google had been chosen for the initial development because of its leadership in Internet mapping technologies and the functionality of its searching application programming interface (API), Bing has been added as an additional search of interest. It is planned to be released before the end of the 2011 calendar year. The enhanced CSU will use the Google API for Internet searching and will exclude from the results list and the map any and all geospatial resources that do not intersect with the user selected viewable area. It is anticipated that a periodic Internet-wide search for Open Geospatial Consortium (OGC) services (e.g., Web Mapping Service) and the creation of a cloud-based database of the results for the CSU application to search will be necessary. Metadata for these services are not directly discoverable by Google and Bing. These services must be interrogated to retrieve information about the layers of data available on the service and their geographic extents. The operational CSU will initially maintain the general look and feel and functionality of the first CSU (http://www.marinebiodiversity.ca/coin/) which was developed with extensive user consultation.

Conclusion

The ACZISC is working to meet the "billion URL challenge" faced by its members and the ICOM community in Atlantic Canada by delivering products such as the CGG and the CIVI. Experience has altered the course of development for these tools towards a more focused exploitation of widely used Internet tools (e.g., Google and Bing API) and international standards (e.g., OGC and ISO). The COINAtlantic GeoContent Generator, as stated above, is useful for smaller organizations but can also be adapted for use by larger organizations that hold metadata in databases that may not be exposed for Google or Bing to discover. The prototypical CSU has proved the concept of finding and displaying geospatial information on the Internet using standard Internet searches. The planned enhancements and use of these tools will improve the discoverability of sources of geospatial information relevant to ICOM and ease the visualization and initial evaluation of the information for users.

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A PHYSIOGRAPHIC CLASSIFICATION OF THE NOVA SCOTIA COASTLINE

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Abstract

Physiographic coastline classifications have been developed at varied scales for a number of different management purposes. In one of their more common applications, such classifications have been used for predicting spatial patterns in biological populations and communities when relevant data are otherwise absent. A physiographic classification of Nova Scotia's coastline is required for the Government of Canada's Marine Protected Area network planning process as well as for other coastal management initiatives in Nova Scotia, such as the Nova Scotia Coastal Strategy. In the coastal zone, existing classifications are primarily terrestrial and were created using varying approaches, often for a single or narrow management application. The need for a new classification of Nova Scotia's coastline to support a diversity of coastal management initiatives was recognized by several federal and provincial departments involved in coastal management. A working group was formed to develop a new classification, building upon previous work. The working group includes representatives from Fisheries and Oceans Canada, Natural Resources Canada, Nova Scotia Environment, the Nova Scotia Department of Natural Resources and Dalhousie University. This classification involved a Delphic approach to identify regional-scale coastline classes using physical and oceanographic data including, but not limited to, geological character (bedrock, surficial geology), coastal substrate (intertidal and backshore), shoreline orientation, topography, tidal range, turbidity and coastal geomorphic features (e.g., sand dunes, beaches, estuaries, cliffs, etc.). The resulting physiographic classification defines thirty-one coastline classes along Nova Scotia's more than 7,500 kilometre-long coast.

COASTAL AND OCEAN MANAGEMENT: USER TASKS AND ARCHETYPES WHEN SEARCHING FOR INFORMATION

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"Environmental wardens" who work in the coastal and ocean management field (COM) require diverse and vast amounts of data and information to make decisions due to the interdisciplinary nature of the field. The information and data needed to inform decisions is distributed among a variety of different sources. To help with this issue our research team has completed an exploratory study whose results will go towards the first steps in designing a system or set of search tools used by these environmental wardens. We recruited and interviewed 18 knowledge workers from the federal and provincial governments, academic institutions, non-governmental organizations, and private consulting companies using a critical incident technique. Interviews were audio recorded and transcribed verbatim by a third-party. Using thematic coding the research team identified ten core tasks that were completed over the course of the projects participants described. We also found that participants could be grouped into six different archetypes or users. Identification of the tasks that they regularly complete and user types of a system are critical to the development of a system/tool(s) to enhance subject specific information retrieval. Based on this exploratory study we recommend further research including interviews with other important stakeholders like individuals in communities and community groups. We also recommend that results from this exploratory study be verified and validated with a larger sample.

MEASURING AWARENESS, USE AND INFLUENCE OF MARINE ENVIRONMENTAL INFORMATION: RESULTS AND INSIGHTS FROM RECENT STUDIES OF THE BOFEP FUNDY INFORMATICS WORKING GROUP

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Introduction

The critical need for reliable scientific information in marine and coastal environmental policy and decision making to mitigate environmental problems is recognized (e.g., Lubchenco and Sutley 2010; Mitchell 2010). Yet the role that existing scientific information plays in policy and decision-making is not commonly considered an issue for urgent and targeted attention and is often not clearly defined. Many researchers have attributed this to the "science-policy divide," a global phenomenon which describes a disconnect between the information and knowledge produced by scientists and the information and knowledge applied by decision-makers (e.g., Ascher, Steelman, and Healy 2010; Hume 2011; Mitchell 2010). Studies show that communication of scientific information is a main issue in increasing general public participation in decision making. The problem of how to better utilize existing information usually does not lie with the information, but instead with its communication to its intended audiences (Soomai, Wells, and MacDonald 2011). Many government and intergovernmental organizations have not undertaken an analysis of the use and influence of their publications and these activities are still poorly understood.

This paper presented the results of two Maritime Canada case studies from a larger program (Environmental Information: Use and Influence research initiative) that assesses use and influence of government-sponsored, marine environmental and fisheries publications. The publications evaluated were: 1) *The 2009 State of Nova Scotia's Coast Report*, released in December 2009 by the Nova Scotia Government as a technical report, summary, and six fact sheets, in print and on the web (Government of Nova Scotia 2009); and 2) *The State of the Gulf of Maine Report*, released in June 2010 by the Gulf of Maine Council on the Marine Environment (GOMC) as a context document and five theme papers on its website (GOMC 2010). Release of these reports was a unique opportunity to examine the awareness, use and influence of the two reports by stakeholders shortly after their initial release.

Methods

The overall research question is: how can marine-related information, produced by a government, be disseminated and used effectively in marine and coastal decision making? The research used interviews and questionnaires, Web analytics, media scans, and citation analysis, conducted soon after public release of the two reports described above. The input of multiple stakeholders was considered, including policy and decision makers, scientists, industry personnel, and the general public. The two case studies were conducted in collaboration with the respective government agencies.

The study on *The 2009 State of the Nova Scotia Coast Report* (Soomai, MacDonald, and Wells 2011a) was conducted between May and July 2010, alongside the efforts of the Provincial Oceans Network (PON) of the Government of Nova Scotia to promote awareness and use of the Report. Data were obtained through eight open houses held in locations throughout the province; a multi-stakeholder meeting; multi-stakeholder interviews; a province-wide telephone survey; analysis of traffic on the government Web site containing digital versions of the Report; link searches to the government's Web site; citation analysis; and searches of library collections.

The study on *The State of the Gulf of Maine Report* (Soomai, MacDonald, and Wells 2011b) was conducted in collaboration with the Department of Fisheries and Oceans Canada between January and May 2011. The main objective of the study was to determine awareness and use of the Report by the GOMC Council and Working Group members, and the readers of the *Gulf of Maine Times*, a digital periodical produced by GOMC. Readers of the Times comprised a wide range of stakeholders: government and non-government organizations, academic institutions, business and industry, and persons working outside of GOMC but within the organizations/jurisdictions to which the GOMC members belonged. Data were collected through three separate online surveys using Opinio software (ObjectPlanet 2011).

Results

Overall, awareness occurred mainly through electronic means, i.e., emails and the Web, and the less technical versions were useful to most audiences. In the case of the Nova Scotia report, 45% of all stakeholders stated that they received an email message of notification from the government or indirectly through a NGO email network with which they were associated. The summary and fact sheets were preferred versions of *The 2009 State of the Nova Scotia Coast Report*, and respondents favoured the individual theme papers of *The State of the Gulf of Maine Report*.

Responses indicate that several communication methods were needed to reach diverse audiences. These include direct communication (e.g., notification letters, and print and digital means), and indirect (e.g., information transferred through government and NGO networks). Various versions of *The 2009 State of the Nova Scotia Coast Report* were also needed, for example, the less technical versions (i.e., fact sheets and summary document) and individual theme papers of *The State of the Gulf of Maine Report* were effective for reaching a range of audiences (e.g., industry, academic institutions, students, and non-governmental organizations).

While produced for different audiences and in different formats, the two reports were considered important sources of baseline information on regional coastal issues and were being used for personal and public education. Indirect benefits were noted, for example, inter/intra agency cooperation increased, and it encouraged other organizations to publish related information. Media reports and Web usage were also greater at the time of the launch of the reports. While Web statistics indicate that usage was steady in the interim periods, periodic attention to the issues increased public awareness. Evidence of use and influence, as determined by citation analysis and statistics on library usage, was limited and is attributed to the recent release of the reports.

Discussion

Challenges to increasing awareness and use of such information included the need to communicate to diverse audiences, to increase use of different media (print and digital), and to engage the general public (stakeholders and individuals) outside of established networks. The methods used to promote awareness of the reports targeted the "interested public" rather than the "general public." For example, attendees at the public consultations (for the Nova Scotia study) and readers of the *Gulf of Maine Times* can be considered to be the "interested public" who belong to established groups that historically/traditionally respond to government surveys and requests for input, who may be better able to inform policy, and who include individuals already active in coastal zone conservation.

The research clearly confirmed awareness of the reports and provided an opportunity to determine whether the release of this information was influencing policy making. In the case of *The 2009 State of Nova Scotia's Coast Report*, the two-way communication between production of information and policy and decision making, across the science-policy interface, was more explicit. Public response to the information was sought to encourage participation in the development of a new policy, the *Coastal Strategy*. A draft of the *Coastal Strategy* was released in mid-October 2011 for public feedback and consultation. This intended policy endpoint was also the driving factor behind the production of environmental information (*The 2009 State of Nova Scotia's Coast Report*), which in turn supported policy development. For the GOMC, *The State of the Gulf of Maine Report* theme papers informed the Working Group on the next action plan (2012–2017) (Wells, pers. observ.).

Conclusion

The case study reports may be fulfilling their intended purpose as a first step in guiding decision making and increasing public participation in decision making. Awareness and use of the reports and interest in addressing coastal and ocean issues generally will be enhanced by ongoing communication initiatives. However, adoption of additional communication methods is needed to ensure that wider audiences outside of the established networks of practitioners of coastal management and marine affairs are reached. Participants in the studies confirmed that information about the coasts is very important for their own understanding of coastal matters, and for informing their involvement in policy making. It is therefore anticipated that use and influence of both reports will increase as time progresses.

The findings of the two case studies are consistent with other scholarly research that identified limited communication of scientific information to wide audiences as one of the main issues involved in increasing public participation in decision making. The case studies were useful in developing methods to measure awareness, use, and influence of marine scientific information. These findings are relevant to the field of information and knowledge management. In addition, it is expected that these findings will benefit research scientists in research settings or in public policy arenas, public sector managers, governmental and non-governmental bodies, and research funders.

Acknowledgements

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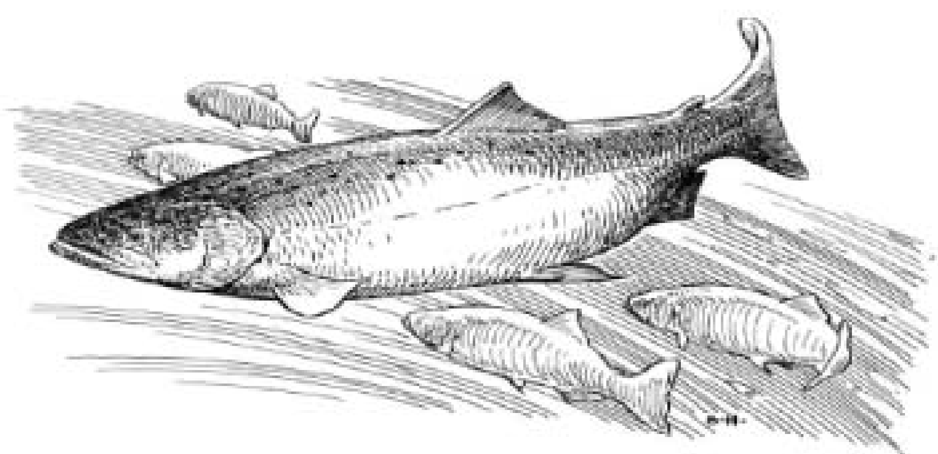
Session E

CONSERVATION AND ECOLOGY OF ESTUARINE FISH

Chair: Jonathan Carr, Atlantic Salmon Federation, St. Andrews, New Brunswick



ASSESSMENT OF AMERICAN EELS IN FUNDY NATIONAL PARK: WHERE ARE ALL THE ELVERS?

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With the drastic decline (99%) of American eels (*Anguilla rostrata*) in Lake Ontario-St. Lawrence Estuary region and resulting species of special concern designation by COSEWIC, there has been renewed interested in determining the status of this species in Atlantic Canada. Of the life-stages found within Fundy National Park, the glass eel and elver stages are the least understood. Targeted sampling efforts in the freshwater and estuarine habitat of the Point Wolfe and Upper Salmon Rivers have been undertaken to estimate the numbers and timing of the movement of individuals from the marine to freshwater environments. Since 2008, sampling techniques have included ramp, habitat and Sheldon traps, and night dip netting with relatively low capture success. Of these techniques, sampling through night dip netting and ramp traps appear to be more effective than either habitat or Sheldon traps. Determining the timing of the elver run is difficult given low catches, however, our results suggest that the run may occur from May to mid-June in Fundy National Park. Observations from electrofishing and smolt wheel operation suggests that adult eels are relatively common in the rivers of Fundy National Park, but low catches of elvers and glass eels suggest that trapping techniques are ineffective or there are very small numbers of glass eels and elvers entering our system for some unknown reason. It remains uncertain whether either of the aforementioned factors or a combination of the two is responsible for our lack of success. However, after four years of sampling with a variety of techniques, we are more confident that it is less likely a problem with sampling technique. Nonetheless, new techniques to sample elvers, such as elver fyke nets and floating habitat traps, will be explored.

USING ACOUSTIC TELEMETRY TO TRACK THE MOVEMENT OF ALEWIVES (*ALOSA PSEUDOHARENGUS*) IN A FRESHWATER AND COASTAL ZONE

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Acoustic telemetry was used to assess the pre to post spawning movements and survival of alewives. A total of 40 alewives were tagged (20 each in 2007 and 2008) after they ascended a fish ladder at the Magaguadavic River's head of tide hydroelectric dam. Fish utilized the lower river reaches and a nearby lake during the spawning period. Six (2007) and two (2008) alewives are believed to have died during the spawning period. To return to sea, all fish must pass the hydroelectric dam. Signals from five (2007) and two (2008) fish were lost near the top of the dam. Nine (2007) and four (2008) fish passed the dam via the turbines and suffered a mortality rate of 62%. No alewives used the downstream fish bypass facility in 2007. However, the bypass efficiency improved to 75% (N=12 fish) in 2008. Improved downstream fish passage may be due to increased attraction flow into the bypass facility. Surviving alewives were tracked through the river estuary and up to 28 km through the coastal zone.

MODELING THE DISPERSAL OF SHORTNOSE STURGEON LARVAE IN THE SAINT JOHN RIVER, NB, CANADA

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Many sturgeon species have similar early life history strategies. Ripe adult sturgeon move as much as 100–200 km upstream in rivers for spawning (Kynard 1997; Bruch and Binkowski 2002). The eggs are negatively buoyant and adhesive, therefore remaining at or close to the spawning grounds. After hatching, the larvae may hide in the substrate for several days before dispersing downstream (Kynard 1997; Kynard et al. 2002; Kynard and Horgan 2002). The larval migration stage is a highly vulnerable phase during the early life history of sturgeon, therefore thorough understanding of the influence of environmental parameters on larval drift is required for sturgeon protection and management.

The shortnose sturgeon, *Acipenser brevirostrum*, is protected throughout its range, which extends from Florida, United States, to New Brunswick, Canada. The Saint John River in New Brunswick is the northernmost occurrence of the species, and its only known habitat in Canada (Dadswell et al. 1984; Kynard 1997). In addition, the local population of shortnose sturgeon is one of the largest throughout the habitat range, second only to the Hudson River (Kynard 1997; Bain et al. 2007), which makes it a useful study model, as larvae can be readily obtained in the wild.

Our objective was to address the knowledge gap of the ecology of the shortnose sturgeon larvae in the wild. Here we report on larval abundance estimates and generalized linear models of larval drift vs. environmental parameters, based on four years of larval collections.

Larvae were collected in 2008–2011 using anchored drift nets at two transects, 13 and 17 km downstream to the spawning site. Approximately 6900 shortnose sturgeon larvae were caught, leading to abundance estimates ranging between 21,000 (2009) and 245,000 (2008) migrating larvae. The abundance estimates at the downstream transect were only 24–51% of those calculated upstream, indicating the mortality/settlement rates within the 4.5 km stretch between the two transects. Water temperature and night-time dam discharge were significant predictors of the overall timing of larval migrations, as indicated by logistic regressions. Dam discharge, length of net deployment and transect location were significant predictors of the number of captured larvae, as indicated by negative binomial models.

This work provides the first estimates of larval abundance in the Saint John River and identifies environmental parameters important for larval dispersal, which will help us to better understand habitat requirements during this vulnerable life stage. In addition, predictive models of larval presence/absence may assist in future sampling and management efforts.

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Best Graduate Oral Presentation

MOVEMENT PATTERNS AND HABITAT USE OF ATLANTIC STURGEON, *ACIPENSER OXYRINCHUS*, FROM THE SAINT JOHN RIVER, NEW BRUNSWICK, CANADA

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Movement patterns and habitat use of Atlantic sturgeon, *Acipenser oxyrinchus*, was investigated using ultrasonic telemetry during 2010 and 2011 in the lower Saint John River, New Brunswick, Canada. Twenty and eighteen Atlantic sturgeon were captured and internally tagged with Vemco V16 ultrasonic coded pingers (27 V16-6X; 5 V16TP; 6 V16P) in June and July 2010 and 2011, respectively. Each fish captured was measured (TL, FL, Girth), digitally imaged, blood sampled, and identified for gender. For females, egg samples were obtained using a trochar. The tagged individuals were tracked using stationary Vemco VR2 receivers located throughout the Saint John River. They were also manually tracked from a 19' Carolina Skiff using a Vemco VR100 receiver equipped with omni-directional and directional hydrophones that allowed us to determine precise locations of the fish through triangulation. Depth, temperature, oxygen concentration, salinity and substrate type was recorded at each directionally triangulated GPS position. In 2011, a Vemco Positioning System (VPS) was deployed to gather additional information about fine-scale movement patterns and habitat use. Atlantic sturgeon selected mean depths (1±SEM) of 6.4±1.0 meters in 2010 and 5.5±1.0 in 2011 and were most commonly found on sandy substrate. Fish were observed upstream as far as river kilometer 107 but were primarily observed between river kilometers 23-55 and exhibited localized movement within this range in both years. Fish initiated downstream migration and exit from the river primarily between late July and late September. Four fish tagged in 2010 were relocated in the Minas Basin following exit from the Saint John River. One fish was relocated in September 2010; 17 days after exit from the Saint John River and three other fish were relocated in June 2011. This work provides vital information to create effective management strategies and protection of this species.

MOVEMENT, BEHAVIOUR AND DIET OF ATLANTIC STURGEON, *ACIPENSER OXYRINCHUS,* TAGGED WITH ACOUSTIC TRANSMITTERS IN THE MINAS BASIN, BAY OF FUNDY, CANADA

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Throughout history, Atlantic sturgeon, *Acipenser oxyrinchus*, Mitchill 1815, have been recognized as economically important commercial fish and have been sought after since the 1600s (Scott and Scott 1988).The fisheries for sturgeon have greatly declined in the last 100 years, owing primarily to over-harvesting pressures as well as pollution and blockage of spawning rivers by dams (Hoff 1980; Dadswell 2006). In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has recently listed the maritime populations of Atlantic sturgeon as 'threatened' (COSEWIC 2011). Designation may stem from the fact that much of the maritime population (~60%, Wirgin et al. 2011in press) comes from the small breeding population within the lower Saint John River area, New Brunswick (COSEWIC 2011). Although fishing pressures have ceased in the United States, the Canadian populations are still subject to regulated commercial and recreational fisheries that have not been closely monitored in terms of their effects on Atlantic sturgeon (COSEWIC 2011). Unfortunately, what makes the monitoring of Atlantic sturgeon so difficult is their highly migratory nature, which can cause a mixing of different populations, and subsequently create an aggregation of individuals being protected under different legislations (Wirgin et al. 2011 in press). Thus is the case for many coastal and estuarine feeding grounds.

Atlantic sturgeon are widely distributed along the east coast of North America; from Florida north to the St. Lawrence River, Quebec, however during their maturation phase at sea they have been recorded as far north as Ungava Bay, Labrador (Dadswell 2006). While at sea, some individuals travel thousands of kilometers to reach summer feeding grounds or spawning rivers. Aggregations of mixed populations are well known in warm summer enclaves, such as the inner Bay of Fundy (Wehrell 2005; Dadswell 2006) and recent analysis of DNA indicates individuals are traveling from natal streams in the United States (including the Hudson River, New York and Kennebec River, Maine) and Canada (primarily the Saint John River, New Brunswick;Wirgin et a. 2011in press). A four year mark and recapture study recently provided a summer population estimate for Minas Basin, Bay of Fundy of approximately 6,000 individuals (Wehrell, unpublished data). Based on size characteristics, Wehrell describes this population as mainly sub-adult and adult Atlantic sturgeon, likely in their intermittent spawning phase. Atlantic sturgeons generally spawn every 1-5 years (Vladykov and Greeley 1963; Dadswell 2006), and during periods of reproductive latency they are often foraging.

Little is known about the movement and behaviour of Atlantic sturgeon in Canadian waters. In this study we are attempting to identify how the summer population of Atlantic sturgeon utilizes the Minas Basin as well as to determine critical habitat by examining spatial distribution and environmental preferences. We are also using fine scale movement patterns of acoustically tagged fish and diet analysis to investigate feeding ecology.

In 2010 we deployed 30 uniquely coded acoustic transmitting tags in Atlantic sturgeon from the seasonal mixed stock feeding aggregation in Minas Basin. Hydroacoustic receivers were placed at strategic locations inside Minas Basin, and in Minas Passage which connects Minas Basin to the rest of the Bay of Fundy (Figure 1). Twenty-eight of 30 tagged sturgeon in 2010 were detected either in the Minas Basin or moving through the Minas Passage (Table 1). Twenty-three of these fish have also been detected in the Minas Basin in 2011, therefore the survival rate of sturgeon post-surgery is high (a minimum of 76.6%–93.3%). In May of 2011, 15

VR2W (Vemco Ltd.) receivers were situated in a VR2W Positioning System (VPS) array at Kingsport Beach (Figure 2). The mudflats of Kingsport are known for frequent visits by Atlantic sturgeon and we propose this is for feeding purposes. The overlapping detection ranges of these receivers allowed for the identification of exact locations over time, so that movement patterns could be estimated and visualized. Through the examination of tagging data (spatial distribution, depth and temperature) as well as stomach analysis, we will attempt to define critical feeding areas and environmental preferences of Atlantic sturgeon in Minas Basin.

Fifty three tags were deployed during the 2011 field season. Data collected by the VPS has been downloaded four times since deployment, and currently 5 of the 2010 and 18 of the 2011 tagged sturgeon were detected within the boundaries of the array (Figure 3). The data provided by this system reveals that sturgeon were displaying consistent linear movement behaviour that we assume is associated with traveling and aggregated movement behaviour that we assume is associated with foraging.

In 2011, twenty stomach samples were collected from Atlantic sturgeon using a gastric lavage procedure (revised from Brosse et al. 2002). Much of the regurgitated prey was still living when it was collected on the sieve, which indicates it has been consumed by the sturgeon recently. Preliminary analysis of gut samples indicated a preference toward soft-bodied benthic invertebrates. Mud worms, bamboo worms and blood worms were all abundant in samples and are all common inhabitants of the Bay of Fundy mudflats (Bromley and Bleakney 1984). Unfortunately, sturgeon prey selectivity cannot be fully assessed as it is impossible to test the overall effectiveness of the gastric lavage method at removing 100% of the stomach contents as sampling was non-lethal.

Currently 39 VR2W receivers remain deployed in Minas Basin and Minas Passage. Final detection logs will be collected in November 2011. Analysis of environmental preference data is ongoing as temperature and water level loggers also remain deployed. Swim depth parameters of tagged Atlantic sturgeon are also in the process of being analyzed. Qualitative and quantitative analysis of gut contents is also ongoing.

Overall this study will provide basal biological data required to implement management plans protecting critical habitat of this threatened species. Disturbance of sediment in the St. Lawrence River has been shown to directly affect a sturgeon's ability to utilize that area for food, thus depleting their resources (Nellis et al. 2007). This is mainly due to a decrease in the abundance and or diversity of benthic prey organisms available to sturgeon consumers. Westhead (2005) noted that the harvesting of bloodworms and clams within Minas Basin has resulted in comparable physical disturbance to the tidal flats. Although the biological implications are still being examined, it is possible that disturbances to sediment type could affect the diversity of benthos living there and subsequently have an effect on Atlantic sturgeon consumers. Should Atlantic sturgeon demonstrate a preferential prey type in their diet, future conservation efforts can be focused on regions of Minas Basin containing those prey items. Subsequently, the movement data obtained from the acoustic transmitters will provide us with behavioural profiles that allow us to identify regions in Minas Basin important to the summer aggregation of sturgeon. Residency times as well as the examination of different movement trends will also provide us with insight into Atlantic sturgeon habitat use and help us to identify key characteristics of critical feeding areas, such as the intertidal zone at Kingsport Beach.

	Receivers Deployed	**Tags Deployed**	**Tags Detected in 2010**	**Detection % 2010**	**Tags Detected in 2011**	**Detection % 2011**
2010	32	30	28	93	23	76
2011	39	53	–	–	42	79

Table 1. The number of VR2W receivers and V16 acoustic tags deployed in Minas Basin, Bay of Fundy during the summer months of 2010 and 2011 and the number of acoustic tags detected from each year-class.

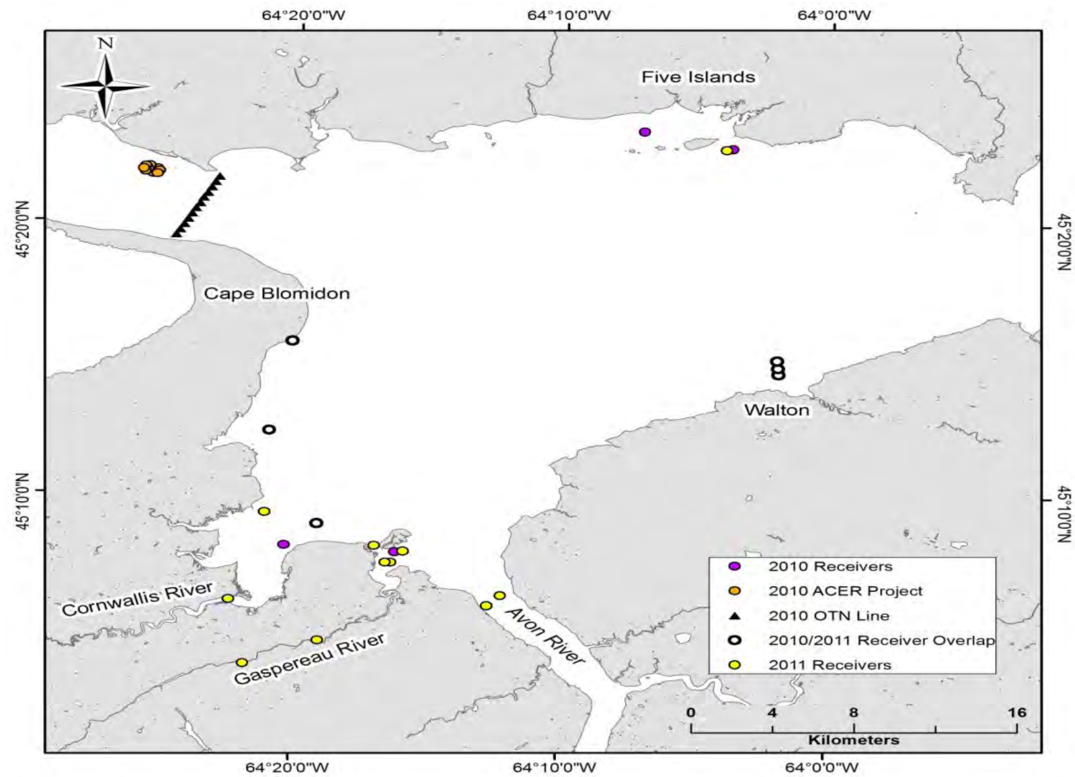

Figure 1.VR2W receiver locations in the Minas Basin, Bay of Fundy during the summer months of 2010 and 2011.

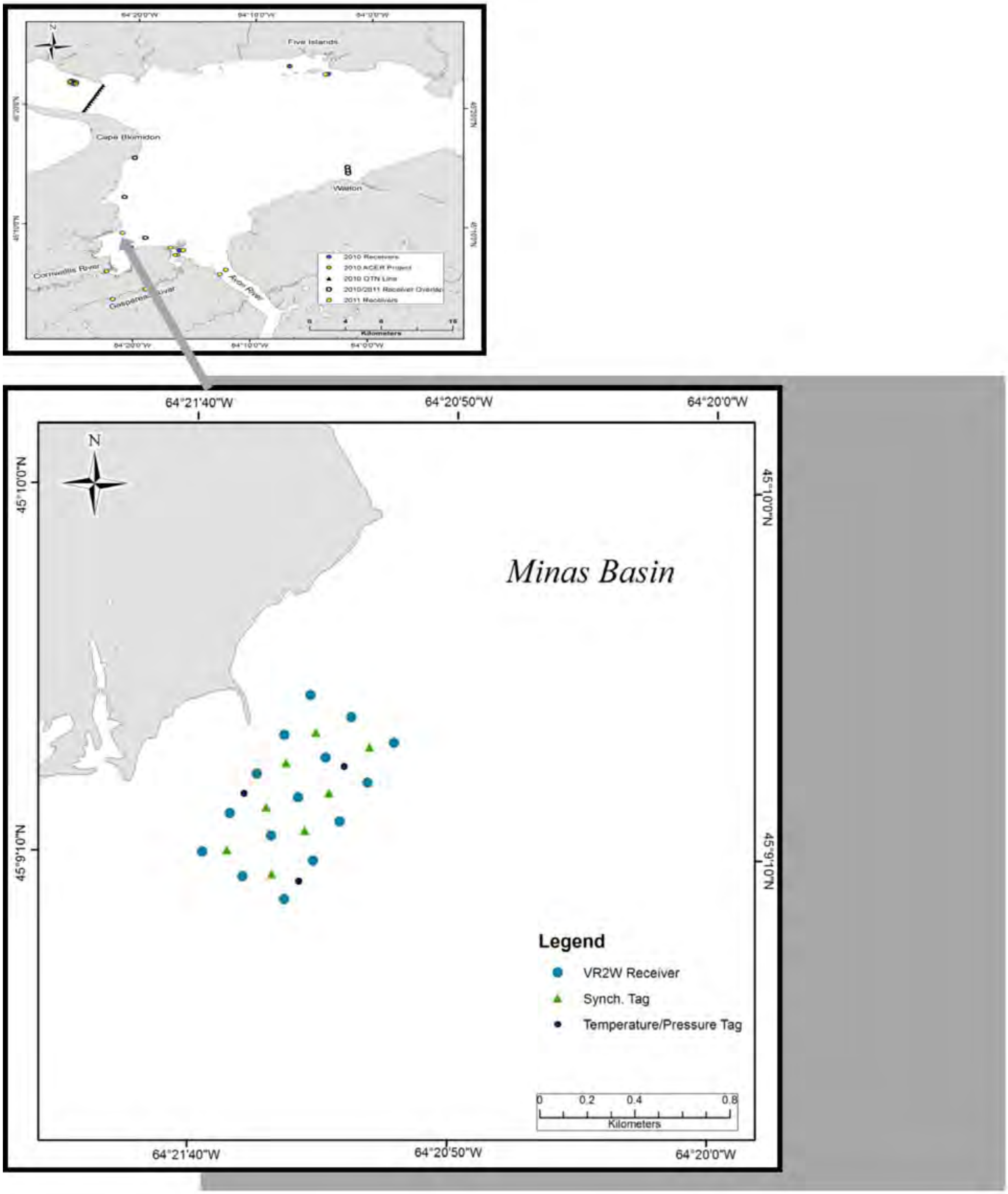

Figure 2.VR2W positioning system (VPS) location at Kingsport Beach, Minas Basin during the summer months of 2011.

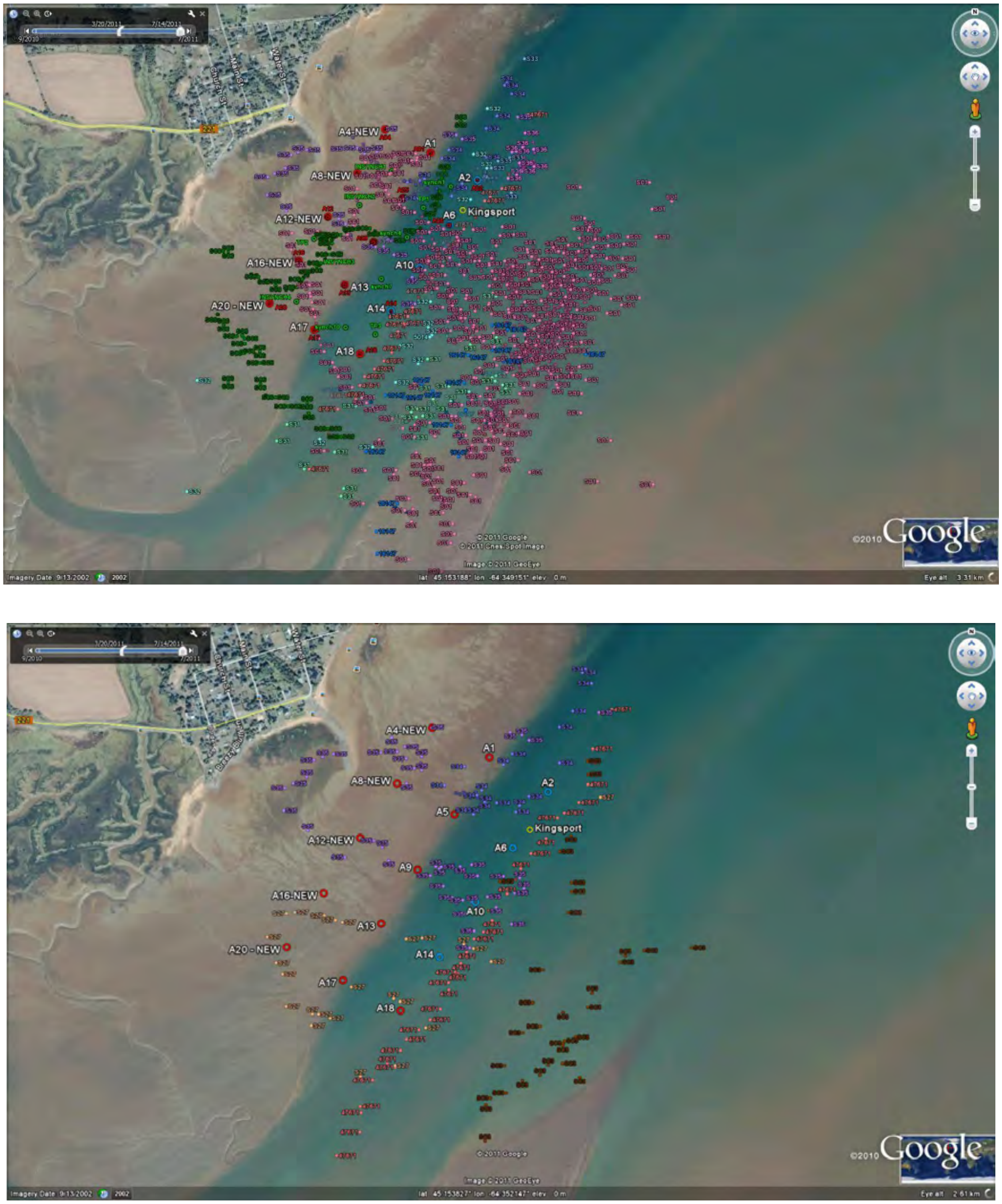

Figure 3. A VR2W positioning system (VPS) allows for fine-scale movements of fish tagged with acoustic transmitters to be visualized. A VPS consisting of 15 VR2W receivers, ten synchronization tags, and three temperature/pressure tags was deployed in the intertidal zone at Kingsport Beach, Minas Basin. Different colours on the map represent an individual sturgeon that was tagged in either 2010 or 2011.

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EFFECTS OF SALTWATER EXPOSURE ON JUVENILE SHORTNOSE STURGEON

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As adults, shortnose sturgeon (*Acipenser brevirostrum*) migrate throughout much of the lower Saint John River (SJR) and surrounding estuary to forage and reproduce. Due to the river's connectivity with the Bay of Fundy, SJR shortnose routinely experience large, fluctuations in salinity, yet very little is known on how (or if) juveniles cope with the associated osmoregulatory challenges. The objective of this study was to assess the acute effects of saltwater exposure in juvenile shortnose sturgeon. In three laboratory experiments, juvenile shortnose sturgeon were exposed to either full or half-strength seawater for up to 24 hours. First, oxygen consumption rates were used to estimate metabolic costs. Second, blood samples were analyzed for the stress hormone cortisol, as well as various measures of osmoregulatory status, oxygen carrying capacity and energy use. Finally, critical swimming speed tests will be used to determine whether salinity affects performance ability. These experiments integrate haematological (cortisol and other blood parameters) metabolic (oxygen consumption), and performance (critical swimming) responses to a range of salinities that could be encountered in nature.

SMALL-SCALE MOVEMENTS OF TOMCOD, *MICROGADUS TOMCOD*, AT MUSQUASH, A MARINE PROTECTED AREA IN THE BAY OF FUNDY, CANADA

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Microgadus tomcod is an anadromous species, one of several numerically abundant demersal fishes that occur in coastal waters of the Bay of Fundy and the Musquash Marine Protected Area, located ca. 20 km southwest of the city of Saint John, NB. Its dominance and wide variety of prey items indicate that this species is a key predator and important in dynamics of energy flow. The primary objective of this study is to determine the extent of tomcod movements within the Musquash MPA. This will be done by tracking 17 sonically tagged tomcod throughout the estuary, over two months during summer. Hence, it should be possible to determine the proportion of tagged tomcod that remain in the MPA and the proportion that move outside the MPA. A second objective is to determine if tomcod move with the incoming and outgoing tides and whether tomcod show evidence of diel movements. Fourteen hydrophones were deployed in the MPA. Conditions in the Musquash Estuary are less than ideal. Consequently an important first step of this study was to determine the distance over which the sonic tags can be detected by the hydrophones. Range testing in the upper estuary identified a detection radius of 200 m whereas hydrophones deployed between the headlands were found to have a detection radius of 300 m. All the fish (> 17 cm) have been sonically tagged. Tomcod recovered quickly and looked healthy after surgery. The movements of all tomcod will now be followed by stationary receivers in addition to active tracking.

SHUBENACADIE RIVER STRIPED BASS EGG, LARVAE AND JUVENILE ABUNDANCE

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Abstract

Abundance estimates in 2010 and 2011 were conducted mostly four kilometres downstream of the confluence between the Shubenacadie and Stewiacke rivers, with some surveying extending the full range of the estuary and into Cobequid Bay. In May and June of both years there were several large spawning events resulting in 1000 - 8000 eggs/m^3 water filtered. From one such spawning (29 May 2011) about 19 billion eggs drifted past the sampling site over the 11 hour ebb-tide, taking into account the change in both the water velocity and cross-sectional area of the water column. About 21,000 females were involved in this single spawning based on a mean fecundity of 9.0 x 105 eggs (± 76354 SE; 6.68 kg body weight). Total number of females spawning in 2011 was about 43,000 based on overall egg production. Daily average density of first feeding larvae peaked at 200 larvae/m^3 in 2010 and 800 larvae/m^3 in 2011, five-fold lower than egg density. Larvae density decreased dramatically in mid-June 2011 and was associated with large freshets and large tides. Advection of both eggs and larvae from the estuary into Cobequid Bay was established. Young of the year (YOY) were distributed throughout the estuary at low abundance in both years. Higher temperatures and lower rainfall in 2010 was associated with better growth compared to 2011. Mean total length in late-August was 7.5 cm (3.16 SE) in 2010, but only 4.5 cm (1.49 SE) in 2011. The high abundance of eggs indicates the adult population is healthy, but survival of early life stages is relatively low and greatly affected by potentially large fluctuations in temperature and freshwater run-off.

Introduction

The Bay of Fundy population of striped bass (*Morone saxatilis*) has been designated as 'threatened' (COSEWIC 2004). Historically, three rivers in the Bay of Fundy supported striped bass populations, but the Annapolis and Saint John Rivers have shown no evidence of successful spawning since the 1970's (Bradford et al. 2001; Douglas et al. 2006). This leaves the Shubenacadie-Stewiacke estuary as the sole spawning and nursery habitat for this population, and the only estuary across the species range dominated by a tidal bore (Rulifson and Dadswell 1995). Knowledge of factors affecting survival of early life-history stages of Shubenacadie striped bass and recruitment is poor. The spawning grounds are close to the head of the tide on the Stewiacke River. Pioneer work in 1994 estimated about 4500 adults produced 61 x 106 eggs (Tull 1997; Rulifson and Tull 1999). Depending on size and age, females each release between 50,000 and 1.46 million eggs (Paramore 1998). Eggs (3.5 mm in diameter) are slightly negatively buoyant but remain suspended in the water column by turbulent water, hatching in 48 hours at 16°C (Rulifson and Tull 1999; Cook et al. 2010). Since the mid-1990s the population has increased considerably. In 2002 the number of adults was estimated between 20–30,000 (Douglas et al. 2003). The Department of Fisheries and Oceans indicated spawning abundance has likely increased further, but there is no data since 2002 (Bradford and LeBlanc, in press). According to local drift-net fishermen, the numbers of adult striped bass are the highest they have seen over the past 50 years (W.H. Stone and R. Meadows, pers. comm.). Our objective was to estimate the abundance of egg and early life stages relative to environmental conditions to gain insight of factors affecting survival, growth and recruitment. The tidal ebb and flow of the high-energy

Shubenacadie estuary dictates the distribution of pelagic striped bass eggs and early larval stages. Their advection from estuary nursery habitat into Cobequid Bay over the long 11 hour ebb-tide has been hypothesized, but not tested (Rulifson and Tull 1999). By comparison, in the low-energy Chesapeake Bay the stratification and associated estuarine turbidity maximum (ETM) plays an important role retaining striped bass eggs and larvae in the estuary nursery habitat (Shoji et al. 2005; North and Houde 2006). With no such retention mechanism in the Shubenacadie, we extended our survey to the estuary mouth and into Cobequid Bay to see if advection was occurring. This work was part of a four-year monitoring program for Alton Natural Gas Storage LP.

Methods

The primary sampling site was 4 km downstream of the Shubenacadie-Stewiacke river confluence at 45° 09.423 N – 63° 23.133 E. The estuary width at high tide is 240 m, decreasing to 150 m at low tide, with a large sand bar on the West bank. Depending on the tide, water depth ranged from 1 to 4 m (measured by sonic ranger SR50), and the cross sectional area of the water column ranged from 150 to 1550 m^2 (surveyed in May and September 2010 using a Leica SR350 GPS). Temperature and salinity were recorded with both a hand-held meter (YSI 85) and loggers (Van Essen CDT; Vemco minilog). Water velocity was determined using a drogue-buoy pair made from plastic bottles (Monahan and Monahan 1973). Differences in water velocity with respect to the cross-section of the estuary over the tidal cycle were analyzed using an Acoustic Doppler Current Profiler (ADCP Teledyne/RDI Rio Grande 600 MHz).

Plankton net tows (1–3 min) were conducted mid-May to July every 30 to 60 minutes for up to eleven hours during the ebb tide and during about one hour of the flood tide. In addition two 36-hour sampling sessions covering three full tidal cycles were completed during peak spawning events. Tows were from the top 0.75 m of the water column using a standard 0.5m conical plankton net (250 µm or 500 µm mesh) with a calibrated flow meter (General Oceanics Environmental). Tows were into the current, from a fixed location.

The spatial distribution and abundance of striped bass eggs, larvae and juveniles was assessed weekly over a 36 km range from the estuary mouth to the head of the tide, using both plankton nets and seine nets (12.5 m x 0.85 m, 5 mm mesh, with the center 1.19 m at 1 mm mesh). Organisms caught were counted, a sample of the striped bass were euthanized and preserved in 10% formalin. In the laboratory, striped bass eggs were enumerated and placed in one of four development stages (new, blastula, 24 hour and close to hatch; Hardy 1978).

The number of eggs flowing past the primary sampling site during a single ebb tide was estimated by factoring in the river cross sectional area (m^2), main channel cross sectional area (m^2), main channel velocity (m/s), and egg density (eggs/m^3). The total egg abundance results reported here are preliminary. Further analysis is needed to account for the subtle changes in water velocity across the cross-sectional area of the estuary during the ebb tide. The estimate of the total number of spawning females was based on fecundity data. Fecundity estimates were made from sixteen mature female striped bass (5.72–8.23 kg) donated by fishermen in spring 2011.

Results and Discussion

In April 2011, 16 pre-spawning females had a mean weight of 6.68 kg (± 0.198 SE) and a mean fecundity of 9.0 x 105 eggs (± 76354 SE). Eggs were detected in 2010 from May 13 to July 2 and in 2011 from May 22 to July 6. Spawning activity was greater in 2011 than 2010. In 2010, there were eight large spawning episodes when daily average eggs density exceeded 100 eggs/m^3, and exceeded 1000 eggs/m^3 at certain times of the tide. The largest spawns were detected May 18 and May 26 when daily average eggs density exceeded 1000 eggs/m^3. In 2011, there where ten large spawning episodes when daily average eggs density exceeded 100 eggs/m^3, and exceeded 1000 eggs/m^3 at certain times of the tide. The two largest spawning events, May 29–30 and June 2, resulted in daily mean egg density of ~4000 eggs/m^3 and ~1700 eggs/m^3 respectively. This density of striped bass eggs is extraordinarily high compared to 0.7 eggs/m^3 on the Miramichi River, the only other river in Atlantic Canada known as a nursery habitat for striped bass (Robichaud-LeBlanc et al. 1996) and 12 eggs/m^3 in tributaries of Chesapeake Bay, the main nursery area for 90% of U.S. striped bass (Setzler-Hamilton et al. 1981; Bilkovic et al. 2002).

The 2010 and 2011 sampling seasons were very different in terms or temperature and rainfall, with 2010 being a warm and dry spring and 2011 being 3–4°C cooler per month and wet (Table 1). These environmental differences influenced early life stage striped bass distribution and growth. During the 36-hour sampling 17–18 May 2010, egg density exhibited a similar change each tidal cycle, increasing progressively to over 4000 eggs/m^3 around nine hours into the ebb tide, and then decreasing just before the arrival of the tidal bore (Figure 1). The eggs were then swept upstream on the flood tide, drifting back down again on the next ebb tide. Due to the low water temperature of 11.3 °C, the developmental stage of the eggs during the 36 hours remained at the blastula stage, suggesting they were the same cohort of eggs. In other estuaries the time from fertilization to hatch at 11 °C is around 4 days, compared to 48 hours at 17 °C (Harrell et al. 1990). The retention of these eggs in the upper estuary in 2010 was due to the unusually dry spring and low freshwater run-off, as indicated by the very high salinity at high tide, reaching 23 ppt (Figure 1). By contrast, during the 36-hour sampling 23–24 May 2011 egg density decreased quickly over the three tidal cycles (Figure 2). The different pattern in 2011 was associated with the wet spring weather and relatively high freshwater run-off, indicated by the relatively low salinity at high tide (7 ppt). Egg density exhibited a similar pattern each tidal cycle, decreasing progressively through the 11 hour ebb tide, increasing during or immediately following the tidal bore, and then continued to decrease during the following ebb tides (Figure 2). Following the first tidal cycle there was a three-fold decrease in the peak density of eggs. The developmental stage of the eggs during the 36 h sampling remained at the blastula stage due to the 12 °C water temperature, similar to 2010. Comparing the temporal distribution of eggs over these two 36-hour sampling sessions, in 2010 the eggs were bring pushed further upstream past the primary sampling site and were taking longer to flow back downstream due to low water velocity. Peak density was not seen until late in the ebb tide in 2010. In contrast, eggs in 2011 were not being carried very far upstream due to the large amount of fresh water counteracting the tide. These eggs were then flowing more quickly downstream due to high water velocities from the influx of fresh water. Proof of advection from the Shubenacadie estuary was established on May 30, 2011 when large numbers of striped bass eggs (20–50/m^3) were detected several kilometers beyond the estuary mouth in Cobequid Bay.

	Precipitation (mm)		Temperature (°C)	
Month	**2010**	**2011**	**2010**	**2011**
April	38	124.2	*	*
May	48	124.2	14.6	10.6
June	100	144.3	16.6	13.7
July	126	94.5	22.2	18.8
August	65	130.1	22.2	18.6
September	118	41.3	18.6	*
October	150	*	14	*

Table 1. Total precipitation for each month for years 2010–2011 recorded at the Stanfield International Airport weather station, and mean monthly temperature of the Shubenacadie River recorded by loggers at the primary river site, with some data from the lower Stewiacke River. * indicates that the data has not yet been collected. April, May and June 2011 had 210.7 mm more rain than 2010 and May and June were 3–4°C cooler.

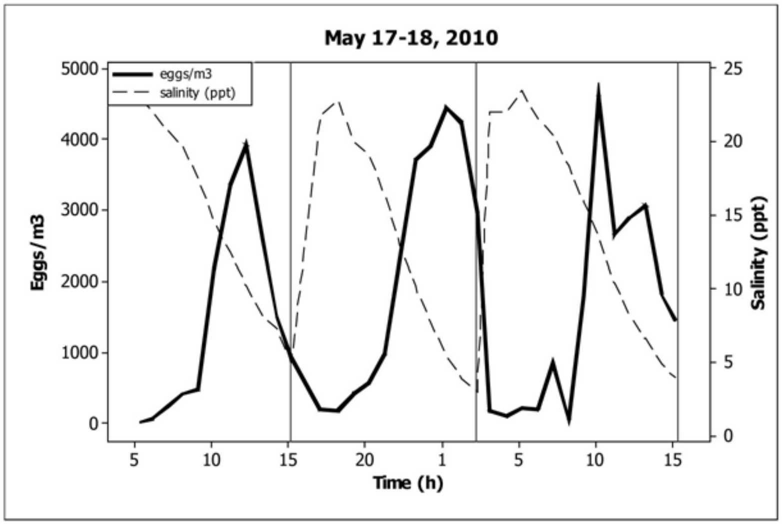

Figure 1. Striped bass egg density (eggs/m^3) and salinity (ppt) over 36 hours May 17 to 18, 2010 at the primary sampling site. Vertical lines indicate the time of the tidal bore (May 17: 03:45h, May 18: 04:04h and 16:35h). The tide begins to ebb about 1 hour and 30 minutes after the tidal bore. Egg stage remained 95% blastula through the 36 hours. Egg density exhibited a similar change each tidal cycle, increasing progressively to over 4000 eggs/m^3 around nine hours into the ebb tide, and then decreasing just before the arrival of the tidal bore. There was unusually low freshwater run-off, as indicated by the very high salinity at high tide, reaching 23 ppt.

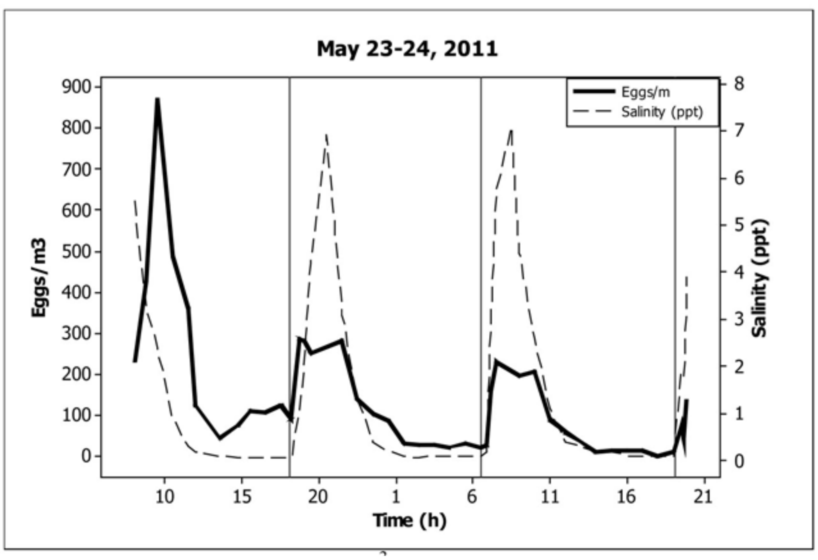

Figure 2. Striped bass egg density (eggs/m^3) and salinity (ppt) over 36 hours May 23 to 24, 2011 at the primary river site. Vertical lines indicate the time of the tidal bore (May 23: 18:10h, May 24: 06:35h and 19:10h). The tide begins to ebb about 1 hour and 30 minutes after the tidal bore. Egg stage remained 95% blastula through the 36 hours. Egg density exhibited a similar pattern each tidal cycle, decreasing progressively though the 11 hour ebb tide, increasing during or immediately following the tidal bore, and then continued to decrease during the following ebb tides. Following the first tidal cycle there was a three-fold decrease in the peak density of eggs. There was relatively high freshwater run-off, indicated by the relatively low salinity at high tide 7 ppt.

Total egg abundance during the largest spawning over the 11 hour ebb tide on 29 May 2011 was estimated at 19 billion eggs from about 21,000 females. For the entire 2011 season, accounting for eggs returning on successive tides, the total number of eggs spawned was estimated at 38 billion, from about 43,000 females. This estimate of egg production is 600-fold higher than in 1994 (Rulifson and Tull 1999) and the estimate of the striped bass spawning population is 4.5-fold higher than in 2002 (Douglas et al. 2003). This increase in egg production and striped bass spawning population size seems large, however Chaput and Douglas (2011) estimated that on the Miramichi River between 1994 and 2010 the spawning population fluctuated between four and 90 thousand.

Larvae were collected in the plankton nets from May 20 to July 7, 2010 and from May 27 to July 11, 2011. Their density (larvae/m^3 water filtered) was 5-fold lower than egg density (egg/m^3) in both years. The vast decrease in density from egg to larvae stages is consistent with other estuaries (Olney et al. 1991; Secor and Houde 1995). In 1994, only 61 striped bass larvae were caught in the Stewiacke River survey (Rulifson and Tull 1999). In 2010, daily average density of first feeding larvae (4–7 mm TL) peaked at 193 larvae/m^3 on May 28, was ~100 larvae/m^3 on two other occasions, and was ~20 larvae/m^3 on several days in June. By comparison, in 2011, most larvae were caught between June 1 and June 13. During this period daily average density of first feeding larvae was highest on June 6 (816 larvae/m^3), and was ~200 larvae/m^3 on six other days. Between June 13 and 15 larvae disappeared from the sampling site in association with heavy rain and high tides related to the full moon. Presumably the larvae had been flushed down-stream, and possibly into Cobequid Bay. On June 22, 2011 low densities of larvae (20-40/m^3) were found in Cobequid Bay, 10 km from the estuary mouth. Tracking of drogue-buoys from the primary sampling site to the estuary reveled water velocities between 6 and 10 km/h, easily sufficient to flush passive eggs and larvae into Cobequid Bay on a single ebb tide. Retention of eggs and young larvae within the estuary when fresh water run-off is high, we propose, is possible only if the flood tide carries them upstream of our primary sampling site. In preliminary surveys in 2011, 10 km up the Stewiacke River and 12 km up the Shubenacadie River from the primary sampling site, we detected both eggs and larvae.

Abundance of YOY was similar in both years of the study, despite the apparent loss of larvae following the 2011 June 13–15 rain event. Striped bass seine net catch per unit effort was 12.7 in 2010, compared to 9 in 2011. In both years the majority of the fish were caught in July (84% in 2010 and 58% in 2011), with abundance decreasing though August and September. In late-summer, YOY are distributed in Cobequid Bay (Rulifson and Dadswell 1995; Bradford and LeBlanc, in press). Body size of YOY striped bass was much greater in 2010 compared to 2011, due to a warmer summer (Table 1). 2010 had 426 more degree days than 2011. Mean total length of YOY in late-August 2010 was 7.5 cm (3.16 SE), reaching 11 cm (16 SE) by late September. By comparison, in 2011, mean total length in late-August was 4.5 cm (1.49 SE) (Figure 3). Striped bass YOY in the Hudson River need to achieve an end-of-season body length of around 10 cm to survive over winter (Hurst and Conover 1998). Assuming the rule holds true for Shubenacadie estuary striped bass, it is unlikely that the 2011 YOY striped bass will reach the crucial 10 cm by the end of the growing season. We predict recruitment from the 2010 year-class is above average and recruitment from 2011 year-class will be very low.

Conclusion

The high abundance of eggs in the Shubenacadie estuary indicates the adult population is healthy, but survival of early life stages is relatively low and greatly affected by fluctuations in temperature and freshwater run-off. Water temperatures through July–September also plays an important role in YOY growth and thus overwinter survival. Recruitment is therefore affected by inter-annual variation in environmental factors. The long length of the Shubenacadie estuary and the high-energy tidal cycle dictates the distribution and retention of early life stage striped bass. Presented here is the first evidence that striped bass eggs and larvae can be advected out of the Shubenacadie estuary and into the Cobequid Bay. However, it is unclear whether early life stages are negatively

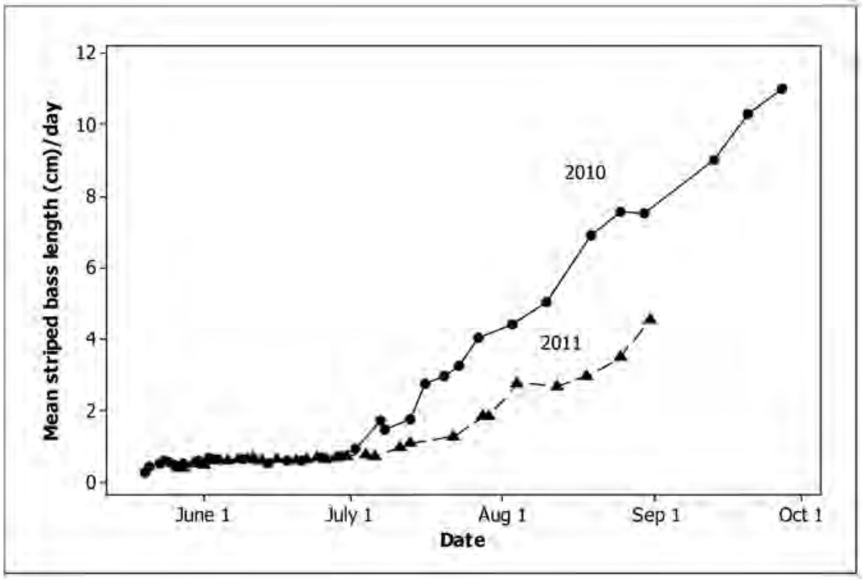

Figure 3. Mean body length of young-of-the-year striped bass caught in the Shubenacadie estuary from the end of May to end of September 2010 and the end of May to end of August 2011. Mean total length in late-August was 7.5 cm (3.16 SE) in 2010, and 4.5 cm (1.49 SE) in 2011.

affected by advection or whether the nursery habitat extends into the Cobequid Bay. The considerable inter-annual variation in environmental factors and abundance of YOY striped bass justifies the need for long-term monitoring to gain an understanding of the factors affecting recruitment and population dynamics of this important species. Presently environmental factors are not included in management planning for striped bass. However, DFO is moving towards an ecosystems based approach to fisheries management, which means identifying and understanding key ecosystem relationships (DFO 2007). Understanding how variation in environmental factors affects striped bass recruit could positively contribute to successful striped bass management.

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CONSERVATION BIOLOGY AND ECOLOGY OF CUSK, *BROSME BROSME*, IN THE BAY OF FUNDY AND SCOTIAN SHELF

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Research vessel survey data collected by Fisheries and Oceans Canada (DFO) in the Scotian Shelf and Bay of Fundy regions (1970–2010) were analyzed to determine if cusk (*Brosme brosme*) population size, total length, and overall distribution continued to decline, showed an increase or showed no change since 2001 when this species was last evaluated by COSEWIC (Committee on the Status of Endangered Wildlife in Canada). It was found that cusk population size declined by 96.2% since 1970 but did not show a significant decline post-2001 (2002–2010). Average length of cusk decreased approximately 11 cm (63.6–52.4 cm) between 1970 and 2010, but there was no significant change post 2001. The proportion of sites in which cusk were caught has declined from 17% in the 1970s to 3% in post 2001 data. Cusk is now primarily found in deep waters at the mouth of the Bay of Fundy near Georges Bank and also near the Grand Manan Bank off southwest New Brunswick. Due to insignificant declines post 2001, it appears that cusk population size, total length, and distribution have stabilized since 2001 at historic lows in the Scotian Shelf and Bay of Fundy.

MUSQUASH ESTUARY, MARINE PROTECTED AREA (MPA), FISH SURVEYS FOR THE DEVELOPMENT OF A BIODIVERSITY BASELINE

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Musquash Estuary, established as a Marine Protected Area (MPA) in 2007, is the first designated MPA in the province of New Brunswick. The main objectives for this project were to: 1) describe fish species composition and abundance at three sites within the MPA in relation to both seasonal and habitat differences; and, 2) make spatial comparisons between the MPA and two estuaries outside the MPA: Dipper Harbour (Campbell's Cove) and Saint's Rest Marsh (Taylor Island, Irving Nature Park). Sampling occurred twice a month with a beach seine and fyke net at all five sites, yielding a total of 20 species (> 7000 individuals) between October 2009 and December 2010. Both fishing gears showed high dominance of a few species; eight species made up 98% of the beach seine catch and four species made up 97% of the fyke net catch. Beach seine species richness correlated positively ($R2=0.52$, $p < 0.01$,) with temperature (ranging -1–21°C). Multivariate analyses (PERMANOVA and ANOSIM in PRIMER) revealed strong seasonal differences in the fish community of Musquash estuary but no significant differences among the three sites within months. However, differences were observed between the fish communities of Musquash estuary and the two neighbouring estuaries. Dipper Harbour and Saint's Rest Marsh differed significantly from each other, with Musquash being intermediate and not significantly different from either site. This pattern suggests an east-west spatial gradient in the fish community rather than an effect of MPA status.

RESTORING FISH PASSAGE TO THE MOOSE RIVER THROUGH THE REMOVAL OF THE CLEMENTSPORT DAM

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The Clementsport Dam, built in the early 1940s to provide drinking water to the wartime Cornwallis Naval Station, spanned the West Branch of the Moose River two kilometres upstream of the river's mouth at the Annapolis Basin, Annapolis County, Nova Scotia. After its use as a drinking water supply ceased in the 1960s, the dam and impoundment was an actively used community-swimming park. Over the past ten years though, interest in the park has waned, with the dam falling into disrepair. High river flows and ice damage had removed large portions of the dam and undermined the structure.

The dam, at 23 m wide and 1.7 m high, was a major barrier to fish passage and a public safety hazard. The Moose River has historically supported Atlantic salmon (*Salmo salar*), with parr and American eel (*Anguilla rostrata*) recently being confirmed below the dam.

September 2011 marked the culmination of four years of planning and preparation, with the successful removal of the Clementsport Dam and restoration of the Moose River. For the first time in more than 70 years, migratory fish will be able to move up the Moose River unimpeded, with the removal of the dam.

The project was the result of partnership across three levels of government, spanning Canada and the United States. The National Oceanic and Atmospheric Administration (NOAA), the Gulf of Maine Council (GoMC) and Fisheries and Oceans Canada (DFO) have worked diligently for more than four years with the Clean Annapolis River Project (CARP) to bring this project to fruition. The project would not have been possible without funding support from NSLC Adopt A Stream, the province of Nova Scotia, the Atlantic Salmon Conservation Foundation and RBC Blue Water Project

At the instigation of the local community, CARP undertook a Feasibility Study of the Clementsport Dam in 2009–2010 to identify the best course of action with respect to its future. After a comprehensive study, which included numerous community meetings, a consensus emerged that the complete removal of the dam and restoration of a natural river channel was recommended. The next step in the process was to complete a restoration design for the dam and obtain the necessary permits.

CARP retained Hurlburt Construction of Yarmouth to undertake the physical restoration. Parish Geomorphic provided onsite engineering oversight. The restoration of the site included a number of components. The dam, derelict fish ladder and concrete abutment were demolished and removed. Three deflector weirs were installed to protect the adjacent Clementsport Road. Three riffles and a grade control structure were also installed to ensure fish passage through the site.

Unlike the vast majority of Nova Scotia rivers that have been adversely impacted by acid rain, the unique local geology of the Moose River watershed provides natural buffering. The Moose River has both good water quality and the necessary habitat needed for the spawning and rearing of the threatened Atlantic salmon. CARP will continue ecological monitoring at the site until the summer of 2013 to better understand how the river has recovered.

The removal of the Clementsport dam represents one of the first planned removals of a derelict dam in Nova Scotia. Through the partnership with NOAA and GoMC, the project has drawn extensively on the extensive American dam removal experience in the New England region. It is hoped that this experience can be used to restore other rivers in the province.

Session F

AQUATIC HEALTH AND MONITORING

Chair: Gary Bugden, Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia

STATE OF THE GULF OF MAINE REPORT

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Introduction

The Gulf of Maine is a dynamic, changing ecosystem. Bordered by the northeastern United States and the Canadian Maritime Provinces, the Gulf of Maine is one of the largest semi-enclosed coastal seas in North America. It is recognized as one of the world's richest marine ecosystems with various marine and estuarine habitats, such as salt marshes, seagrass beds, tidal mud flats, underwater rocky outcrops, and kelp beds. Over 10 million people live in the Gulf of Maine watershed. Along its western and northern shores lie the cities and towns of coastal Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia. The Gulf has supported a long tradition of fishing, marine transportation, coastal development, and recreation, and continues to be a valuable resource for the people who live and work in the region.

On 9 June 2010, the Gulf of Maine Council on the Marine Environment launched *The State of the Gulf of Maine Report*. The Report is a living, web-based document that has been written as a series of issue or theme papers and is available at www.gulfofmaine.org/stateofthegulf.

The main objective of *The State of the Gulf of Maine Report* is to inform decision makers on the main issues affecting the Gulf. The aim is to provide the information in a form that is easily accessible and readable, without compromising scientific validity. It is currently being used to inform future action planning of the Gulf of Maine Council. It is hoped that the report will be used on an ongoing basis by a wider audience to inform government policy decisions, assist in municipal planning, and provide material for education and outreach for conservation of the Gulf.

The reporting framework is the driving forces-pressure-state-impacts-response (DPSIR) framework, which makes the linkages between the environment and socio-economic factors. It also lends itself most easily to reporting on an issue-by-issue basis, so that the pressures, state, impacts and responses are described for each issue in turn. Seven priority areas have been identified for the report, including: climate change; fisheries and aquaculture; coastal development; aquatic habitats; eutrophication; contaminants and biodiversity. The report also documents some of the emerging issues facing the region. The reports are written by subject matter experts and are peer reviewed. The overall reporting process is over seen by an editor-in-chief and editorial committee, drawn from the membership of the Gulf of Maine Council.

This paper will provide an overview of some of the findings of the report, based on the issue papers that have been developed so far, including Climate Change and its Effects on Humans, Climate Change and its Effects on Ecosystems, Coastal Ecosystems and Habitats, Marine Invasive Species and Emerging Issues.

Summary of the Theme Papers Developed as Part of *The State of the Gulf of Maine Report*

There are two theme papers that deal with climate change: climate change and its effects on ecosystems, habitats and biota, and climate change and its effects on humans. The climate of the earth is changing, as a result of increases in greenhouse gas emissions (GHGs) from human activities. Although the natural release of greenhouse gases occurs, releases from human activities are considered the main drivers of climate change.

Climate Change and its Effects on Ecosystems, Habitats and Biota

Written by Janet Nye, National Oceanic and Atmospheric Administration

The atmosphere and the oceans are warming. These changes are altering the physical oceanography and the ocean chemistry of the Gulf of Maine. Changes in sea surface temperature (SST) and salinity have been observed. The rate of increase of coastal SST in the Gulf of Maine is about 0.7 °C over the last century. The rate of increase has accelerated in recent years and regional studies indicate that SST in this region has increased about 0.23 °C from 1982–2006. The salinity of the Gulf of Maine is decreasing as a result of the melting ice caps and increased precipitation.

These changes in temperature and salinity have altered the state of the Gulf of Maine ecosystem.

- In the last 20 years the position of the Gulf Stream has been consistently further north. How future changes in temperature will effect the hydrography is unknown.
- The Gulf of Maine has experienced changes in thermal habitats. Thermal habitats in the 5–15 °C range, which most species prefer, have decreased over the last twenty years, but the coldest and warmest habitats have been increasing.
- There has also been a suggested increase in primary productivity in the region from 1958–2002 and a shift in phytoplankton species from large diatoms to small dinoflagellates. There may have also been a change in the timing of the occurrence of different phytoplankton species.

With climate change it is predicted that organisms will shift their spatial distribution in response to changes in temperature, salinity, and hydrography. In the Gulf of Maine over half of the 36 fish stocks examined have shifted their spatial distribution to a greater depth or further north. Fish generally remain in their preferred temperature, but shift to higher latitudes or depths. Changes in oceanographic conditions may also cause organisms to shift the timing of migration and spawning. There is concern that organisms may shift events so that they are out of phase with other elements of the ecosystem such as they prey they rely on.

Zooplankton assemblages have changed from large zooplankton to small zooplankton. This has higher trophic level consequences, as less energy is transferred up the food web.

Fish and invertebrate assemblages in the Gulf of Maine have also changed. There has been a shift in dominance from more cold-water species to more warm-water species.

More detailed information is available in the theme paper. http://www.gulfofmaine.org/state-of-the-gulf/docs/climate-change-and-its-effects-on-ecosystems-habitats-and-biota.pdf

Climate Change and Its Effects on Humans

Written by Dan Walmsley, Walmsley Environmental Consultants

Climate change will have many impacts on human populations. The Gulf of Maine has already experienced changes that will impact on human populations.

- Weather patterns in the Gulf of Maine have undergone changes. There has been an increase in average summer and winter land temperatures.
- Increased precipitation, more extreme precipitation events and severe drought periods have also been experienced. Melting and thawing of snow occurring earlier.

- Average sea level rise for stations in the Gulf of Maine range from 1.2 mm in Portland, ME to 4.1 mm in Yarmouth, NS. A rise in sea level increases the impacts of storm surges by allowing surges to reach further inland. Highest surges around the Gulf of Maine tend to occur at the head of the Bay of Fundy and in Massachusetts.
- For storm events and hurricanes, although no specific long term trend of increase is apparent, the Atlantic Basin is currently experiencing an active period.

Provinces and states surrounding the Gulf of Maine have been preparing for the impacts of climate change. An assessment of the vulnerability of coastal environments to sea level rise was undertaken in the United States. The findings indicate that the Gulf of Maine coast is considered to have a relatively low risk ranking, there are areas which are of high risk, particularly in the southern parts. A similar study was also conducted in Canada. Rankings varied from low to high, depending on the location.

The direct risks and impacts of climate change will depend largely on the density of human populations and characteristics of settlements on the coastal strip. Impacts from climate change fall into the categories of human well-being, disruption of infrastructure and networks, access to goods and services, and adaptive capacity of communities to deal with the issue.

There are two strategies for responding to the potential risks and impacts of climate change: 1) mitigation, which involves reduction of GHG emissions, and 2) adaptation, preparing for and minimizing, the predicted impacts.

Currently the international focus is on the reduction of GHG emissions. The Conference of New England Governors and Eastern Canadian Premiers has committed to a Climate Change Action Plan that identifies steps to address those aspects of global warming that are within the region's control to influence. A mid-term goal is to reduce regional GHG emissions by 10% below 1990 levels by 2020. Emergency preparedness is also occurring at the municipal and provincial/state level.

More detailed information is provided in the theme paper.
http://www.gulfofmaine.org/state-of-the-gulf/docs/climate-change-and-its-effects-on-humans.pdf

Coastal Ecosystems and Habitats

Written by Kent Gustavson, Raidho Resource Consulting Ltd.

Coastal habitats found in the Gulf of Maine include: salt marshes, mudflats, seagrass beds, kelp beds, shellfish beds, rocky and cobble shore, and sandy shore. The structure and function of coastal ecosystems are threatened by several pressures that can have important impacts. Increasing population, economic growth and coastal development lead to increased physical habitat alteration and destruction, increased contamination and pollution and an increased need for renewable resource extraction. This, together with the pressures from a changing climate, can alter physical and chemical environments, change the distribution and extent of coastal habitats, affect the distribution and abundance of species within coastal ecosystems, and reduce the provision of critical ecosystem goods and services. Key biophysical changes of concern are site energetics (wave and tidal action); nutrient loading; oxygen demand and availability; water turbidity (and availability of light); habitat fragmentation, and pollution and contamination with toxic chemicals. Overall coastal ecosystems are particularly susceptible to effluent from wastewater treatment and outfalls; runoff and sedimentation from coastal development, forestry and agricultural activities; contamination from aquaculture facilities; and direct destruction of habitat through infilling and other activities that remove habitat from production.

Table 1 summarizes the pressures, current status and impacts by habitat type in the Gulf of Maine. There are many actions and responses in place to reduce the impacts on coastal ecosystems and habitats in the Gulf of Maine. These include: regulatory control of development, pollution and direct habitat disturbance; habitat protection

Habitat Type	Pressures	Status	Impacts
Salt marshes	• Habitat alteration and destruction through coastal development • Sea level rise • Pollution and contamination	Salt marshes tend to be largest and most common in Nova Scotia, New Brunswick and Massachusetts. Salt marshes within the Gulf of Maine are declining. Within New Brunswick and Nova Scotia approximately 65% of salt marsh area has been lost since European settlement. Approximately 50% of salt marsh area has been lost in Massachusetts and 25–50% in Maine.	Pressures on salt marshes result in negative impacts on the ability of salt marshes to provide refuge and nursery areas for fish and shellfish species, as well as resting, feeding and breeding areas for birds and food for other animals. A reduction in the amount and quality of fish rearing grounds has a negative impact on commercial and recreational fisheries.
Mudflats	• Pollution and contamination • Navigational dredging • Renewable resource harvesting	Information is not readily available for the distribution and spatial extent of mudflats.	Mudflats are important feeding grounds for birds and contain organisms that provide an important trophic link between primary coastal productivity and higher trophic levels. They support important commercial fisheries. Deposition and accumulation of contaminants in mudflats has an impact the harvest of species. Inputs of nutrients from agricultural and sewage sources can lead to massive growth of bottom algae, and the subsequent biological oxygen demand can further stress and have an impact on mudflat species.
Seagrass habitat	• Changes in seawater properties (sedimentation; turbidity) • Pollution	Eelgrass is the dominant seagrass species throughout the region and has been identified by Fisheries and Oceans Canada as an ecologically significant species. Seagrass habitats throughout the Gulf of Maine are thought to be in significant decline. It is estimated that eelgrass has declined 20% since European settlement.	Pressures lead to a reduction in the ecological functions provided by seagrass habitat. Specifically the ability for seagrass beds: to trap suspended sediment and reduce the load entering the marine environment from land; absorb dissolved nutrients; provide refuge, spawning, feeding and nursery areas for many species of fish and shellfish; serve as a source of vegetative detritus for marine filter feeding organisms; and provide habitat space for a number of coastal species.
Kelp beds	• Storm events • Changes in seawater properties (temperature) • Renewable resource harvesting	Although there is no readily available information on the distribution and spatial extent of kelp beds, the deforestation of kelp beds is a general concern.	Impacts include loss of habitat, food source and key provider of primary production to the ocean waters.

Habitat Type	Pressures	Status	Impacts
Shellfish beds	• Renewable resource harvesting • Pollution and contamination • Changes in seawater properties (temperature and acidification) • Navigational dredging	Information is not readily available for the distribution and spatial extent of shellfish beds.	Fishing has a direct impact on the size, community structure and habitat structure of shellfish beds. Persistent organic pollution and metal contamination are also of particular concern to shellfish. Loss of shellfish beds can also lead to a loss of habitat.
Rocky shores	• Changes in seawater properties (sedimentation; turbidity, temperature) • Renewable resource harvesting	Information is not readily available for the distribution and spatial extent of rocky shores. However, rocky and cobble shores are not seen to be under threat.	Biophysical impacts on rocky and cobble shore habitat include reduced habitat complexity for the protection and development of a number of species.
Sandy shores	• Habitat alteration and destruction through sand extraction • Storm events • Beach nourishment	Information is not readily available for the distribution and spatial extent of sandy shores. However, sandy shore habitat has been documented to be in decline.	Disturbance of important nesting grounds. Loss of beach access.

Table 1. Pressures, current status and impacts by habitat type in the Gulf of Maine

and the creation of conservation areas; habitat restoration initiatives (the Gulf of Maine Council has developed a habitat restoration strategy); and environmental mapping and monitoring to inform adaptive management.

More detailed information is available in the theme paper.

http://www.gulfofmaine.org/state-of-the-gulf/docs/coastal-ecosystems-and-habitats.pdf

Marine Invasive Species

Written by Adrienne Pappal, Massachusetts Office of Coastal Zone Management

Marine invasive species are defined as non-native species that cause or are likely to cause harm to ecosystems, economies, and/or public health. The primary driving force behind marine introductions is transportation, trade practices and other human activities. In addition, habitat modification and climate change alter the survival rates of both native and non-native species and may influence establishment of marine invaders.

In the Gulf of Maine, at least 64 invasions have occurred and the majority of marine invaders originate from Europe. Commercial shipping has lead to the introduction of marine invasive species into the Gulf of Maine through two primary mechanisms: transport by ballast and fouling on ship surfaces. Mysids, amphipods, cladocerans, copepods, numerous microscopic planktonic organisms, algal filaments, and fish have been observed to survive in ballast tanks in journeys lasting nearly two weeks, while polychaete larvae and copepods can survive voyages of 30 days or more. In the Gulf of Maine, it is hypothesized that the red alga *Furcellaria lumbricalis* was introduced via ballast water and the colonial tunicates *Botrylloides violaceus* and *Diplosoma listerianum* were fouling introductions due, in part, to their short larval period. Modern vessels are faster, have shorter times in port, and are more frequently maintained, thus the role of hull fouling in recent transoceanic introductions has been questioned.

Transport of marine introduced species from their point of introduction to other areas regionally can occur through many vectors. Coastwide trade (short-sea shipping) and recreational boating are likely important transport vectors throughout and between the Gulf of Maine, southern Atlantic, and northern Canada. Boat hulls, propellers, chains, anchors, and ropes are easily fouled by marine invaders, facilitating spread when the vessel relocates or is cleaned, particularly for species capable of reproducing through fragmentation, such as colonial tunicates and algae.

Transfer of non-native species for aquaculture, particularly oysters, has been identified as a major vector of marine introductions in North America. Species have been introduced directly to the Gulf of Maine for aquaculture purposes, as with the European oyster, *Ostrea edulis*, or may be secondarily associated with aquaculture organisms. It is hypothesized that introductions of ubiquitous and aggressive species such as the colonial tunicates *Didemnum vexillum* and *Botrylloides violaceus* and the green algae *Codium fragile* ssp. fragile resulted from the transfer of oysters for aquaculture.

Currently, the number and abundance of marine species in the Gulf of Maine appears to be increasing. The abundance and dominance of marine invaders has also shifted over time. The immediate concern has been focused on marine invaders that have been recently introduced to the Gulf of Maine, introduced species that have expanded their range significantly in recent years, or species that threaten to invade the region. Since these organisms are relatively new invaders, or have not yet been introduced, their impacts and spread within the Gulf of Maine are difficult to predict. The theme paper highlights four emerging threats: a red alga, *Grateloupia turuturu*; a tunicate, *Didemnum vexillum*; mitten crab, *Eriocher sinensis*; and lionfish, *Pterois volitans*.

Marine invaders can have many impacts on native species in the Gulf of Maine, including competing with native species for food and habitat and preying on native species. Economic impacts of non-native species may include monetary costs for management, cost and damages incurred due to fouling of equipment and vessels, aesthetic and/or recreation impacts, and actual losses relative to impacts to fishery or aquaculture resources. In the Gulf of Maine, fouling, particularly by invasive tunicates, and impacts to commercially harvested species is a concern.

There are also potential for public health impacts associated with marine invaders. Introduced pathogens, such as *Vibrio cholera*, the bacteria responsible for cholera in humans, have been found in ballast water and could potentially be discharged to local waters. Organisms that result in concentrated toxins in seawater and/or seafood are also a concern.

In the Gulf of Maine, the primary instrument for prevention of marine introductions is the regulation of ballast water by the U.S. Coast Guard under the *National Invasive Species Act* and Transport Canada under the *Canada Shipping Act*. Mandatory ballast water exchange and reporting requirements have been in place for all U.S. waters since 2004 and in Canada since 2000. Other responses include the development of a coordinating bodies and panels. Provincial and state management of marine invasive species is largely vector based, with aquaculture as a prime example.

More detailed information is available in the theme paper.

http://www.gulfofmaine.org/state-of-the-gulf/docs/marine-invasive-species.pdf

Emerging Issues

Written by Peter G. Wells, International Ocean Institute and Faculty of Management, Dalhousie University

Emerging issues are defined by Munn et al. (1999) as "an issue positive or negative, which is not yet generally recognized but which may have significant impact on human and/or ecosystem health in the 21st century... an emerging issue is associated with one or more of the following: a) political, social, economic , financial, institutional or technological developments that may cause changes in trends of human activities …; b) new evidence or theory that suggests potentially large environmental change, but which is currently either not widely accepted, or is considered unproven …; and c) lack of adequate policy, action or leadership on an existing issue, which may become more significant or more urgent in the future. An emerging issue is not necessarily an issue no one has heard of, or that comes as a shocking surprise". The emerging issues in the theme paper are categorized as pressures (i.e., human activities), impacts (i.e., environmental change), and societal response.

Emerging pressures in the Gulf of Maine include: changes in coastal economies; marine energy; marine mining; and climate change.

Emerging impacts in the Gulf of Maine include: understanding change in the Gulf's ecosystem; protecting and conserving habitats and biodiversity; hydrocarbons; chemical contaminants; emerging diseases in marine organisms; and addressing cumulative effects of multiple stressors.

Emerging actions and responses include: information management; changes in ocean governance; practicing integrated coastal and ocean management; practicing ecosystem-based management and ecosystem-based fisheries management; promoting protected areas in the Gulf; recognizing links between ecological and human health; and understanding communicating ecosystem services.

More detailed information is available in the theme paper.

http://www.gulfofmaine.org/state-of-the-gulf/docs/emerging-issues.pdf

Reference

Munn, R.E., Whyte, A.V.T., and Timmerman, P. (1999) Emerging Environmental Issues for the 21st Century: a Study for GEO-2000. International Council of Scientific Unions and UNEP. http://www.unep.org/geo2000

Conclusion

Theme papers are being developed incrementally and will be updated as necessary. Theme papers that will be released over the next year include: Microbial Pathogens and Toxins; Aquaculture in the Gulf of Maine; Offshore Ecosystems and Habitats; Watershed Status; Eutrophication; and Toxic Contaminants.

For more information on the State of the Gulf of Maine, please visit the website www.gulfofmaine.org/stateofthegulf or contact Melanie MacLean at melanie.maclean@dfo-mpo.gc.ca.

OVERVIEW OF CHEMICAL CONTAMINANTS IN THE BAY OF FUNDY

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Mankind has been synthesizing and producing chemicals at an ever increasing rate such that thousands of them are intentionally or inadvertently released to the environment. Vast numbers of these contaminants enter coastal waters due to human activities directly through spills or indirectly via runoff or atmospheric transport. It is difficult to separate which route a contaminant category follows because it is often a combination of the two and no two contaminant categories behave the same. Pollutants enter estuarine, coastal and oceanic waters directly by a number of avenues. This can be as simple as field fertilizer runoff from agricultural applications resulting in algal blooms downstream, known as eutrophication. In extreme situations eutrophication results in deoxygenated coastal waters and can cause massive die-offs of shellfish and fish. Pesticides sprayed on agricultural fields and forests for crop protection and wetlands for insect control either enter the hydrological flow to the coast or are transported atmospherically to coastal waters, either by direct drift of the spray or re-evaporation and drift. Pesticides that are applied to finfish aquaculture operations to remove "sea lice" also kill other crustaceans in the vicinity. The organochlorine and organobromine compounds are the most notorious of manmade toxic chemicals because they accumulate as they progress higher up the marine food chain. Mercury also bioaccumulates in the methylated form and, although occurring naturally, has increased threefold in the atmosphere due to our combustion of fossil fuels. There is an array of chemicals, such as heavy metals and polycyclic aromatic hydrocarbons, alkanes and other hydrocarbons and the most toxic chemicals known, the polychlorinated dibenzodioxins and furans (PCDD/DFs) that are produced both naturally by fire or by combustion of fossil fuels. This atmospheric input is inclusive of industrial activities, municipal and domestic furnaces and transportation, particularly the automobile because of its prevalence. Science has recently been directed at the inadvertent addition of cosmetics, antibiotics and other pharmaceuticals in domestic sewage. However, the more troublesome chemicals are still those that have been created by man as pesticides and for high-pressure industrial use, particularly the organochlorines, because of their extreme toxicity, persistence and bioaccumulation in the environment. This is an assessment of known chemical contaminants in the Bay of Fundy and vicinity.

AN ECOLOGICAL RISK ASSESSMENT OF MERCURY AND DDT FOR THE BAY OF FUNDY

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Mercury (Hg) and the pesticide DDT are persistent pollutants that concentrate through food webs to concentrations that can affect the health of fish-eating fish, birds and mammals. Although studies have shown that Hg and DDT are present in biota living in the Bay of Fundy, it is not clear whether the concentrations represent a risk to their health. For this reason, an ecological risk assessment was done using the data available for several species of invertebrates, fish, birds, and marine mammals. Mercury and total DDT concentrations were compiled and compared against chronic lab toxicity data to calculate Risk Quotients (RQs; < 1.0 low or no risk, > 1.0 possible risk) or against Canadian Tissue Residue Guidelines (TRG) for the protection of fish-eating wildlife. The RQs for DDT indicated that the fish-eating birds (e.g., cormorants, Greater Yellowlegs) may be at risk. In addition, concentrations of DDT in mussels and some fish species (e.g., cod, mackerel) exceeded the TRG (0.014 ug/g ww), but not concentrations that may affect the health of the fish themselves (0.6 ug/g ww). More Hg data were available for Bay of Fundy species. The RQs and TRG (0.033 ug/g ww) suggest that fish-eaters were also at risk from Hg toxicity, and some fish (tuna, swordfish, shark) had Hg concentrations above a level believed to be protective of their health (0.2 ug/g ww). However, most data used for this assessment are from the 1970s and 1980s and would likely not reflect the current exposure for fish-eating wildlife. For this reason, there is a need for a current assessment of pollutants in wildlife living in the Bay of Fundy.

IMPLICATIONS OF THE DEEPWATER HORIZON BLOWOUT (GULF OF MEXICO) TO OIL SPILL PREPAREDNESS AND RESEARCH IN ATLANTIC CANADA, ESPECIALLY THE GULF OF MAINE AND BAY OF FUNDY

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The Deepwater Horizon blowout occurred in April 2010 in offshore waters of the Gulf of Mexico. It was an offshore blowout in deep water, took several months to control, led to the unprecedented use of oil spill dispersants, and greatly affected inshore and onshore coastal habitats and species, especially the salt marsh coastlines of Louisiana and Mississippi. The question arises: is Atlantic Canada ready to respond appropriately to such an event, given the activity already in deep waters off Labrador, the oil reserves on Georges Bank that may be tapped in the future, and the tanker movements in and out of the region? The Gulf of Maine and Bay of Fundy have already had small spills and most recently, the loss of an oil-carrying barge off southwest Nova Scotia that still sits on the bottom as a threat to the marine environment and local fisheries. This presentation describes some of the implications of the Deepwater Horizon to our response and research capacity in the region, and to our responsibilities for wildlife conservation and protection, and the protection of valuable fisheries.

Note: This paper is presently in preparation for a journal article (2/12).

MODELING OF FECAL BACTERIA IN ANNAPOLIS BASIN WATERSHEDS, NOVA SCOTIA

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The contamination of shellfish harvesting areas by fecal bacteria in the Annapolis Basin is a recurring problem which has consequences for industry, government, and local communities. This study contributes to the development of an integrated water quality forecasting system to improve the efficiency and effectiveness of industry management. The integrated forecasting framework is composed of a database containing contamination sources, hydrodynamics of the Annapolis Basin, *E.coli* loadings and watershed hydrology scenarios, coupled with environmental conditions of the region (e.g., temperature, precipitation, evaporation, and ultraviolet light). This research was concerned with addressing the *E.coli* loadings and watershed hydrology scenarios. This involved identifying fecal bacteria sources, modeling the hydrologic and hydrodynamic characteristics of the watersheds, and determining the resulting bacteria loadings based on different environmental conditions. The watershed hydrology and transport of bacteria loadings was developed using the hydrologic, hydrodynamic and advection dispersion capabilities of the 1-dimensional model, MIKE 11. For a given set of forecasted environmental conditions, matching scenarios will be extracted from the database to determine the concentration of *E.coli* bacteria at confluence points within the estuary. Loadings at each confluence can then be modeled using developed estuarine hydrodynamics, which will be used to simulate the transport, dispersion and spatial extent of *E.coli* concentrations in the Basin.

DETERMINATION OF *ESCHERICHIA COLI* DECAY RATES FOR APPLICATION IN A WATER QUALITY FORECAST MODEL FOR THE ANNAPOLIS BASIN, NOVA SCOTIA, CANADA

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Introduction

Fecal pollution of shellfish growing waters is a worldwide problem posing both health and economic risks to the people and communities involved in the consumption and harvesting of these shellfish. In the Annapolis Basin of Nova Scotia, where the shellfishery is largely a contributing factor to the local economy, the Applied Geomatics Research Group (AGRG) of Middleton, NS is using hydrodynamic software and particle tracking modules to develop a water quality forecast to model *E. coli* distribution within the basin. This type of forecasting system may lead to more efficient closures and openings of shellfish areas after wastewater treatment over-flows and heavy river run-off due to rain events, saving both time and resources within the shellfish industry. As part of this water quality forecast, understanding and integrating the decay of *E. coli* bacteria is crucial for validation of the contaminant model. There are several biotic and abiotic environmental factors that contribute to the die-off and survival of *E. coli* bacteria such as:

- Solar UV radiation (McGuigan et al. 1998)
- Salinity (Greenberg 1956)
- Water temperature (Troussellier et al. 1998)
- pH (Carlucci and Pramer 1960)
- Turbidity and sediment re-suspension (Pachepsky and Shelton 2011)
- Microbial predation (McCambridge and McMeekin 1981)
- Genetics (Hung et al. 2008)
- Several others (Greenberg 1956; Troussellier et al. 1998)

For the purpose of this study focus remained on the decay of *E. coli* bacteria in relation to solar UVA radiation, dynamic salinities such as those near the end of wastewater treatment pipes and salinity gradients that occur in tidal estuaries such as the Annapolis Basin. To relate laboratory results to real-world scenarios, UV meter readings and GIS tools will be used to link appropriate decay equations with local UV weather forecasts, this will then be applied to the particle-tracking module being used for the water quality forecast.

Methods

Laboratory experiments were carried out between April and September of 2011 and involved exposing prepared *E. coli* stock solution in quartz glass beakers to several different intensities of UVA radiation within a photo-reactor, several different saline conditions, a saline gradient over time using Instant Ocean[tm] artificial seawater, combinations of UVA intensities with saline conditions as well as exposing contaminated basin water to UVA radiation. Control experiments were carried out in dark conditions using prepared *E. coli* buffer stock solution (8.5 g NaCl /L). All stock solutions were made using cultured *E. coli* K-12 and sterile Milli-Q water and all experiments were repeated four times (A, B, C, D) using stir plates to avoid the settling of bacteria and kept at room temperature. Table 1 further clarifies the design of these experiments.

Experiments	**UVA Exposure**	**Salinity**	**Salinity + UVA Exposure**	**Basin Samples**
A, B, C, D	10 W/m^2	10 ppt	20 ppt 10 W/m^2	Edge of Basin 10 W/m^2
A, B, C, D	20 W/m^2	20 ppt	30 ppt 10 W/m^2	Middle of Basin 10 W/m^2
A, B, C, D	30 W/m^2	30 ppt	20 ppt 20 W/m^2	
A, B, C, D	40 W/m^2	35 ppt	30 ppt 20 W/m^2	
A, B, C, D	Gradient 10–35 ppt			

Table 1. Design of each experiment carried out in quadruplicate

UVA intensities were converted to dosages using a variation of a Bolton Spreadsheet (Bolton and Linden 2003) taking into account several factors such as proximity to light source, absorption coefficients, time exposed and distribution of light intensity. Each of the laboratory prepared stock experiments were run for 8 hours and enumerated every 2 hours using serial dilution and membrane filtration, however, due to the relatively low amount of *E. coli* in the collected basin water samples, these samples were enumerated every 15 minutes for 1 hour using the IDEXX Colilert-24 Most Probable Number (MPN) method. Bacteria counts were converted to log reductions and compared within experiments, across experiments and to control results using ANOVA one-way analysis of variance.

Results and Discussion

UVA Exposure

All treatments within the UVA exposure experiments produced significantly different results from one another and from their controls, with higher intensities resulting in quicker and more dramatic die-off of *E. coli*. The bacteria did not, however, survive the total 8-hour period of exposure under 30 W/m^2, which lasted only 6 hours and 40 W/m^2 which survived only 2 hours of exposure. Preliminary test results suggested that more bacteria needed to be used to obtain a decay rate over 8 hours for these experiments, however the increase in bacteria skewed the results because of the effect on absorption coefficients used for dosage conversions. For this reason, analysis was carried further carried out using 10 W/m^2 and 20 W/m^2 only. With these results, the following equation was extrapolated using regression analysis (R^2 0.8672):

$$(0.009\ (\text{Dosage mJ/cm}^2)) - 1.0245 = \text{log reduction of } E.\ coli$$

Salinity

Statistical analysis shows that experiments carried out in 10 ppt salinity differed significantly from those in 20 ppt, 30 ppt and 35 ppt and those using a seawater gradient, however they did not differ from controlled results and exhibited no first-order decay as seen with all of the other salinity experiments. These results could be expected, however, given that a salinity of 10 ppt, although slightly different in salt constituents, was quite similar to the concentration of NaCl (8.5 ppt) in the buffer solution that was used for control experiments. From this, one might conclude that a sewage outfall pipe, for example, would not be best placed in brackish water with such salinity. It was also found that *E. coli* in a salinity gradient (10 ppt–35 ppt), 20 ppt and 30 ppt behaved similarly, but a notable increase in die-off occurs at 35 ppt. With these results, the following equation was extrapolated using regression analysis (R^2 0.691):

$$(0.0019 \text{ x } (\mathit{ppt\ x\ hrs})) - 0.0894 = \text{log reduction of } \mathit{E.\ coli}$$

UVA and Salinity Combinations

Treatments at 10 W/m^2 in 20 ppt and 30 ppt salinity were significantly different from one another, and from combination treatments exposed to 20 W/m^2, however those combination experiments carried out under 20 W/m^2 of UVA exposure (20 ppt and 30 ppt) behaved statistically the same. This may suggest that salinity plays a more crucial role at lower UVA intensities. All treatment results differed from those kept under control conditions and the general trend was that increased salinity and UVA exposure resulted in higher die-off rates of *E. coli*, with UVA radiation being the dominant variable. With these results, the following equation was extrapolated using regression analysis (R2 0.8987):

$$(0.0021 \text{ x } (\mathit{ppt\ x\ hrs} + \mathit{UVA\ dosage})) - 1.214 = \text{log reduction of } \mathit{E.\ coli}$$

E. coli - Contaminated Basin Samples

Samples were taken from the edge of the Annapolis Basin, where the salinity was 20 ppt, and from the middle of the Annapolis Basin, where the salinity was 32 ppt. Both samples were irradiated with UVA 10 W/m^2 for 1 hour and were found to decay in the same way, with statistically no difference in die-off rates. It was hypothesised, based on previous results involving seawater and UVA radiation, that due to differing salinity of the Basin samples (20 ppt on the edge and 32 ppt in the middle), the middle samples would have a larger log reduction than the edge samples. The samples taken from the middle of the Basin had a slightly higher absorbency coefficient, which likely affected the dosage of UVA the sample was actually receiving, perhaps there was something in the seawater acting as a buffer for bacteria decay, or it could be that the bacteria found on the edge of the Basin was more resistant than the bacteria found in middle waters.

In addition, when salinity values, exposure time and dosage were input in the previous equation for combination results, actual values did not agree with expected values ($p<0.0001$). Although the Basin samples decayed in a first-order fashion, their decay was much slower than the decay of those used in the lab. These findings could be a result of several factors, including bacteria resistance, source, strain, and length of previous environmental exposure.

Conclusion

It is clear that both UVA dosage and saline conditions contribute to *E. coli* die-off rates, however the next step in this process is to determine a possible relationship between results found using prepared stock solution and field-collected Basin samples. This will involve further data collection and investigation. Also, to apply these results to real-world scenarios, a ‘Bolton-like’ function needs to be extrapolated to an estuarine environment so that given UV forecasts and water conditions, a proper solar dosage can be determined, and the proper bacteria decay function can be applied.

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INTEGRATED WATERSHED WATER QUALITY FORECASTING SYSTEM FOR THE ANNAPOLIS BASIN, NOVA SCOTIA, CANADA

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Water quality is important to those living within coastal communities, the shellfish industry, and regulatory bodies. This work focuses on developing an integrated forecasting system to predict areas of poor water quality within the Annapolis Basin as a result of *E. coli* contamination. Forecast information will provide the predicted spatial extent, concentration, and source of contamination. Forecast information will be used to improve the efficiency of regulatory sampling, reduce unnecessary harvest closures, and aid in municipal planning by identifying major sources of contamination. Water quality forecasts are determined by linking dynamic environmental variables (such as time, temperature, precipitation and ultraviolet light) to a robust database composed of contamination sources, estuarine hydrodynamics, watershed hydrology, and *E. coli* loading scenarios. Loading concentrations and decay rates of *E. coli* are calculated for surrounding watersheds, and anthropogenic sources (municipal wastewater treatment and rural septic systems) using hydrological, hydrodynamic, and advection dispersion models which incorporate land cover attributes and flow dynamics. To increase model efficiency, and allow for real time predictions, a database approach was adopted. A database of concentration extractions was developed by identifying unique tidal scenarios (n = 104) to undergo a battery of particle tracking runs (n = 319,488) in order to simulate all possible contamination extents for each source point. Loading scenarios were developed to account for environmental and seasonal *E. coli* concentrations on the watershed level. Future Web hosting development will allow the end-user to rapidly retrieve a contamination extent, concentration, and source based on current and predicted environmental conditions.

WATERSHED HEALTH AND MONITORING—TURTLE CREEK WATERSHED

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The City of Moncton has been managing over 15,000 acres of forest land since the early 1990s. The Forestry Program involves management of various land bases from potable drinking water supplies, community forests, urban forests, watersheds and reservoir lands. All these areas require a different management focus depending on goals and objectives set through sustainable forest management plans. The Turtle Creek Watershed Model has been used elsewhere in New Brunswick and beyond into other Maritime provinces as a way to control and monitor the health and condition of the watershed and all resources surrounding it. Our watershed model involves all landownership within the designation sharing management strategies/plans identifying water quality as the main priority before any activity takes place in the watershed. Over 35 water quality sampling stations are set up throughout the watershed to identify point and non-point sources of contamination. Also a local citizen community group was formed involving various government departments/stakeholders who meet two to four times per year. Managing the forest for timber production alone is a method of the past. The various partnerships increase the awareness of managing the forest for water quality first along with improving overall forest health. Results are being seen with this proactive approach to managing all natural resources within the entire watershed designation without owning all the land. A sharing of information provides this strategic approach to landscape level management.

ASSESSING AQUATIC CONNECTIVITY IN THE ANNAPOLIS RIVER WATERSHED AND NOVA SCOTIA

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Aquatic connectivity, networks created by brooks and streams as they flow into one another and eventually reach the ocean, is a very important aspect of good habitat for fish and broader ecosystem health. Fish need access to a variety of habitat features found throughout a watershed in order to complete various life stages and to find favourable conditions at various times of the year. Improperly installed culverts and other watercourse crossings can prevent fish from travelling upstream or downstream, restricting their range and ability to survive. In order to assess the impact that culverts are having on aquatic connectivity in the Annapolis River watershed, Clean Annapolis River Project (CARP), a charitable non-profit environmental organization, has been conducting assessments on watercourse crossings for impediments to fish passage. The organization is now completing their third field season working toward this goal.

There are four main stages to culvert assessment in a watershed. First, the road-stream crossings need to be identified by GIS or topographic maps. Second, the identified crossings are prioritized to maximize the quantity and value of data that can be collected during the field season. Upstream habitat, sub-watersheds and/or proximity to a main river are ways CARP narrows the selection of crossings. Thirdly, CARP staff conducts field assessments. Preliminary assessments look for obvious barriers such as large outflow drops, insufficient water depths, high velocities, and broken or damaged culverts. If the culvert is an obvious impediment, then a full assessment is performed. If the culvert is 100% backwatered or has a natural bottom, giving rise to a low flow notch, then the crossing is considered passible. If there is some question, preliminary measurements are taken to obtain concrete values that may or may not exceed guidelines. Full assessments include measuring culvert dimensions, stream and culvert gradients, water depth and flow, cross sections and water chemistry. The fourth and final stage is prioritizing all barrier culverts for restoration. The same characteristics used in prioritizing culvert surveys are used in this stage, as well as habitat quality and ease of remediation.

Clean Annapolis River Project conducted culvert surveys in 2007, 2010 and 2011. The results are organized below in Tables 1 and 2 by year and percent barriers per year respectively.

CARP, in cooperation with NSLC Adopt A Stream, has shared the experience and knowledge gained by providing training, guidance and resources to seven watershed groups in Nova Scotia who conducted similar projects in the summer of 2011. In total, seven groups attended training sessions on 13 July 2011 and 14 July 2011. Three groups (Cornwallis Headwaters Society, Friends of the Cornwallis River, and Friends of the Pugwash Estuary) conducted research and returned data to CARP. Table 3 details the results of their assessments in 2011.

Additional information on culvert surveying may be found at the Clean Annapolis River Project Web site (http://www.annapolisriver.ca).

Barrier Type	**2011**	**2010**	**2007**
Passable culvert	62	231	27
Partial barrier	14	123	11
Culvert	68	162	22
Barrier culvert	29	114	-
Passable bridge	2	5	-
Barrier bridge	37	142	-
Not fish habitat	16	-	-
Not accessible	-	-	-
TOTAL	**228**	**777**	**268***

* Total visited sites, 60 assessments performed

Table 1. Results by year

	2011	**2010**	**2007**
% Barriers	57	55	55
Total Assessed	144	516	60

Table 2. Percent barriers per year

Group		**Passable**	**Partial Barrier**	**Full Barrier**	**Total Barrier**
Cornwallis Headwaters Society	Accessed	3	0	2	2
	% Barriers	60	0	40	40
Friends of the Cornwallis River	Accessed	5	5	3	8
	% Barriers	38	38	23	62
Friends of the Pugwash Estuary	Accessed	13	5	6	11
	% Barriers	54	19	25	46

Table 3. Culvert assessment results from Cornwallis Headwaters Society, Friends of the Cornwallis River and Friends of the Pugwash Estuary

Further Reading

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Session G

PRODUCTIVITY OF ANTHROPOGENIC STRUCTURES IN THE COASTAL ZONE

Chair: Simon Courtenay, Fisheries and Oceans Canada at Canadian Rivers Institute, University of New Brunswick, Fredericton, New Brunswick

ROCKY BREAKWATERS DO NOT OFFER THE SAME QUALITY OF HABITAT FOR A BENTHIC INTERTIDAL BIOTA AS NATURAL ROCKY ENVIRONMENTS

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Present policy regards construction of rocky breakwaters as destroying habitat for coastal biota and this triggers a requirement for compensation. Furthermore, construction of breakwaters and coastal armouring is expected to increase as numbers of people living along coasts increase, sea levels rise, and severe meteorological events become more frequent. Yet there is very little information available on whether such anthropogenic structures really do reduce habitat for plants and animals or, in fact, present new or different habitat. During Summer 2010 we quantified the abundance of intertidal macro-algae and macro-invertebrates living on 18 established breakwaters and 30 nearby, natural, rocky areas between Pleasant Bay, NS, and Petit-Cap, NB, in the southern Gulf of St. Lawrence. Preliminary analyses of data indicate greater species richness and overall abundance of biota on wave-sheltered than on wave-exposed areas for both breakwaters and natural rocky shores. The relatively low richness and abundance found on exposed surfaces was similar between breakwaters and natural areas. However, in sheltered areas, breakwaters had significantly lower species richness and overall abundance than natural rocky areas. Multivariate analyses are underway to explore which species are driving community differences between habitats. The benthic biota represent only one aspect of habitat productivity and other studies will be required to examine fish and highly mobile invertebrates such as lobster and crab. However, based on our data for benthic intertidal biota, the present study suggests that breakwaters do not offer the same quality of habitat as natural rocky shores.

EFFECTS OF WHARF AND BREAKWATER CONSTRUCTION ON COASTAL FISH HABITAT: NET LOSS OR NET GAIN?

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Construction activities in marine coastal areas (e.g., wharves, breakwaters and similar facilities) are undertaken to improve access to nearby marine resources and sea lanes and to protect industrial and personal property onshore. Habitat quality of coastal fishes is altered both during and following construction of coastal structures. Despite the need for scientifically defensible approaches, empirical studies of the ecological impacts of wharfs and breakwaters have been few and limited in scope. Estimating scientifically defensible gains and losses due to construction in the face of high natural background variability is a challenge. Vertical structures, with associated rugosity, are often productive and are considered desirable features of the coastal environment due to introduced edge-effects. However, the extent to which wharves and breakwaters self-compensate is rarely quantified. We are addressing this knowledge deficiency via a ten-year study (2007–2016) of a total of eighteen sites (twelve wharf-breakwater and six control) to quantify the habitat and fish productivity associated with wharves and breakwater constructions in coastal Newfoundland. In a three-way DFO collaboration among Small Craft Harbours, Habitat Management, and Science, we are empirically quantifying changes in habitat, fishes, and epibenthic macroinvertebrates associated with the wharves and breakwaters using video imagery and fish density surveys collected by scuba divers along replicated 100 m transect lines. The objective is to provide proponents with analytical tools necessary to evaluate potential effects of other such developments, and assist habitat managers by guiding their mitigation and compensation decisions.

SMALL CRAFT HARBOURS IN THE PACIFIC REGION: HABITAT IMPACT, BENIGN ALTERATION OR HABITAT CREATION? AN EXPERIMENTAL APPROACH WITH PRELIMINARY DATA

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Introduction

In the Pacific Region during the last few decades unprecedented coastal development pressures are a result of a growing population's demand for recreational, industrial and residential properties. Natural beaches have been replaced with modifications to inter and shallow sub-tidal habitat that include rock rubble walls, floating breakwaters, dredged harbours, docks and marine service outlets. As a population seeks access to the water or acts to avoid losing uplands to climate-induced increases in sea level (Sobocinski et al. 2010) these structures will become increasingly common. Canada's small craft harbours represent a small portion of this development, but they contain structures commonly found throughout coastal British Columbia and thus provided an experimental microcosm to examine the wider influence of coastal development on local ecosystems.

Canada has 1078 small craft harbours, 114 on the Pacific coast, all of them the responsibility of the Fisheries and Oceans Canada (SCH - website). With the assistance of local harbour authorities, the department caters to the needs of local boat owners but is also mandated to address the environmental regulation and liability of these (and other) federal sites. Following a policy of "no net loss", to habitat productivity, harbour construction and operation attempts to avoid having a negative influence on local biota (DFO 1986). In fact many recent harbour development plans include habitat compensation features to mitigate for possible environmental impacts. The harbour structures themselves may also provide substrate for biological communities but the type of community they promote and its value relative to the habitat and communities being lost to construction remain common and unresolved issues that date back to the 1980s. We still seek quantitative metrics to apply to compensation schemes for habitat loss, if such a formula exists at all (Waldichuk 1993).

This report provides the results of preliminary (one year, 2010) investigations of three small craft harbours (SCH) on Canada's Pacific coast. It addresses two of the three objectives posed originally to Science Branch by habitat regulators (Ecosystem Management Branch) and property managers (Real Property, Safety and Security Branch) within Fisheries and Oceans. The three objectives are:

1. Develop habitat assessment and monitoring tools to support the assessment and comparison of SCH's by the Federal Contaminated Sites Action Plan (FCSAP - website). The FCSAP currently ranks federal properties based on their environmental liability using sediment contamination metrics. Methodology developed in this report seeks to provide insight into the biological response to contamination and other environmental consequences associated with harbour development. This methodology is designed to contribute another dimension to the FCSAP's liability estimation capability among SCH's.

2. Quantify the influence of a variety of common harbour features on biological communities. Docks, floating and rubble-mound breakwaters, anchors and pilings represent an alteration to the "pre-harbour" habitat but create colonization substrate in their own right. On balance, the features, while created from different substrate, may fully or partially offset habitat losses to harbour development and thus act as

compensation for habitat lost to other harbour activities. An analysis of the relative impacts and productive capacities of specific habitat types is required.

3. Compensation and Mitigation. Recently, harbour development plans have created space for mitigation measures to compensate for the loss of specific habitat features during harbour construction. For example, the productive capacity of soft sediment communities and communities associated with vascular and non-vascular plants may decline with the creation of deep-water boat basins (dredging), construction of breakwater or upland facilities (infilling), or the anchoring of docks and floating breakwaters (shading). Aquatic vegetation is frequently used as a surrogate for productive habitat in coastal zones (Levings 2003) but habitats created to increase marsh habitats are not always successful (Pomeroy et al. 1981). An analysis of the success rate of mitigation in SCH's is required.

Methods

An analysis of the development history, age, features, size and annual use of many of the 114 "more active" harbours on the Pacific coast produced a summary matrix from which three harbours were chosen for preliminary analysis. Harbours at Cowichan Bay, Port Hardy and Lund had many features in common, including both floating and rubble-mound breakwaters as well as docks, wharfs and a history of marine service outlets (e.g., fuel docks, marine ways, shipyards etc.) (Figure 1). Cowichan and Port Hardy had areas set aside where eelgrass transplants had been created for mitigation purposes.

Through the first two weeks of June of 2010, several trips were made to each harbour to install temperature loggers, deploy settling plates, collect invertebrate samples from both rubble-mound and floating breakwaters and collect benthic samples from the soft sediment both inside and, outside of each harbour. Benthic collections from outside locations provided a reference to the harbour treatment. Ten settling plates, randomly located were divided equally between the exposed and protected side of each breakwater in each harbour, 50 cm beneath the surface on the floating breakwater and at 1.0 M above tidal datum on the rubble-mound structures. Quadrats were deployed in a similar manner and number to sample invertebrate communities on the breakwaters. Sediment samples were also replicated at each of the harbours (n=10) and each was of sufficient volume to allow a portion to be sieved (500 micron mesh) to remove invertebrates for taxonomic analysis and the rest to be sent for grain size, toxicity and chemical contaminant analyses. Invertebrates captured by PONAR grab were identified to the species or genera when possible. Plates and quadrat samples were identified to order. Several return trips to each harbour were made to monitor the plate deployment and data loggers through December 2010 when the plates were removed and samples preserved. Temperature and salinity profiles were measured during many of these trips both inside and outside of each harbour. Greater detail and specifications of sampler design, sample collections and analysis methods will be specified in a technical report that is currently being produced.

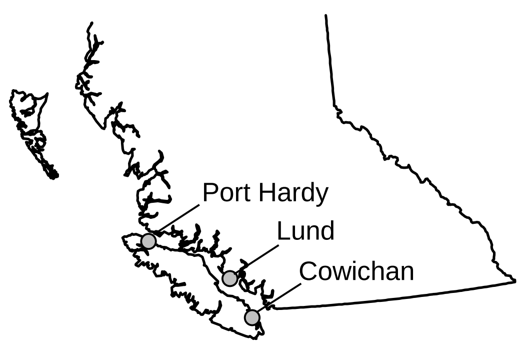


Figure 1. Locations of British Columbian small craft harbour sites examined in this study.

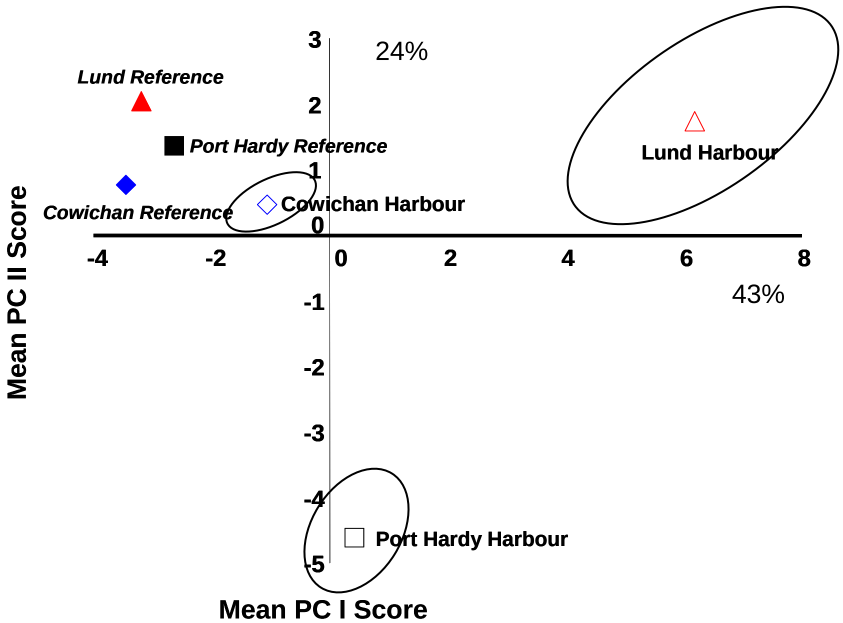
Abundance data were analyzed using multivariate techniques with the aid of Primer (Clarke and Warwick 2001). These techniques include principle component analysis to identify suites of sediment chemicals unique to each harbour and non-linear multi-dimensional scaling with "ANOSIM" to identify taxonomic groups responsible for harbour discrimination.

Results and Discussion

Despite considerable search effort, a dearth of historic information exists for small craft harbours on the Pacific coast. The search for information will continue, but currently it is difficult to categorize and rank harbours based on the amount of vessel activity or other environmental pressures that have occurred and may continue to occur at each harbour. A two-dimensional matrix, harbour by environmental pressure, is currently being populated, with a view to identifying harbour activities and/or specific events as reliable predictors of chemical and biological responses. Should they exist, measuring these predictors may be the initial step in the identification of sites most deserving of mitigation or compensation efforts.

There were distinct chemical signatures associated with sediments in each harbour (Figure 2), although considerable variation existed among samples taken within each harbour suggesting sample size and choice of sample location may be important considerations in future monitoring designs. The Cowichan harbour sediment had relatively lower levels of most contaminants, particularly metals and petroleum hydrocarbons. Concentrations of copper and some PAHs at Cowichan did exceed Interim Sediment Quality (ISQ) guidelines but overall, Cowichan chemistry was nearer to reference levels than the other harbours (ISQ website). Port Hardy and Lund harbours had distinctive chemical signatures, that were likely directly related to harbour history. Elevated levels of PAHs and lead distinguished Lund from Port Hardy, while the highest levels of other hydrocarbons and some metals were detected at Port Hardy. PAHs are a particularly concern to Federal Contaminated Site authorities, given their known carcinogenic potential, low water solubility and adsorption to marine sediments (Waldichuk 1993). Goyette and Boyd (1989) found skin tumours and liver lesions in benthic fish in association with high levels of PAHs. Contaminants are a concern because of their toxicity, bioaccumulation and persistence. Lead and other metals detected in the harbour sediments may have originated from historic events and thus provide an integrated record of human-derived inputs and allow estimates of human impact and environmental liability (Nixon et al. 1986; Burd et al. 2008). However, based on the results from three toxicity trials (amphipod bioassay, echinoid fertilization, Microtox), sediments in the harbours and the reference locations were largely benign. This finding may guide future data analysis away from the sediment triad approach (Green et al. 1993) to a graded approach that begins with an analysis of sediment chemistry, followed with estimates of biological productivity and ecological health (biomass, biodiversity). Avoiding toxicity tests reduces analysis costs and drastically reduces sample volume and will still allow the ranking of harbours by level of degradation. This is not to imply that sites with sediments contaminated to the point of failing toxicity tests should not receive the highest priority for compensation and/or mitigation.

Invertebrate community assemblages were expected to vary considerably between breakwater type as floating structures provided continual shallow sub-tidal habitat but the rubble-mound sampling sites experienced water depths ranging from 3 m to several hours of drying with each tidal cycle. Similarly, communities found in soft sediments, sampled with a PONAR grab, were logically different from consolidated substrate communities, scraped from within a quadrat or sampled after adhering to a settling plate. Evidence of these differences were so obvious presentation of the results is not warranted. Community assemblage comparisons were most useful for detecting differences among harbours from the perspective of each distinctive habitat separately as sampled with each method.



PCI	PCII
Benzo(ghi)perylene	Molybdenum
Indeno(123-cd)pyrene	HEPH
Benzo(b)fluoranthene	EPH19-32
Benzo(k)fluoranthene	F2(C10-C16)
Benzo(a)pyrene	Cadmium
Anthracene	Cobalt
Dibenz(ah)anthracene	EPH10-19
Phenanthrene	LEPH
Benz(a)anthraene	Vanadium
Chrysene	Zinc
Fluorene	Chromium
Pyrene	Nickel
Fluoranthrene	Copper
Acenaphthylene	Arsenic
Tin	F4(C34-C50)
Acenaphthene	F3(C16-C34)
Lead	
Mercury	
Uranium	
Naphthalene	

Figure 2. Analysis of sediment chemistry samples collected by Ponar grab. Variables responsible for the variation described by the first principle component (PC1-43%) are primarily PAHs (blue) and metals (black) while PC2 variation is explained primarily hydrocarbons (red) and metals. Ellipsoids describe 95% bounds on the PC scores in each harbour.

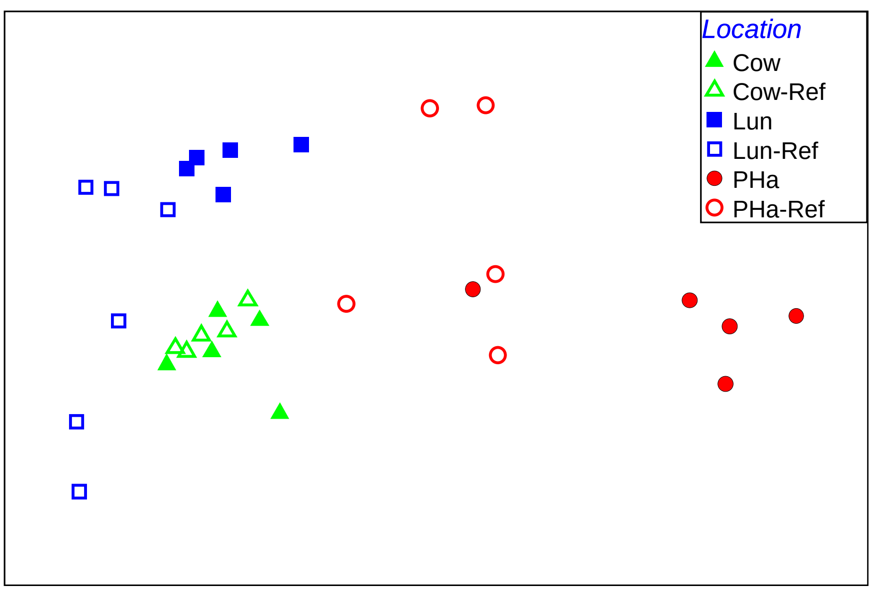


Figure 3. A MDS plot of macro-fauna (>500 um) abundance from Ponar sediment grabs (23 cm x 23 cm) collected from three Small Craft Harbours and adjacent reference locations. Data were square root transformed prior to Bray Curtis similarity analysis. Stress = 0.10. Cow = Cowichan, Lun = Lund, PHa = Port Hardy.

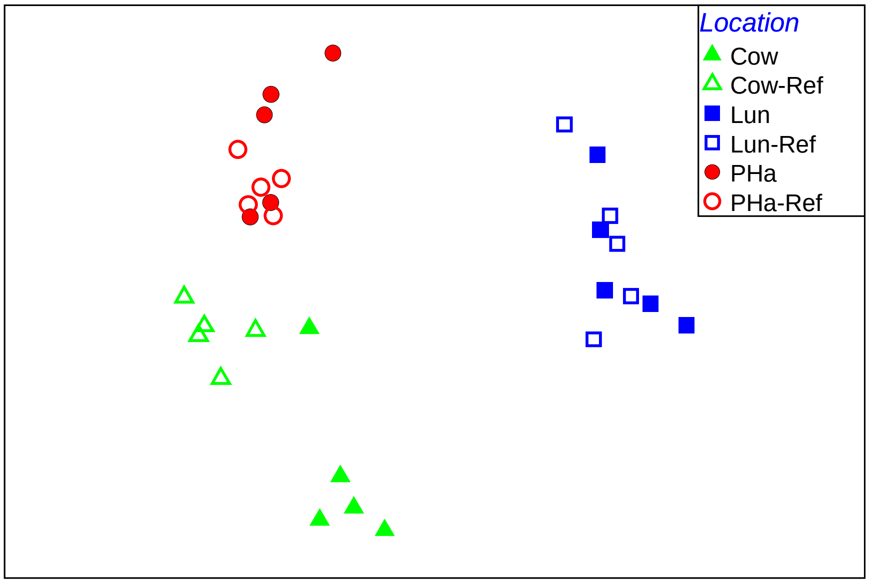


Figure 4. A MDS plot of macro-fauna (>500 um) abundance data from quadrats (10 cm x 30 cm) collected from the protected and exposed (reference) sides of floating breakwaters at three small craft harbours. Data were square root transformed prior to Bray Curtis similarity analysis. Stress = 0.12. Cow = Cowichan, Lun = Lund, PHa = Port Hardy.

Taxonomic characteristics were tightly grouped among soft sediment samples within each harbour but each harbour had a distinctive invertebrate community (Figure 3). Infaunal communities composed of clams (*Rochefortia tumida*) and oligochaetes (*Tectidrilus* sp.) distinguished Cowichan from the other sites (Table 1). Polychaete (*Asabellides* spp.) and tanaids (*Leptochelia savignyi*) were common at Lund. Port Hardy harbour benthos was unpopulated in comparison. Established communities sampled by scraping both the exposed and protected sides of the floating breakwaters were also distinguishable among harbours (Figure 4). In fact, based on comparisons of R values (ANOSIM), scraping floating structures provided the greatest harbour discrimination among all sampling methods; scraping rubble-mound structures provided the least (supporting figures not provided). Epifaunal communities of caprellids supported by a mussel/barnacle community distinguished Port Hardy from the other sites (Table 1). Amphipods were more common at Cowichan and isopods at Port Hardy. However, estimates of diversity and number of individuals (Simpson's Index) when completed and coupled with taxonomic characteristics are required to provide full insight into which sampling method provides the best method to compare harbours.

Reference soft sediment communities also differed among locations but within location variability was generally higher outside of the harbours than inside. Evidently, the choice of reference sampling sites was an important factor in this study and will likely be a consideration in the development of monitoring schemes for future harbour examinations. The challenge of locating nearby reference locations with physical characteristics similar to each other and to the pre-impacted harbour was demonstrated in Port Hardy where at least two of the reference samples may have had extraneous environmental influence (Figure 3). They were located on the periphery of a log storage site and contained a large amount of woody debris and coarse sediment. As a consequence the crustaceans *Nebalia* sp. and amphipods (e.g., *Anisogammarus* sp.) were more common, and clams less common, than at other reference sites, particularly those adjacent to the other harbours (Table 1; Figure 3). Several studies have demonstrated the progression of invertebrate functional groups from suspension to deposit feeders in the presence of even small amounts of bark accumulation (Conlan and Ellis 1979; and Freese and O'Clair 1987).

Cowichan was the only location among the three harbours where soft bottom communities at reference and harbour sites were indistinguishable; this is a possible reflection on its lower levels of contamination relative to the other harbours (Figure 3). At Port Hardy and Lund more clams, amphipods and leptostracans were found in the reference samples than in the harbour sediments (Table 1). However, Cowichan was also the location where exposure had the greatest influence on floating breakwater community composition (Figure 4). Isopods, mussels and barnacles responded positively to the exposure rendered on the outside of the breakwater (Table 1). A comparison of treatment and reference conditions based on community metrics may be the most direct method to incorporate biological health into habitat compensation and remediation objectives. However, some metrics such as diversity and taxonomy are analytically labour intensive and do not adapt well to a synoptic monitoring scheme. This approach also depends on the identification of representative reference sites, a challenging task as demonstrated by this research (Green 1979).

Comparison **In-Out**	**R**	**Quadrat-Floating**	**R**	**Ponar Grab**
Cow	0.79	Isopods(O) /Barnacles(O)	-	ANOSIM not significant
Lun	-	ANOSIM not significant	0.38	Polychaetes(I)/Clams(O)/ Tanaids(I)
Pha	0.34	Isopods(O)/Barnacles(I)/ Mussels(O)	0.56	Leptostraca(O)/Amphipods(O)/ Clams(O)
In-In				
Cow-Lun	1.00	Mussels(L)/Caprellids(L)/ Barnacles(L)	0.97	Clams(C)/Oligochaetes(C)/ Tanaids(L)
Cow-Pha	0.90	Isopods(P)/Barnacles(P)/ Amphipods(C)	0.96	Clams(C)/Oligochaetes(C)
Lun-Pha	1.00	Mussels(L)/Isopods(P)/ Caprellids(L)	0.97	Polychaetes(L)/Tanaids(L)
Out-Out				
Cow-Lun	1.00	Isopods(C)/Mussels(L)	0.34	Oligochaetes(C)/Amphipods(L)/ Clams(C)
Cow-Pha	0.88	Isopods(C)/Amphipods(C)/ Barnacles(C)	0.83	Leptostraca(P)/Clams(C)/ Amphipods(P)
Lun-Pha	1.00	Isopods(P)/Mussels(L)	0.84	Leptostraca(P)/Amphipods(P)/ Clams(L)

() indicates location with largest abundance

Table 1. SIMPER summary–main taxonomic groups driving the differences detected by ANOSIM. R value is a relative term with 0.00 indicating no difference and 1.00 indicating complete difference.

Conclusions and Future Activities

The analysis to date has provided some guidance for future sampling approaches. For example, sampling invertebrate communities on rubble structures by scraping the substrate using a quadrat as a guide may be unreliable. In this situation photographic approaches may be an improvement but have not been adequately tested. Underwater photographs of both consolidated and soft sediment substrates using high definition frame grabs taken from an ROV will be tested in the near future.

To be of most relevance, the methodologies and sampling designs that emerge from this study must be applicable for synoptic surveys among many sites and, to avoid the influence of time on the observations, over a relatively short period. Both sampling effort and analysis costs may be rationalized by considering optimum taxonomic resolution or using presence/absence data, and substituting biomass, diversity or specific taxonomic indicators for traditional counts of invertebrate species (Cranston 1990). These considerations will be defined as a future direction to this research project.

Despite the recognized importance of synoptic approaches, opportunities exist for a more intensive investigation of the ecological processes that are influenced by coastal development within this small craft harbour experiment. Future examinations may examine tidal current profiles and related water exchange rates, the influence of docks on light attenuation and on the amount of benthic debris, and the behaviour of migrating fish in harbours. Ultimately this work will result in a deeper understanding of the influence of harbour construction on the pathways of ecological effects.

There remains considerable uncertainty regarding the management of altered coastal environments including harbours, waterlots and other coastal developments, many of which are federal contaminated sites. This study supports a risk management inventory initiative led by Real Property Safety and Security providing valuable information regarding habitat productivity, long-term monitoring methods, risk assessment and risk management (RA/RM) methods to FCSAP custodian departments. Other organizations that regulate and manage small craft harbour facilities, waterlots, and harbour basins may also benefit from the studies' results through an increased awareness of the environmental implications associated with development. These include municipalities, regional districts and harbour authorities.

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Session H

Management, Planning and Conservation

Chair: Ashley Sprague, Ecology Action Centre, Halifax, Nova Scotia

THE INTERNATIONAL OCEAN INSTITUE–CANADA: PROMOTING THE BAY OF FUNDY

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The International Ocean Institute-Canada is a leading member of the IOI network of Operational Centres operating worldwide in over 25 countries (refer to Map 1). IOI-Canada has been based at Dalhousie University in Halifax, Nova Scotia, since being founded by Professor Elisabeth Mann Borgese in 1979. IOI-Canada's mission is to promote responsible ocean governance and the stewardship and sustainable use of coastal and ocean resources in Canada and around the world. Its goal is to encourage and develop the potential and capacity of individuals, institutions and communities dedicated to effective coastal and ocean governance (http://internationaloceaninstitute.dal.ca).

The mission and goal of the IOI are achieved primarily through education and training. Other activities include collaborative research and outreach. Several of IOI-Canada's initiatives and activities have contributed to the promotion and a better understanding of the Bay of Fundy.

IOI-Canada's foremost endeavour continues to be the annual 8-week Training Program on Ocean Governance: Policy, Law and Management, conducted annually at Dalhousie University since 1981. Participants are exposed to broadly interdisciplinary subject matter presented in thematic modules such as: Ocean Science; Law of the Sea and Ocean Governance; Integrated Coastal and Ocean Management; Management of Living Resources; Maritime Security, Emergency and Disaster Management; Integrated Maritime Compliance and Enforcement; Oil and Gas and other Energy Sources; Marine Transportation; and Tourism. Practical skills sessions are also included in areas such as negotiation; media and communications; geomatics and remote sensing; and project planning and management. Various aspects of the Bay of Fundy are invariably featured in the presentations by many of the 80 course lecturers.

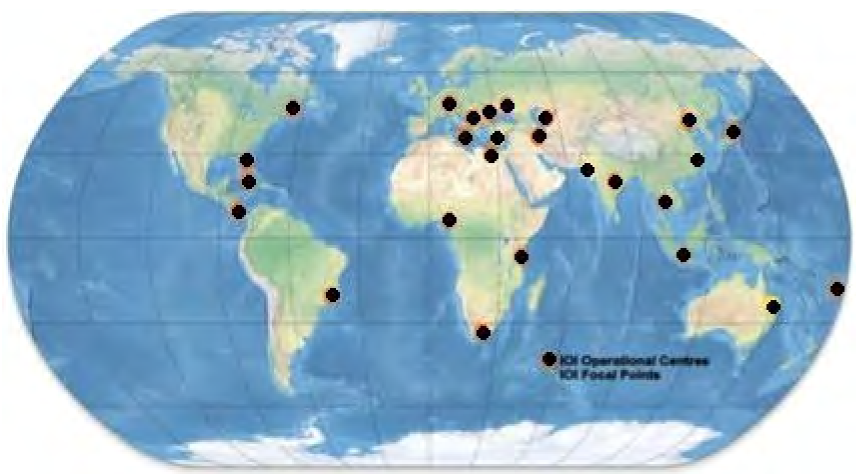
In recent years, a major component of the Training Program has been a three-day field trip to the Annapolis Valley area and the adjacent Bay of Fundy. Locations visited have included:

1. Windsor Aquaculture: land-based fish farming operation
2. Grand Pré National Historic Site: centre of Acadian settlement
3. Royal Canadian Air Force Greenwood: surveillance and air/sea rescue
4. Annapolis Tidal Power Station, one of three tidal power plants in the world; and the Annapolis Royal Marsh, developed as a constructed wetland to serve as a tertiary sewage treatment facility and nature park
5. Habitation at Port Royal: early French settlement
6. Acadian Seaplants: seaweed research and production facility in Cornwallis
7. Cooke Aquaculture: marine-based fish farming operation, Digby Gut
8. Lobster fishery: Digby area
9. Bear River First Nations Cultural Centre: Mi'kmaq ecological traditions and knowledge
10. Innovative Fishery Products: a clam depuration facility in Belliveau Cove

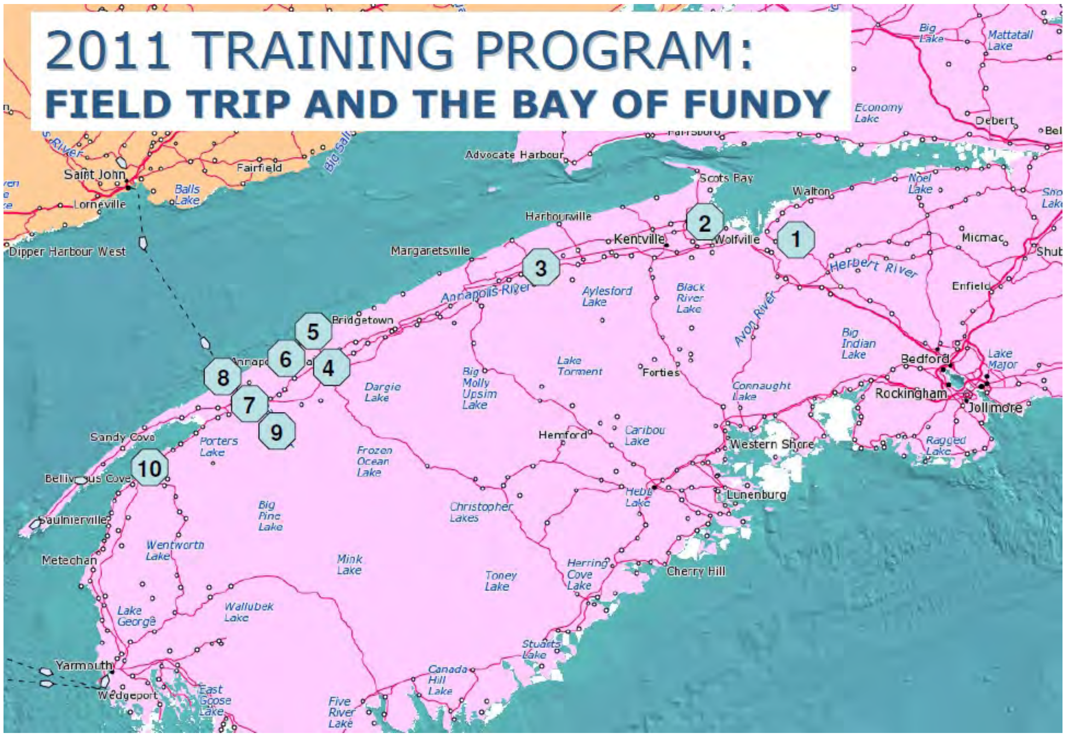
Note: The numbering of the locations above corresponds to the numbers on Map 2 and the photographs.

In addition to the Training Program, other events organized by IOI-Canada and its partners coincidently 'promote' the Bay of Fundy. These have included the annual Elisabeth Mann Borgese Ocean Lecture and the Oceans Film Festival. Also the research programs of the IOI Senior Research Fellows often focus on various aspects of the Bay.

A serendipitous benefit of IOI-Canada's 'promotion' of the Bay of Fundy has been the awareness and appreciation of the unique characteristics of the Bay worldwide through the IOI-Canada alumni, now exceeding 600 from over 100 countries. The enthusiasm for the Bay by the course participants was reflected by Parinda Ranasinghe, Sri Lanka, in his remarks on behalf of the course participants, in the closing ceremonies of the 2011 Training Program: "We were made to believe one thing; that ... there was only one Bay in the world and that was the Bay of Fundy. … vindicated when we actually saw the Bay of Fundy for ourselves ... it was truly awesome!!!"



Map 1: Locations of IOI Operational Centres and Focal Points worldwide



Map 2 and Photographs: Locations visited during the IOI-Canada field trip to the Bay of Fundy area.

REVISITING THE ROLE OF INTEGRATED RESOURCE AND ENVIRONMENTAL MANAGEMENT IN THE BAY OF FUNDY ECOSYSTEM

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Domestic and industrial activities in coastal watersheds and salt marshes pose considerable risks to ecosystem health. Risks include the cumulative impact from the disposal of biosolids and oxygen-consuming organic compounds and nutrients into receiving waters, and from industry-generated toxic chemical contamination. Three industries that contribute to the broader ecotoxicology of the Bay of Fundy are reviewed and their potential mitigation strategies are discussed.

Agriculture: Coastal communities in the Bay of Fundy have been engaged in allied agricultural practices for many decades. Excess organic and chemical compounds (e.g., fertilizers and pesticides) often contaminate water and soil sediments in the watersheds and ultimately the coastal marshlands of the Bay of Fundy, threatening vulnerable aquatic species and the human food web. The present, conventional methods of crop production need to be gradually replaced by non-toxic and sustainable practices, such as implementing the use of biocontrol agents (BCA) over chemical fertilizers and pesticides (all'Adige 2004). Potential BCA includes fungus species adapted to enhance plant growth and protect them from infectious diseases (Larkin and Fravel 1998). Cyanobacteria has also been suggested for use as a BCA, as it is capable of producing antibacterial and antifungal materials considered to be of lesser threat to the environment than conventional agricultural products, and can be grown in mass culture (Kulik 1995). However, further research is required to thoroughly assess the interaction of cyanobacteria and fungi for this application. The use of BCA fall under organic farming practices, and currently the global market for organic products are recovering from losses that were a result of the economic crisis. BCA should strongly contribute to the realization of an integrated nutrient management system for the crop production in the Bay of Fundy ecosystem.

Aquaculture: Several components of the aquaculture industry contribute to contaminant disposal into the Bay of Fundy, such as large scale recirculating fish grow-outs, hatcheries and seafood processing plants (Stricker et al. 2009). By embracing integrated aquaculture management, effective waste-water treatment processes and water conservation systems can be achieved. Techno-economic feasibility studies on enhanced nitrification and organic matter removal must be undertaken to ensure long-term viability. It would be desirable to embark on the implementation of the design and development of waste water processes in order to reduce pollutant disposal, and for recovery of value-added products (e.g., biogas, CO_2, and soil amendment compounds).

Mining and Energy: Many decades of mining activities and now emergence of shale gas exploration in New Brunswick and Nova Scotia contribute to contaminants mobility into water resources and ultimately in the Bay of Fundy (Bruce 2011). As well, installation of tidal power infrastructure may cause the Bay of Fundy to experience further eco-toxicological stress, either during the trial studies and/or at full-scale operations (Fournier 2011). The overarching strategy for energy sequestering should strive towards integrating sound technologies, socio-economic issues and government policies devoted to sustainability and long-term ecosystem health. Concerted efforts should be directed towards enacting best practices in handling polluted water from petroleum and mining exploitation, gradually setting effective bioremediation processes; understanding the strategies to minimize salt water-intrusions in coastal communities, investigating groundwater pollution potentials using

GIS in order to produce vulnerability maps of the aquifers, and striving for transparency and due diligence on policies for licensing and property acquisition.

The role of integrated resource and environmental management within New Brunswick and Nova Scotia is vital to safeguard the integrity of the Bay of Fundy ecosystem. Provincial standards for chemical usage risk need to be set and values for the economic benefit, ecological, and environmental sustainability need to be adopted. This approach would result in future opportunities for investment, employment security and economic strength. Moreover, it would facilitate the mechanism for monitoring and managing the amount of dangerous chemicals and fertilizers contaminants and prevents them from entering the water table and food chain. Such an approach would need to be tied into provincial food quality standards (organic) and provincial water/wastewater quality standards.

Acknowledgement

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TOOLS FOR HEALTHY WATERSHEDS: WHAT WE HEARD FROM MUNICIPAL PLANNERS AROUND THE BAY OF FUNDY

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In March 2011, the Ecology Action Centre, in partnership with BoFEP, held a series of workshops for land use planners around the Bay of Fundy focused on exploring the impacts of land-based activities on the health of coastal habitats and watersheds. The workshops identified local priority issues related water quality within the Bay of Fundy watershed and the tools and resources that planners are currently using to minimize impacts of these issues in their region. The workshops also identified information requirements such as data gaps and additional planning tools required by the planning community to more effectively manage impacts of pollutants, sewage, climate change and other land-based activities on coastal ecosystems and water quality; and assessed how groups like the EAC and BoFEP can work to develop support tools and information resources to better meet the needs of planners.

Note: The Final Report for the Workshop is available at http://www.bofep.org/PDFfiles/planners_workshops/Final%20Report%20April%2014.pdf

Session I

Marine Protected Areas

Chairs: Maxine Westhead, Fisheries and Oceans Canada, Halifax, Nova Scotia and Rodrigo Menafra, Canadian Parks and Wilderness Society, Halifax, Nova Scotia

MARINE PROTECTED AREAS IN THE BAY OF FUNDY: NOTES ON AN OPEN DISCUSSION AND QUESTIONS

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COMMON / IMPORTANT MESSAGES

- Progress in designating marine protected areas (MPAs) is too slow.
- New scientific research and data collection is not the solution for moving forward; lack of political will is the biggest reason for lack of progress.
- Community support is vital to making progress in MPA establishment and better communication of the benefits of MPAs is key.
- Environmental non-governmental organizations (ENGOs) have an important role to play in ensuring communities are engaged early in the process and can communicate the benefits of MPAs.
- In the Bay of Fundy it is important to apply lessons learned.
- Small, early wins are important for making long-term progress.

ANSWERS TO OPEN DISCUSSION QUESTIONS

1. What do you think the MPA network should aim to protect and why?
   - Areas that are most threatened and areas that are still natural should be prioritized for protection.
   - The baseline for "naturalness" keeps changing.
   - Spawning areas we know are under threat should be prioritized.

2. What unique considerations should be taken into account when planning for MPAs in the Bay of Fundy?
   - The 7 Wonders contest can help rally people. There's only a month left.
   - The liquified natural gas (LNG) terminal proposal was a concern for fishermen in Passamaquody. There has been talk about an MPA to keep LNG out. It was suggested that the LNG issue could be a driver for an MPA in the Bay of Fundy.
   - There are many lessons learned that should be applied in the Bay of Fundy. It is important to understand the history of Parks Canada's unsuccessful attempt to establish a national park in the Passamaquody region.

3. What role can your organization or interest group have in the development of the MPA network and how do you want to be involved?
   - The Canadian Wildlife Federation (Sean Brilliant) wants to know what they can do to speed up the process.
   - The Canadian Parks and Wilderness Society (CPAWS-NS) suggested that ENGOs have a role to play in making sure that communities and resource users are involved in the early stages of the process.

ADDITIONAL DISCUSSION THEMES

Community Engagement/Concerns

- There was agreement that progress is slow, particularly at the federal level. Communities are still not convinced about the benefits of MPAs and communities are still divided between conservation and development. CPAWS works in the Digby Neck and Islands area, which is a top ecological site within the Bay of Fundy, but there is still some hesitation from the community. Salmon farming and other development may bring jobs, but there has not been discussion in government about areas where aquaculture should *not* occur.
- The ecological significance of areas does not necessarily need to be justified. More education on the benefits of MPAs needs to occur. We need to apply lessons learned from other areas, such as Passamaquody Bay.
- It's all about process, and there has to be a comfort level with the communities in the process. Organizations, interest groups and users all need to be included in any MPA effort. Someone who is good with people that can work through the issues would be an asset.
- The degree of protection is always a question where livelihoods are concerned, and a displacement policy could make stakeholders more agreeable.
- People are tired of being asked and consulted with because programs change every few years and they aren't paid to be asked.
- Is there appetite from DFO to be open to community proposals? Yes, there is.
- On lessons learned: It's important to get local communities involved from the start which can be a very important role for ENGOs. Get people together and generate the discussion on MPAs and communicate the benefits. One idea is to bring in fishermen from established MPAs. The message: don't say no right away, at least listen to the debate first.
- Generally, there is a fear of 'outsiders' coming into a community and imposing conservation measures, so it's important to have community leaders or ambassadors.
- There are two ways to galvanize people: (1) big threats and (2) making small but early wins (take small steps). People feel good with early wins, even if they're small. In the long run more will get done, as this is a driver for bigger change.
- Although a groundswell of support for an MPA from the bottom-up is the best way to go, it may not be possible to wait for this to happen. Interest in DFO MPAs has not really happened since the late 1990s when sites were nominated by communities. It is imperative that progress is made while engaging the community at the same time.

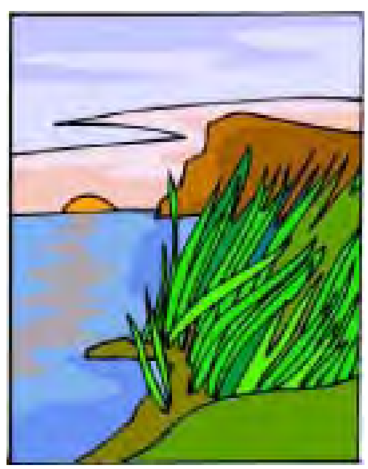
Using Terminology Other Than "MPAs"

- Some felt that the name "Marine Protected Area" negatively influences the process because not all activities will be restricted.
- Could use the terminology "marine hot spots". This is a good way to catch attention and communicate that marine hot spots are a way to focus management spatially.
- Could also call them Marine Special Areas – MARPOL designated areas.

Other Discussion Items

- It is not necessary to gather new scientific data/information to make progress with MPA planning and establishment – we need to use the information we have now. Political will is what is lacking.
- The economy is the priority issue. In this economic climate, politicians will be hesitant.
- There is no single map for the Bay of Fundy that outlines all conservation measures.
- There is an Environment Canada map (?). Other mapping and protected area Web tools include those of the Canadian Council on Ecological Areas and Conservation Area Reporting and Tracking System (CARTS). CARTS is an online mapping tool with several protected areas (http://www.ccea.org/en_carts.html). CARTS is on the cusp of including non-legislated protected areas (e.g., Nature Conservancy of Canada lands). You can export Google Earth (.kmls) from this.

POSTER SESSIONS*



* Some posters have been augmented with papers from the presenters

Session J. Ecology

Best Undergraduate Poster

THE INFLUENCE OF TIDAL CREEK NETWORKS ON WETLAND VEGETATION COLONIZATION IN A MACRO-TIDAL SYSTEM

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Six years of research and experience with restoring Bay of Fundy (Nova Scotia) salt marshes has shown that salt marsh plant species can colonize readily without planting, if the barriers to tidal flow are removed and suitable abiotic conditions (i.e., elevation) are present. However, little is known about the recovery dynamics of targeted species on a small scale. Reactivated hybrid creek networks are potentially highly important to the restoration process, as they may represent the primary transport mechanism for seeds and vegetative material for re-colonization. However, it is unknown how important creeks are for the actual colonization of target species (*Spartina alterniflora*; *S. patens*; *Salicornia european*; *Sueda maritima*; *Atriplex* spp.). Utilizing the Cogmagun River salt marsh restoration site (Hants County), which was restored in 2009, this research aims to examine if there is a relationship between proximity to creek and colonization rates of common salt marsh species, as well as if there is a difference in seedling coverage of salt marsh annuals and other native species at varying distances from the creek. The results of this research will provide a fine-scale complement to existing and ongoing macro-scale studies and further clarify the relationships between abiotic properties of a recently restored tidal wetland and colonization.

TIME-SERIES OF COASTAL ZOOPLANKTON ABUNDANCE FROM SEVERAL MARITIME COUNTIES

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Bay of Fundy coastal zooplankton abundance has been estimated from larval herring surveys. Because there are several types involved, they have been separated into functional & taxonomic groups for several counties in New Brunswick and Nova Scotia that surround the Bay of Fundy. Time series (1982–1998) of the abundance of zooplankton are presented in a way to allow comparisons between areas.

CONSIDERATIONS IN THE USE OF HIGH RESOLUTION, LOW-ALTITUDE AERIAL PHOTOGRAPHY FOR COASTAL WETLAND RESTORATION

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Effective assessment of the success of a coastal wetland restoration project requires a solid pre- and post-restoration monitoring program and comparison to a reference condition. Low-altitude aerial photography (helium balloon and camera system) can provide high resolution digital imagery to track changes in landscape level morphological conditions and vegetative re-colonization. The current practice of surveying vegetation at specific points along a transect is time consuming and fails to capture change that occurs in areas outside of these specific points. This is very important when trying to capture change overtime at a restored wetland site and aerial photography is not available at the temporal scale needed for change. Another alternative would be low-altitude plane flights, but this option can be cost prohibitive and they are unable to detect adequate sub-meter accuracy. The purpose of this presentation is to explore the benefits and challenges of using low-altitude aerial photography within salt marsh restoration projects in Nova Scotia.

AN INVESTIGATION OF CYANOBACTERIA DYNAMICS IN THREE SOUTHWEST NEW BRUNSWICK LAKES: UTOPIA, CHAMCOOK AND DIGDEGUASH

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Abstract

Lake Utopia and Chamcook Lake, located in southwest New Brunswick, are traditionally known for high water quality. Both of these lakes are widely used for recreation and the latter as a drinking water supply. In recent years, these lakes have exhibited blooms of toxin-producing cyanobacteria, *Microcystis aeruginosa* and *Gloeotrichia echinulata* species respectively. The differential capacity of these cyanobacteria species to utilize nutrients has necessitated an investigation into the environmental conditions promoting their growth. The purpose of the surveying effort presented here is to compile baseline monitoring data with the aim to contribute to the understanding of cyanobacteria dynamics in these lakes and apply this knowledge to promote proactive management of lakes. Presented here are preliminary data from a comprehensive lake survey that is being conducted between June 2011 and January 2012. The study lakes include the aforementioned lakes as well as Digdeguash Lake, which is located in the same region but is not known to exhibit blooms. Parameters being investigated include those pertaining to phytoplankton, water quality, and sediment chemistry. Thus far, this years' survey indicates that Lake Utopia is not exhibiting cyanobacteria blooms, while Chamcook and Digdeguash are both showing signs of proliferation. Preliminary analyses of water and sediment chemistry data, as they correspond to these observations, are at present inconclusive. Based on phosphorus data to date, the current status of all three lakes is oligotrophic. These are examples of some of the survey information that will eventually be elaborated on for this project.

Introduction

Southwest New Brunswick has an abundance of lakes, which vary widely with respect to water quality, trophic stability, and ecosystem integrity. These variations are largely a result of differential environmental pressure from anthropogenic sources such as shoreline development, point source discharges, water abstraction or hydrological interference, and recreational activities. When such pressures threaten lakes, signs of eutrophication (typically a consequence of nutrient loading) begin to emerge, which include blooms of blue-green algae (i.e. cyanobacteria). Cyanobacteria not only suffocate lakes by depriving these systems of oxygen but some strains produce substances that can be toxic to humans and animals, which is a current cause of concern in two of our study lakes, Lake Utopia and Chamcook Lake. Blooms of toxin-producing cyanobacteria in these two lakes, *Microcystis aeruginosa* and *Gloeotrichia echinulata* species respectively, have presented significant challenges. Most recently, blooms in Chamcook Lake are impacting this municipal water supply for the local township of St. Andrews. While the phenomena of eutrophication is well studied, unpredicted blooms of the cyanobacteria group of phytoplankton continue to precipitate concern across the globe due to uncertain implications for human and aquatic health, potential loss of recreation opportunities, and reduced tourism and property values. In New Brunswick, environmental pressures are intensifying due to increased human encroachment of rural areas.

However, despite upward trends in residential shoreline development and aquatic recreational activities, there is limited and intermittent monitoring of lakes it the province.

The purpose of the present surveying activities, and the larger monitoring project of which they are a part, is to attain a better understanding of why blooms are happening and to promote and initiate long-term and consistent monitoring of lakes and the watersheds of which they are a part. To achieve this, baseline survey data, which includes aspects of phytoplankton abundance and characterization, water quality, and sediment chemistry, are being gathered. This baseline surveying is a subset of a holistic three lakes monitoring project that is being conducted by Eastern Charlotte Waterways Inc. (ECW) in partnership with the New Brunswick Department of the Environment.

The three lakes under investigation for this project are all located in southwest New Brunswick. They include the two aforementioned lakes as well as Digdeguash Lake, a lake located in the same region but is not known to exhibit blooms. Baseline surveying and preliminary data analyses among the three lakes are being used to assess the current condition of the lakes and draw on observations that may be indicative of why blooms are occurring. Work towards data collection and analysis for this baseline survey is presently underway; however, preliminary data and findings are presented here.

Methods

Study Sites and Monitoring Schedule

The three southwest New Brunswick lakes being monitored for this study are Lake Utopia (45°10’34.94”N, 66°47’13.13”W), Chamcook Lake (45°08’46.07”N, 67°05’30.13”W), and Digdeguash Lake (45°13’19.06”N, 66°55’01.26”W). Seven, six and four sample sites, respectively, are being monitored on the lakes whose locations are identified in Figure 1. The samples sites are long-standing with the New Brunswick Department of the Environment, having been established in the 1970s, and thus have been chosen to facilitate comparisons with historical data, where possible, as this project progresses. The following sections provide detailed information on the activities that are occurring at each of the three lakes, which includes phytoplankton characterization and abundance, water quality, and sediment chemistry sampling and analysis. Monitoring on the three lakes is scheduled to occur periodically from June 2011 to January 2012; thus far, activities have been completed from June to early September 2011, with some water chemistry analytical results pending for the latter sampling (see Figure 2 for details on the monitoring schedule).

Phytoplankton Characterization and Abundance

Two phases of phytoplankton sampling, in July and August of 2011, have been conducted to capture changes in phytoplankton community dynamics at peak population growth from early to late summer (Figure 2). Surface grab samples of 500 mL were collected from two sample sites on each Lake Utopia (AQ0001 and AQ0005) and Chamcook Lake (AR0010 and AR0012), and one site on Digdeguash Lake (AQ0018); refer to Figure 1 for the location of these sites. At each site, two phytoplankton samples were collected, one at the surface and one at Secchi depth, for a total of ten samples. A Kemmerer water sampler was used to obtain the Secchi depth sample. Phytoplankton samples were sent to M.A. De Sève Consultants in Quebec for species identification and determination of overall and relative abundance of the species present. This information is of interest since phytoplankton species vary with respect to their ability to produce toxins and to take up nutrients in different forms.

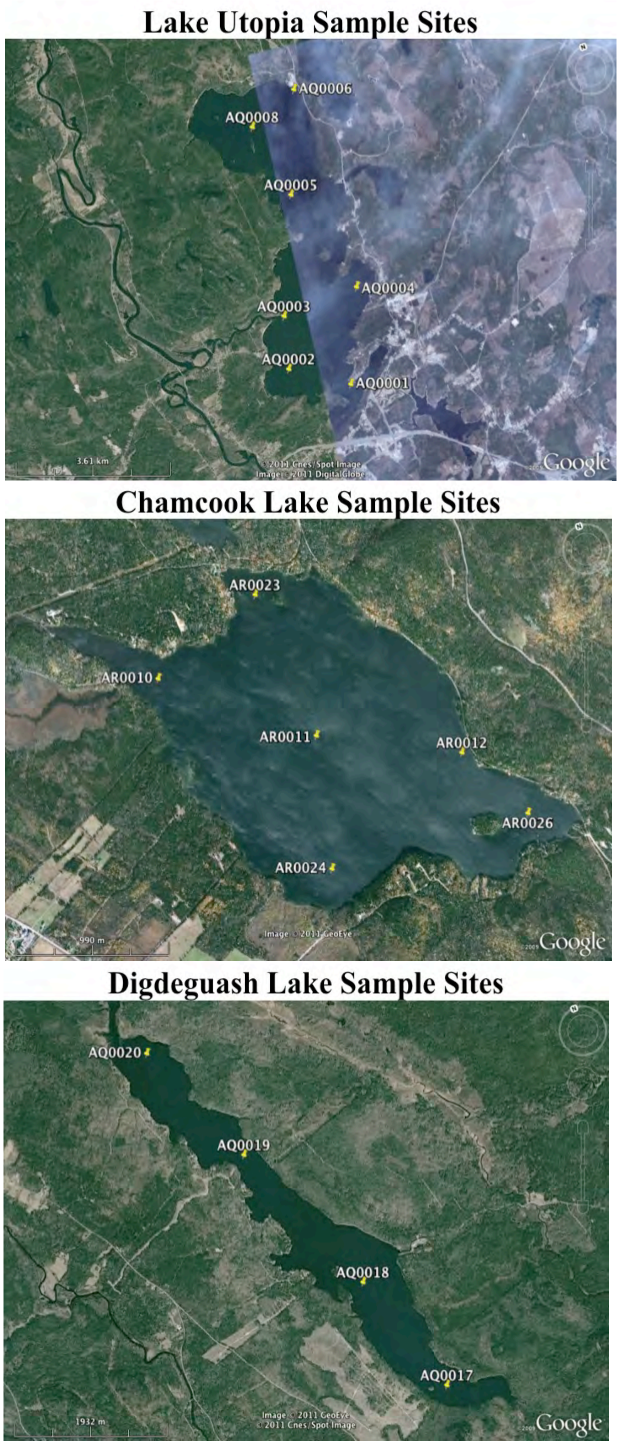

Figure 1. Maps for each of the three southwest New Brunswick (NB) study lakes, Lake Utopia, Chamcook Lake, and Digdeguash Lake, showing their corresponding sample sites (seven, six, and four respectively). Coordinates of each site are depicted in the table to the right. Sample sites were chosen on the premise that they are long-standing with the NB Department of the Environment and thus facilitate data comparisons to historical information. Maps source: Google Earth.

Water Quality

To assess water quality, surface water data is being collected from all 17 sample sites across the three lakes (see Figure 1 for information on sample sites). Throughout the course of this study, water quality monitoring, which includes sampling water chemistry, is occurring three times on a bi-monthly basis from late June until late October, and once again in January using an ice auger to capture winter conditions (see Figure 2 for monitoring schedule). Upon arrival at each sample site, a hand-held YSI multi-meter is used to record water temperature, dissolved oxygen, and conductivity at about 15 cm below the water surface. Secchi depth is assessed using a Secchi disk and lake depth is measured using the rope from the boat's anchor. As well, surface pH is measured with an EcoSense pH10A pen.

In addition to onsite measurements, surface water grab samples (at about 15 cm under the surface) are collected and couriered overnight to the Analytical Services Section of the New Brunswick Department of the Environment in Fredericton. The samples are analyzed for all 31 parameters comprising the *B analytical package for surface water and aquatic protection (NBDENV, n.d.; Figure 3) as well as chlorophyll a. Each sampling unit consists of five sample bottles: 2 x 125 mL and 2 x 500 mL for *B and 1 x 1 L for chlorophyll a. While all this data is valuable and will contribute to baseline monitoring data, the following parameters are being isolated and scrutinized more closely in the present study: total nitrogen, total phosphorus, total organic carbon, aluminum, iron, and chlorophyll a.

The impact of water depth on water chemistry has also been taken into consideration through the collection of depth samples at the same five sites across the three lakes as indicated in the previous section on phytoplankton characterization and abundance. Using a Kemmerer, grab samples are obtained at Secchi depth, mid-depth, and lake bottom and analyzed for chlorophyll a, *B, and *B respectively. Stratification of the water column at these depth sites is also measured. This exercise consists of taking temperature and dissolved oxygen measurements at one meter intervals throughout the water column to a maximum depth of 15 m, the extent of the YSI cable, or up to one meter above lake bottom.

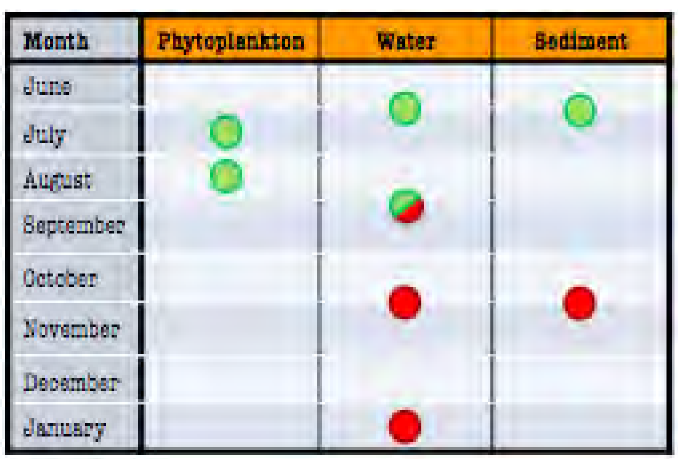

Figure 2. Three lakes monitoring schedule for Lake Utopia, Chamcook Lake and Digdeguash Lake. The green circles indicate completed sample collection and lab analysis. The red circles indicate pending activity. The one split circle, green and red, indicates field work completed but lab results pending.

ELG\EGL
Analytical Services
Package Information

INORGANIC

Package Name: *B
Description: SURFACE WATER, AQUATIC PROTECTION mod.04.04

=NO3
=TH
Al
ALKALINITY
As
Ca
Cd
Cl
CLRA
COND
Cr
Cu
F
Fe
K
Mg
Mn
Na
NH3-T
Ni
NO2D
NOx
Pb
pH
Sb
SO4
TN
TOC
TP-L
TURB
Zn

Bottles Required	Handling Instructions
2 500 ml	cool - MI H2SO4, cool - Nut
1 125 ml	HNO3 -Met
1 125 ml 'nitrate'	cool - Nut

Figure 3. List of parameters tested under the *B analytical package for surface water and aquatic protected set for by the NB Department of the Environment (NBDENV, n.b.).

Sediment Chemistry

Sediment chemistry is being analyzed to determine if significant nutrient availability within lake sediment may contribute to the proliferation of cyanobacteria. In conjunction with the late June and late October water chemistry sampling events described above, ECW is also collecting sediment samples using an Eckman grab sampler. Sediment samples are being collected from the same five sites across the three lakes as with phytoplankton sampling. Sediment samples are couriered overnight to the Research and Productivity Centre in Fredericton immediately following sampling. The samples are analyzed for total nitrogen, total phosphorus, total organic content, and aluminum. Thus far, sampling and laboratory analysis from only the late June sampling event have been conducted.

Data Analysis

Data collection and analysis for this project are still underway. For immediate purposes, the derived data has been analyzed to identify the state of the lakes in the current study period, as well as to make preliminary observations among the parameters being investigated. Ultimately, this data will be compiled with additional information on each lake, including details on land use, topography and historical water quality data. All the information gathered will be used for a comparative analysis across the three lakes to facilitate identification of trends that correspond with the proliferation of cyanobacteria in this region.

Preliminary Observations

Since surveying and data analysis for this project is still largely underway, the results presented here are limited to a sample set of surface water and sediment observations. Consideration of differences that may arise throughout the water column of the lakes has been omitted for present illustrative purposes.

Phytoplankton Characteristics and Abundance

Field observations this year have given no indication that Lake Utopia is experiencing a proliferation of cyanobacteria. Chamcook Lake and Digdeguash Lake, on the other hand, are both exhibiting some degree of blooming given the appearance of characteristic shoreline scum accumulation. Phytoplankton analyses substantiated these observations. From July to August, total phytoplankton abundance observed from surface grab samples in Utopia decreased by 20% (Table 1). In contrast, phytoplankton abundance in both Chamcook and Digdeguash increased by 503% and 117% respectively during the same period, mostly on account of increases in cyanobacteria numbers. In these two lakes, the dominant cyanobacteria species detected at peak observation are *Gloeotrichia echinulata* and *Merismopedia tenuissima* in Chamcook and Digdeguash respectively. In Chamcook Lake, an active municipal drinking water supply, cyanobacteria made up 91% of the total phytoplankton community in August sampling. More information on the relative abundance and biodiversity dynamics of the phytoplankton communities across the three lakes is provided in Table 1. While these observations do indicate some degree of phytoplankton proliferation, the cyanobacteria concentrations detected in this survey fall within the recommended guideline of 100,000 cells/mL as indicated in the Health Canada *Guidelines for Canadian Recreational Water Quality* (Health Canada 2009). The highest cyanobacteria concentration detected across the ten samples that were collected is 1737 cells/mL (surface grab sample on 17 August 2011 from Chamcook Lake, site AR0010).

Water and Sediment Chemistry

Contrary to indications that nutrient levels and the availability of sequestering metals have a bearing on the proliferation of cyanobacteria, the data to date do not reveal any obvious patterns. Variability of nutrient and metal levels across the three lakes is apparent (Figure 4). Nutrient levels in these lakes are low for what is expected to support cyanobacteria blooms. For example, based on our surface water results for phosphorus (P) levels, Utopia and Digdeguash are both classified as oligotrophic lakes (0.004–0.010 mg/L) and Chamcook, surprisingly, is classified as ultra-oligotrophic (<0.004 mg/L) (CCME 1999). An oligotrophic lake is one that has relatively low

Lake	Biodiversity Indicator	July	August	Change
Utopia	***Abundance***			
Site AQ0005	Phytoplankton Community	609 cells/mL	485 cells/mL	20% decrease
	Cyanobacteria Community	242 cells/mL	304 cells/mL	26% increase
	Proportion of Cyanobacteria in Community	40%	63%	23% increase
	Richness			
	Phytoplankton Community	20 species	18 species	10% decrease
	Cyanobacteria Community	5 species	8 species	60% increase
	Proportion of Cyanobacteria in Community	25%	44%	19% increase
	Simpson's Index of Diversity			
	Phytoplankton Community	0.78	0.91	increase
	Cyanobacteria Community	0.56	0.83	increase
	Evenness Index (Relative Abundance)			
	Phytoplankton Community	0.65	0.88	increase
	Cyanobacteria Community	0.63	0.9	increase
Chamcook	***Abundance***			
Site AR0010	Phytoplankton Community	318 cells/mL	1919 cells/mL	503% increase
	Cyanobacteria Community	125 cells/mL	1737 cells/mL	1289% increase
	Proportion of Cyanobacteria in Community	39%	91%	51% increase
	Richness			
	Phytoplankton Community	18 species	17 species	6% decrease
	Cyanobacteria Community	3 species	9 species	200% increase
	Proportion of Cyanobacteria in Community	17%	53%	36% increase
	Simpson's Index of Diversity			
	Phytoplankton Community	0.83	0.47	decrease
	Cyanobacteria Community	0.5	0.36	decrease
	Evenness Index (Relative Abundance)			
	Phytoplankton Community	0.73	0.42	decrease
	Cyanobacteria Community	0.69	0.39	decrease
Digdeguash	***Abundance***			
Site AQ0018	Phytoplankton Community	496	1079	117% increase
	Cyanobacteria Community	365	885	142% increase
	Proportion of Cyanobacteria in Community	0.74	0.82	8% increase
	Richness			
	Phytoplankton Community	11	8	27% decrease
	Cyanobacteria Community	4	4	no change
	Proportion of Cyanobacteria in Community	0.36	0.5	14% increase
	Simpson's Index of Diversity			
	Phytoplankton Community	0.67	0.49	decrease
	Cyanobacteria Community	0.42	0.27	decrease
	Evenness Index (Relative Abundance)			
	Phytoplankton Community	0.63	0.54	decrease
	Cyanobacteria Community	0.51	0.41	decrease

*Abundance = cell count per mL of lake water

*Richness (S) = total species count

*Simpsons Index of Diversity = 1 – [sum(Pi)^2], where Pi is the proportion of each species in the sample relative to the total number of species. This index, therefore, takes into account species richness and relative abundance. It ranges from 0 to 1, where 0 is no diversity and 1 is infinite diversity.

*Evenness Index (E) = H/ln(S), where H is -sum(Piln[Pi]). This index is a measure of how similar the abundance of different species are; a value of 1 indicates evenness and the farther the value increase from 1, the more dissimilar the abundances.

Source of Biodiversity Indicators: http://www.mdsg.umd.edu/programs/education/interactive_lessons/biofilm/studnt1.htm

Table 1. Phytoplankton abundance and diversity for three lakes in July and August of 2011. Data represents three separate surface grab samples of 500 mL from one site on each lake. July samples were all collected on July 17th, while in August the Chamcook Lake sample was collected on the 17th and the other two lakes were sampled on the 18th.

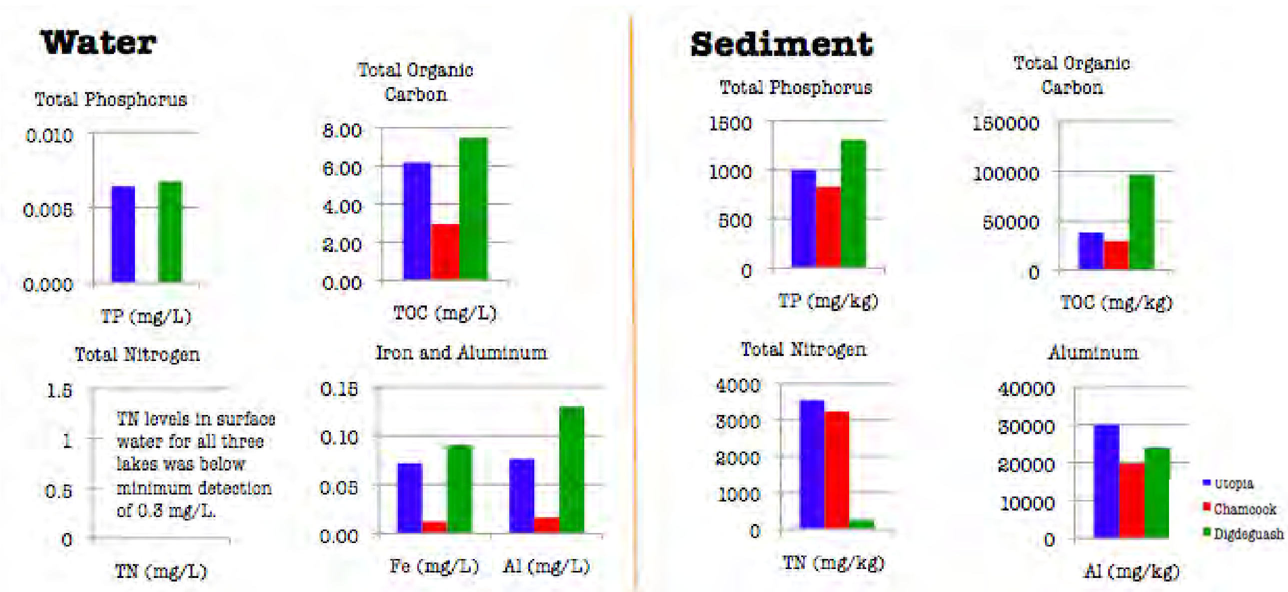

Figure 4. Column graphs showing various measures of surface water and sediment chemistry across the three study lakes. Values have been averaged for samples taken on 23 June, 4 July, and 7 July 2011 for lakes Utopia, Chamcook, and Digdeguash respectively.

primary production (i.e., low phytoplankton concentration) and low nutrient levels; as opposed to mesotrophic, which is moderate, and eutrophic, which is on the high end of the trophic spectrum. Samples have also been analyzed for metals, iron (Fe) and aluminum (Al), due to their ability to sequester nutrients and render them biologically unavailable for cyanobacteria (Norton et al. 2008). It is important to consider that too much metal in a lake can become detrimental to the overall quality of the lake. Standards for water metal concentrations put forth by the Canadian Council of Ministers of the Environment indicate tolerance limits of 0.3 mg/L for Fe and 0.1 mg/L for Al (CCME 1999). Results for these lakes fall well within these limits set for aquatic life protection, with the exception of Digdeguash where the average surface water Al concentration during the early July 2011 sampling event was 0.13 mg/L.

Summary

Results thus far indicate a highly complex relationship between cyanobacteria and lake chemistry, highlighting the need for a holistic approach to lake monitoring. While many of the traditional indicators point to high water quality and good lake health, other measures suggest trophic statuses may be slowly changing. ECW will be completing data collection as planned and will conduct further analyses in an effort to identify trends. In addition to the immediate focus of the surveying efforts presented here, work is being done to acquire additional information on the unique conditions of each lake, which will ultimately also include details on land use, topography, historical water quality data, and a literature review on the biology of the cyanobacteria species in question. The entire project will culminate in recommendations for improved monitoring of lakes to better predict the onset of blooms and to highlight the importance of proactive management. Project completion is anticipated for the spring of 2012.

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An Investigation of Cyanobacteria Dynamics in Three Southwest New Brunswick Lakes: Utopia, Chamcook and Digdeguash

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@ 9th BoFEP Bay of Fundy Science Workshop
September 27-30, 2011

Introduction

Lake Utopia and Chamcook Lake, located in Southwest New Brunswick, are traditionally known for high water quality. Both of these lakes are widely used for recreation and the latter as a drinking water supply. In recent years, these lakes have exhibited blooms of toxin-producing cyanobacteria, *Microcystis aeruginosa* and *Gloeotrichia echinulata* species respectively. While the phenomena of eutrophication is well studied, unpredicted blooms of this one group of phytoplankton, cyanobacteria, continue to precipitate concern across the globe due to uncertain implications for human and aquatic health, potential loss of recreation opportunities, and reduced tourism and property values. The differential capacity of the aforementioned cyanobacteria species to utilize nutrients has necessitated an investigation into the environmental conditions promoting their growth. The purpose of the present study is to investigate the conditions contributing to the identified blooms. A comprehensive lake survey is being conducted between summer 2011 and early 2012 on the aforementioned lakes as well as Digdeguash Lake, which is located in the same region but is not known to exhibit blooms. See Figure 1 and Table 1, below, for information on the location of the three study lakes. Parameters being investigated include those pertaining to phytoplankton, water quality, sediment chemistry. Additional information on each lake will eventually also be compiled, including details on land use, topography and historical water quality data. All the information gathered will be used for a comparative analysis across the three lakes to facilitate identification of trends that correspond with the proliferation of cyanobacteria. The study will also culminate in recommendations for improved monitoring of lakes to better predict the onset of blooms and highlight the importance of proactive management.

Objective: Compile baseline monitoring data in an effort to contribute to the understanding of cyanobacteria dynamics in lakes and promote proactive management.

Study Lakes

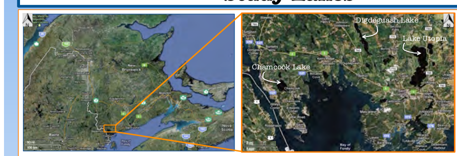


Figure 1. Left map shows New Brunswick with the US state of Maine to the west. Right map is zoomed into the study region, showing the three study lakes, Chamcook, Digdeguash and Utopia. These lakes are located in Charlotte County, Southwest New Brunswick. Image source http://maps.google.com/

Table 1. UTM coordinates of study lakes.

Lake	Coordinates
Utopia	45°10'34.94"N 66°47'15.13"W
Chamcook	45°08'45.07"N 67°05'30.13"W
Digdeguash	45°15'19.08"N 66°53'01.26"W

Methods

Phytoplankton Characterization and Abundance
Two phases of phytoplankton sampling, in July and August of 2011, have been conducted to capture changes in phytoplankton community dynamics from early to late summer. Surface grab samples were collected from two sample sites on each Lake Utopia and Chamcook Lake, and one site on Digdeguash Lake. Phytoplankton samples were sent to M.A. De Sève Consultants in Quebec for species identification and determination of the relative abundance of the various species present.

Water Chemistry
To assess water quality, we are collecting surface water data from seven, six and four locations on Lake Utopia, Chamcook Lake and Digdeguash respectively. The samples sites are long-standing and thus have been chosen to facilitate comparisons with historical data. Throughout the course of the monitoring study, sampling for water chemistry is occurring three times on a bi-monthly basis from late June until late October, and once again in January to capture winter conditions. Surface water grab samples are collected and sent to the Analytical Services Section of the New Brunswick Department of the Environment in Fredericton immediately following sampling. Here they are analyzed for numerous parameters including: total nitrogen, total phosphorus, total organic carbon, aluminum and iron.

Sediment Chemistry
Sediment chemistry is being analyzed to determine if significant nutrient availability within lake sediment may contribute to the proliferation of cyanobacteria. In conjunction with the late June and early October water chemistry sampling events described above, ECW is also collecting sediment samples using an Eckman Sediment Grab. Sediment samples are being collected from the same five sites across the three lakes as with phytoplankton sampling. Sediment samples are sent to the Research and Productivity Centre in Fredericton immediately following sampling. The samples are analyzed for total nitrogen, total phosphorus, total organic content, and aluminum.

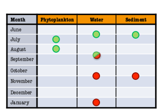


Figure 2. Three lakes monitoring schedule. Green circles indicate completed sample collection and lab analysis. Red circles indication pending activity. The split circle indicates field work completed but lab results pending.

Preliminary Findings

Phytoplankton Characteristics and Abundance
Field observations this year have given no indication that Lake Utopia is experiencing a proliferation of cyanobacteria. Chamcook Lake and Digdeguash Lake, on the other hand, are both exhibiting some degree of blooming given the appearance of characteristic shoreline scum accumulation. Phytoplankton analyses substantiated these observations. From July to August, total phytoplankton abundance observed in Utopia decreased by 20% (Figure 3). In contrast, abundance in both Chamcook and Digdeguash increased by 503% and 117% respectively during the same period, mostly on account of increases in cyanobacteria numbers. In Chamcook Lake, the most worrisome in this monitoring study on account of it being a drinking water supply, cyanobacteria made up 91% of the total phytoplankton community in August sampling. More information on the relative abundance and biodiversity dynamics of the phytoplankton communities across the three lakes is provided in Figure 3.

Water Quality Guideline Value[1]: Total cyanobacteria ≤ 100,000 cells/mL
Maximum detected cyanobacteria concentration in present study: 1737 cells/mL

Water and Sediment Chemistry
Contrary to indications that nutrient levels and the availability of sequestering metals have a bearing on the proliferation of cyanobacteria, the data to date do not reveal any obvious patterns. Variability across the three lakes is apparent (Figure 4). Nutrient levels in these lakes are low for what is expected to support cyanobacteria blooms. For example, based on our surface water results for phosphorus (P) levels, Utopia and Digdeguash are both classified as oligotrophic lakes and Chamcook, surprisingly, is classified as ultra-oligotrophic (definitions of trophic statuses[2] are provided in the textbox to the bottom right). Samples have also been analyzed for metals, iron (Fe) and aluminum (Al), due to their ability to sequester nutrients and render them biologically unavailable for cyanobacteria. It is important to consider that too much metal in a lake can become detrimental to the overall quality of the lake. Standards for water metal concentrations put forth by the Canadian Council of Ministers of the Enviornment[2] indicate tolerance limits of 0.3mg/L for Fe and 0.1mg/L for Al. Results for our lakes fall well within these limits with the exception of Digdeguash, whose average surface water Al concentration is 0.13mg/L.

[1]Health Canada. 2009. Guidelines for Canadian Recreational Water Quality, Third Edition.
[2]Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life.

Lake Chemistry

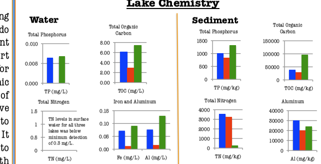
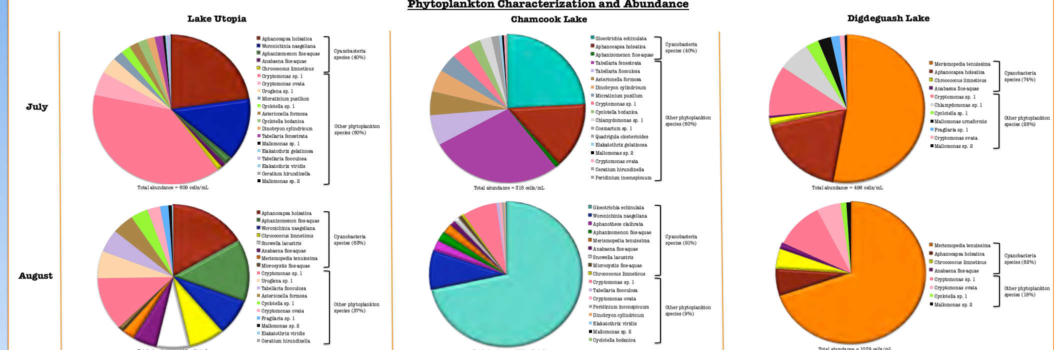


Figure 4. Column graphs show various measures of surface water and sediment chemistry across the three study lakes. Values have been averaged for samples taken on June 23, July 4, and July 7 2011 for lakes Utopia, Chamcook, and Digdeguash respectively.

Definitions of Trophic Statuses[2]
Oligotrophic: Water body exhibiting low primary productivity and low nutrient levels, P<10μg/L.
Mesotrophic: Water body exhibiting moderate primary productivity and moderate nutrient levels, P=10-35μg/L.
Eutrophic: Water body exhibiting high primary productivity and high nutrient levels, P>35μg/L, which is prone to blooms of cyanobacteria.

Phytoplankton Characterization and Abundance



Lake Utopia

Biodiversity Indicator	July	August	Observed Change
Abundance*			
Phytoplankton Community	609 cells/mL	485 cells/mL	20% decrease
Cyanobacteria Community	242 cells/mL	304 cells/mL	26% increase
Proportion of Cyanobacteria in Community	40%	63%	23% increase
Richness**			
Phytoplankton Community	20 species	18 species	10% decrease
Cyanobacteria Community	5 species	8 species	60% increase
Proportion of Cyanobacteria in Community	25%	44%	19% increase
Simpson's Index of Diversity***			
Phytoplankton Community	0.78	0.91	increase
Cyanobacteria Community	0.56	0.83	increase
Evenness Index****			
Phytoplankton Community	0.65	0.88	increase
Cyanobacteria Community	0.63	0.90	increase

Chamcook Lake

Biodiversity Indicator	July	August	Observed Change
Abundance*			
Phytoplankton Community	318 cells/mL	1919 cells/mL	503% increase
Cyanobacteria Community	125 cells/mL	1737 cells/mL	1289% increase
Proportion of Cyanobacteria in Community	39%	91%	51% increase
Richness**			
Phytoplankton Community	18 species	17 species	6% decrease
Cyanobacteria Community	3 species	9 species	200% increase
Proportion of Cyanobacteria in Community	17%	53%	36% increase
Simpson's Index of Diversity***			
Phytoplankton Community	0.83	0.47	decrease
Cyanobacteria Community	0.50	0.36	decrease
Evenness Index****			
Phytoplankton Community	0.73	0.42	decrease
Cyanobacteria Community	0.69	0.39	decrease

Digdeguash Lake

Biodiversity Indicator	July	August	Observed Change
Abundance*			
Phytoplankton Community	496	1079	117% increase
Cyanobacteria Community	365	885	142% increase
Proportion of Cyanobacteria in Community	74%	82%	8% increase
Richness**			
Phytoplankton Community	11	8	27% decrease
Cyanobacteria Community	4	4	no change
Proportion of Cyanobacteria in Community	36%	50%	14% increase
Simpson's Index of Diversity***			
Phytoplankton Community	0.67	0.49	decrease
Cyanobacteria Community	0.42	0.27	decrease
Evenness Index****			
Phytoplankton Community	0.63	0.54	decrease
Cyanobacteria Community	0.51	0.41	decrease

* Abundance = cell count per mL of lake water
** Richness (S) = total species count

Figure 3. Figure shows phytoplankton characterization and relative abundance information across three lakes and two sample events, July and August of 2011. The July samples were all collected on July 17th, while in August the Chamcook Lake sample was collected on the 17th and samples for the other two lakes were collected on the 18th. These surface samples were shipped to M.A. De Seve Consultants in Quebec for external analysis. Each pie graph represents counts deduced from one surface sample (500mL) at one site on each lake. Phytoplankton species are organized into two groups, cyanobacteria species and all other phytoplankton species, and the species within these two groups are sorted in descending order of abundance. The proportion of cyanobacteria species to non-cyanobacteria species, as well as the total abundance represented by each pie, are also given. The tables in this figure summarize diversity statistics for across each of the samples in each lake. These include species abundance and richness, as well as the Simpson's Index of Diversity and the Evenness Index, as measures for biodiversity. See figure inlet for details on these measures and indices.

Continuing From Here Results thus far indicate a highly complex relationship between cyanobacteria and lake chemistry, highlighting the need for a holistic approach to lake monitoring. While some measures indicate high water quality and lake health, other measures may suggest otherwise. ECW will be completing data collection as planned and conduct further analyses in an effort to identify trends. Project completion is anticipated for the spring of 2012. A final report will be made available on our website: www.ecwinc.org

Acknowledgements
We thank Environment Canada and the New Brunswick Department of the Environment (DENV) for funding this monitoring initiative. We would also like to thank Don Fox, Erin Douthwright, John O'Keefe, and Mark Bader of the DENV for collaborating with us on this project and providing advisory support. Special thanks to Karl Whalen, Benny Travis, Michelle LeBlanc, and Mario Jones for their assistance in the field, this project would not be possible without their help.

COMPARISON OF GRAIN SIZE DETERMINATION USING COULTER LASER DIFFRACTION AND COULTER ELECTRICAL SENSING ZONE METHOD FOR SALT MARSH RESTORATION MONITORING

Christa Skinner[1,2] and Danika van Proosdij[1,2]

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[2] Intertidal Coastal Sediment Transport Research Unit, Saint Mary's University, Halifax, Nova Scotia

One of the indicators of success of a salt marsh restoration project is if the site is trending towards conditions present at a reference site. The grain size spectrum of a sample location is influenced by source material and velocity of current. If the grain size spectrum is incorrectly identified, it can alter the assessment of the success of a salt marsh restoration project. The purpose of this project is to explore the differences and limitations of using a Coulter LS 200 Laser Diffraction Method as compared to using a Coulter Counter Multisizer 3. It is hypothesized that the Laser Diffraction Method will overestimate the grain size spectrum. The research was conducted within a newly restored salt marsh (and associated reference site) in the Upper Bay of Fundy currently being monitored as a compensation project. The samples taken in 2008 were processed through a Coulter LS 200 and a Coulter Counter Multisizer 3. A grain size spectrum was produced for each sample. The resulting grain size spectrums from both methods were compared to identify differences in interpretation of hydrodynamic processes for salt marsh restoration monitoring.

Best Graduate Poster

PREDATION EFFECTS ON JUVENILE INVERTEBRATES IN TWO ROCKY SUBTIDAL COMMUNITIES

Betsy L. Barber and Heather L. Hunt

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In marine systems, variability in recruitment can limit the distribution and abundance of adults. One possible source of variability is early post-settlement mortality. Predation is potentially one of the more influential sources of mortality but previous studies looking at predator influences on juveniles have shown opposing results. The objective of this study was to investigate the effect of the presence of predators on developing invertebrate communities in the rocky subtidal in the southwest Bay of Fundy. The experiment was carried out using cobble-filled collectors made of lobster trap wire. Three predator treatments were set up: the first excluded predators >5 mm, the second allowed complete access to the collector, and the third was partially covered with mesh to test for caging artifacts caused by the exclusion treatment. A total of 135 collectors were placed at two sites. Ninety were removed after three months (July–October 2010), and at one site 45 collectors were removed after 10 months (July 2010–May 2011). This was done to look at variation in the effect of predation through time. Invertebrates from each collector are being identified to the lowest taxonomic level possible and counted. A portion of these juveniles will be measured for size distributions. Biomass will be estimated for certain prey species. Multivariate analyses of whole communities within collectors as well as analyses of individual species will be done to test for predator effects. Preliminary results will be presented.

Session K. Information

CONCEPTUALIZING KNOWLEDGE WORKER'S TASKS IN THE COASTAL AND OCEAN MANAGEMENT FIELD

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This poster is derived from recommendations of an exploratory study conducted between May 2010 and August 2011. The exploratory study intended to discover the information needs of knowledge workers in the coastal and ocean management domain, which is essential in developing tools that these knowledge workers could potentially use. Eighteen knowledge workers were interviewed during the exploratory study using the critical incident technique. Participants were questioned about one specific project they worked on and the steps used to complete that project. All interviews were audio recorded and transcribed professionally. The study identified ten tasks and six archetypes, or potential user groups of the tool. The poster being presented will conceptualize and map one of the ten tasks found, which includes examining the components and steps required to complete that task. Possible tools or applications for this task will be explored for use in domain specific information retrieval. I am interested in communicating the results of the study and receiving feedback on the emerging model for one of the tasks and confirming and expanding on the different user archetypes of a potential tool(s). Informal feedback and questions are welcomed, however, an additional opportunity will be available to part-take in a short demographic survey and drawing exercise taking no longer than five minutes. Feedback from the conference will be represented in a major project as a requirement for the Master of Resource and Environmental Management degree at Dalhousie University.

AWARENESS, USE AND INFLUENCE OF COASTAL AND MARINE ENVIRONMENTAL INFORMATION: CASE STUDIES OF GOVERNMENTAL AND INTERGOVERNMENTAL ORGANIZATIONS

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[3] School for Resource and Environmental Studies, Marine Affairs Program, and International Ocean Institute, Dalhousie University, Halifax, Nova Scotia (oceans2@ns.sympatico.ca)
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Solutions to serious environmental issues, such as the declining health of Canada's and the world's coasts and oceans, depend as much on efficiently finding existing information and applying it in policy solutions as on the creation of new relevant information. Knowledge and understanding of these coastal and marine problems have developed from wide-ranging scientific research and synthesis by many governmental, intergovernmental, and non-governmental organizations. However, in spite of the sizeable and rapidly growing volume of primary and grey literature, many of the environmental problems persist, suggesting that significant barriers still exist between information production and its use in timely and effective policy action.

The Environmental Information: Use and Influence project seeks to understand the science-policy interface by developing techniques to measure use and influence of information in policy making contexts, and to identify barriers as well as enablers to communication of information (MacDonald et al. 2010). The research initiative assesses the use and influence of marine environmental information produced as grey literature (i.e., publications not controlled by commercial publishers) by governmental and intergovernmental organizations focused on environmental protection. An underlying hypothesis of the research is that many of the problems currently facing the marine environment and its living resources could be mitigated or solved by better use of existing information contained in grey literature published by such organizations.

This poster presented results from five case studies completed by the Environmental Information Use and Influence research initiative. The case studies examined information life cycles of publications of one governmental and three intergovernmental organisations: the Provincial Oceans Network, Government of Nova Scotia; Gulf of Maine Council on the Marine Environment (GOMC); United Nations (UN) Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP); and the UN Food and Agriculture Organization/Caribbean Regional Fisheries Mechanism (Cossarini 2010; Hutton 2009, 2010; Soomai 2009; Soomai, Wells, and MacDonald 2011; Soomai, MacDonald, and Wells 2011a, 2011b).

The research asked: What are the pathways of scientific information from its production to use in policy decisions on marine environmental issues? A suite of research methodologies (citation analysis, content analysis, surveys, and interviews) were applied to the case studies to enhance understanding of the production, diffusion, and use of information in scientific and public sector settings. The research has produced databases of selected organization's publications and citations; knowledge on the sources, frequency, and patterns of citations, the geographic location of citing authors, as well as the subject areas of citing publications. Information pathways that demonstrate how publications are published and how they move from producers to users have also been developed for several of the case study organisations.

Results of the case studies have contributed to knowledge on the publication practices and use of scientific information produced by the selected governmental and inter-governmental bodies. In spite of increasing application of information technologies and methods of distribution, challenges to effective use of information in policy and decision making remain. Awareness remains a major barrier to effective and widespread communication and use of scientific information. The results, particularly for the GOMC case studies, highlight the critical role of information in managing the Gulf of Maine/Bay of Fundy region and support the Fundy Information Collaboratory (in preparation through the Bay of Fundy Ecosystem Partnership, BoFEP). Efficient access to and effective use of information are critical to understanding cumulative changes in the region's ecosystems, both natural and anthropogenic. In spite of increasing information technologies, there are many challenges to effective use of information in support of policies and management actions. The question to be asked is: how can linkages between science and policy making be improved for conservation and protection of the Bay of Fundy?

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Awareness, Use, and Influence of Coastal and Marine Environmental Information: Case Studies of Governmental and Intergovernmental Organizations

B.H. MacDonald, P.G. Wells, S.S. Soomai, D.M. Cossarini, R.E. Cordes, G.R.G. Hutton, C.E. Delany, E.M. De Santo

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Abstract

Our research investigates marine information produced as scientific grey literature (i.e., not controlled by commercial publishers) and its potential use and influence in policy making contexts. Results from a suite of research methodologies (citation analysis, content analysis, surveys), applied to five case studies have enhanced our understanding of the production, distribution, and use of information in scientific and public sector settings. Awareness remains a major barrier to effective and widespread communication and use of marine information, in particular for the Gulf of Maine/Bay of Fundy region.

Introduction

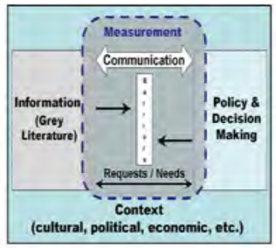
- Marine ecosystems globally are at great risk due to human pressures.
- The Gulf of Maine/Bay of Fundy is one such ecosystem undergoing much change.
- Much of the key scientific data and information for finding solutions is in the grey literature, an increasingly important knowledge base.
- This information informs timely and effective policy making.
- Understanding information production, distribution and use will enable evaluation of its influence.

Methods

To date, our methods have included:

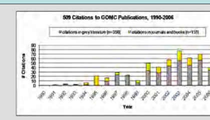
- Creation of databases of each organization's publications and citations.
- Analysis of citations to determine
  - Sources, frequency, and patterns.
  - Geographic location of citing authors.
  - Subject areas of citing publications.
- Content analysis of publications for characteristics that promote distribution and awareness.
- Surveys (e.g., interviews) of stakeholders to determine information pathways.

Our Guiding Framework and Questions



- What, where, and how have selected marine environmental and fisheries organizations published?
- What is the evidence of distribution and use of their publications?
- What methods best measure the influence of information in grey literature on decision making in marine environmental fields?
- How can marine environmental information in grey formats be more influential in decision making?

Results

Case Study	Production	Distribution	Use
GOMC Gulf of Maine Council on the Marine Environment *Bibliographic Study*	Publications are reviewed but publication practices are not uniform. However, this has now been addressed by a new publication policy.	An informal process exists for the region, resulting in uneven awareness and access (for older publications).	 Frequency of citations to publications
GOMC Gulf of Maine Council on the Marine Environment *State of the Gulf of Maine Report*	Clear strategy behind its production. Five theme papers and a context paper are available in digital formats (as of June 2010).	The theme papers were posted on the GOMC website and a notice of its release was included in the *Gulf of Maine Times* in 2010.	Reports are used by Council and Working Group Members primarily as baseline information on coastal issues in the Gulf of Maine /Bay of Fundy region. Low reported use by the public to date.
GESAMP UN-Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection	Rigorously reviewed reports are available in a Technical Report series. Reports and studies are posted on the Web site.	Reports are sent out by UN agencies and are also on the GESAMP website.	 Frequency of citations to publications
FAO/CRFM UN-Food and Agriculture Organization/ Caribbean Regional Fisheries Mechanism *Shrimp and Groundfish Scientific Working Group*	There is a formal Technical Report series on the regional shrimp and groundfish fisheries of the Brazil-Guianas Shelf.	Reports are sent out by agencies and are also on the website. An informal process exists in Trinidad and Tobago (the country case study).	Reports are used primarily within the scientific community. Limited evidence of use and impact on policy making.
NSFA Nova Scotia Department of Fisheries and Aquaculture *2009 State of Nova Scotia's Coast Report*	Clear strategy behind the project. Three types of the report are available in print and digital formats (as of December 2009)	The three types of the report were distributed by mail, at public meetings, by email, and through press releases from 2009 to 2010.	Reports are used by multiple stakeholders primarily as baseline information. Government sought stakeholder involvement in developing a knowledge-based coastal policy for Nova Scotia.

Relevance to the Bay of Fundy and its Watersheds

- Information is critical for managing the Gulf of Maine/Bay of Fundy region.
- Results of our case studies support the Fundy Information Collaboratory (in preparation).
- Efficient access to and effective use of information are critical to understanding cumulative changes in the region's ecosystems, both natural and anthropogenic.
- In spite of increasing information technologies, there are many challenges to effective use of information in support of policies and management actions.
- How can linkages be improved between science and policy making for conservation and protection of the Bay of Fundy?

Next Steps

Our future research includes:

- Developing better methods for evaluating the influence of information in grey literature on decision making in marine environmental fields.
- Adding new case studies such as BoFEP.
- Partnering with other environmental and resource research groups to increase the interdisciplinary nature of the project and optimize research findings.

Theses/Papers

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Soomai, S. S., MacDonald, B. H., & Wells, P. G. (2011a). *The 2009 State of Nova Scotia's Coast Report: An initial study of its use and influence*. Halifax: Dalhousie University.

Soomai, S. S., MacDonald, B. H., & Wells, P. G. (2011b). *The State of the Gulf of Maine Report: An initial study on awareness, use and influence of the theme papers*. Halifax: Dalhousie University.

Supported by:

9th Bay of Fundy Science Workshop
September 27 – 30, 2011
Saint John, New Brunswick

Environmental Information: Use and Influence (EI:UI)
Website: www.eiui.ca
Email: eiui.@dal.ca

USING OBIS FOR THE BAY OF FUNDY: A WEB PORTAL FOR MARINE BIOGEOGRAPHY DATA

Mary Kennedy and Claude Nozères

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The Ocean Biogeographic Information System (OBIS) is an evolving, strategic alliance of people and organizations sharing a vision to make marine biogeographic data, from all over the world, freely available over the Internet. Through datasets and maps, OBIS is helping to contribute to a more comprehensive portrait of life in our oceans. The system hopes to stimulate research about our oceans to generate new hypotheses concerning evolutionary processes, species distributions, and roles of organisms in marine systems on a global scale.

OBIS serves as portal to search and browse datasets with information on species observations. The datasets are integrated, enabling searches by species name, higher taxonomic level, geographic area, depth, and date. The search results are then available with a generated map, along with options to download data or to seek out environmental data on the selected locations.

The international community of OBIS or iOBIS, is comprised of a number of nodes, with OBIS Canada serving as the Canadian Regional node. OBIS Canada is supported by Fisheries and Oceans Canada (DFO), and also hosts the regional data repository at DFO's Bedford Institute of Oceanography in Dartmouth, NS. A public website for OBIS Canada (see http://OBISCanada.marinebiodiversity.ca/) is currently hosted by the Centre for Marine Biodiversity at Dalhousie University. The website provides information about the datasets contributed to OBIS Canada, and also related resources, including spatial area definitions.

To demonstrate the utility of OBIS for research, an example is given for a regional search of Bay of Fundy records (Figure 1). The results are available as a map, or may be viewed in tables, by dataset provider or year. Search results may also be downloaded as data, as a summary or full records, and as text data (csv) or map points (kml).

Browsing OBIS may reveal large numbers of available records, however several marine regions and taxa may be underrepresented (see examples in Vandepitte et al. 2011). As as result, OBIS is continually seeking data sets to help fill in these data gaps. Assistance on submitting data is available by contacting the data manager at OBISCanada@dfo-mpo.gc.ca. Submissions are required to include two basic components:

1. The Data – a spreadsheet containing biogeographical information, such as scientific name, date, latitude, and longitude.
2. The Abstract – a summary paragraph describing the dataset, including a title and citation.

The benefits of contributing datasets to OBIS Canada include:

Project visibility: brings increased global visibility to the very high standard of biodiversity research going on in Canada, integrating datasets from small projects to large monitoring programs.

Authoritative and accessible: Datasets will be processed by OBIS Canada to ensure data are authoritative (species names and hierarchical classifications); discoverable (listing data collections and their characteristics in a searchable catalogue); accessible (serving data on a public web portal); and interoperable (visualizing and analyzing data from several different sources and disciplines).

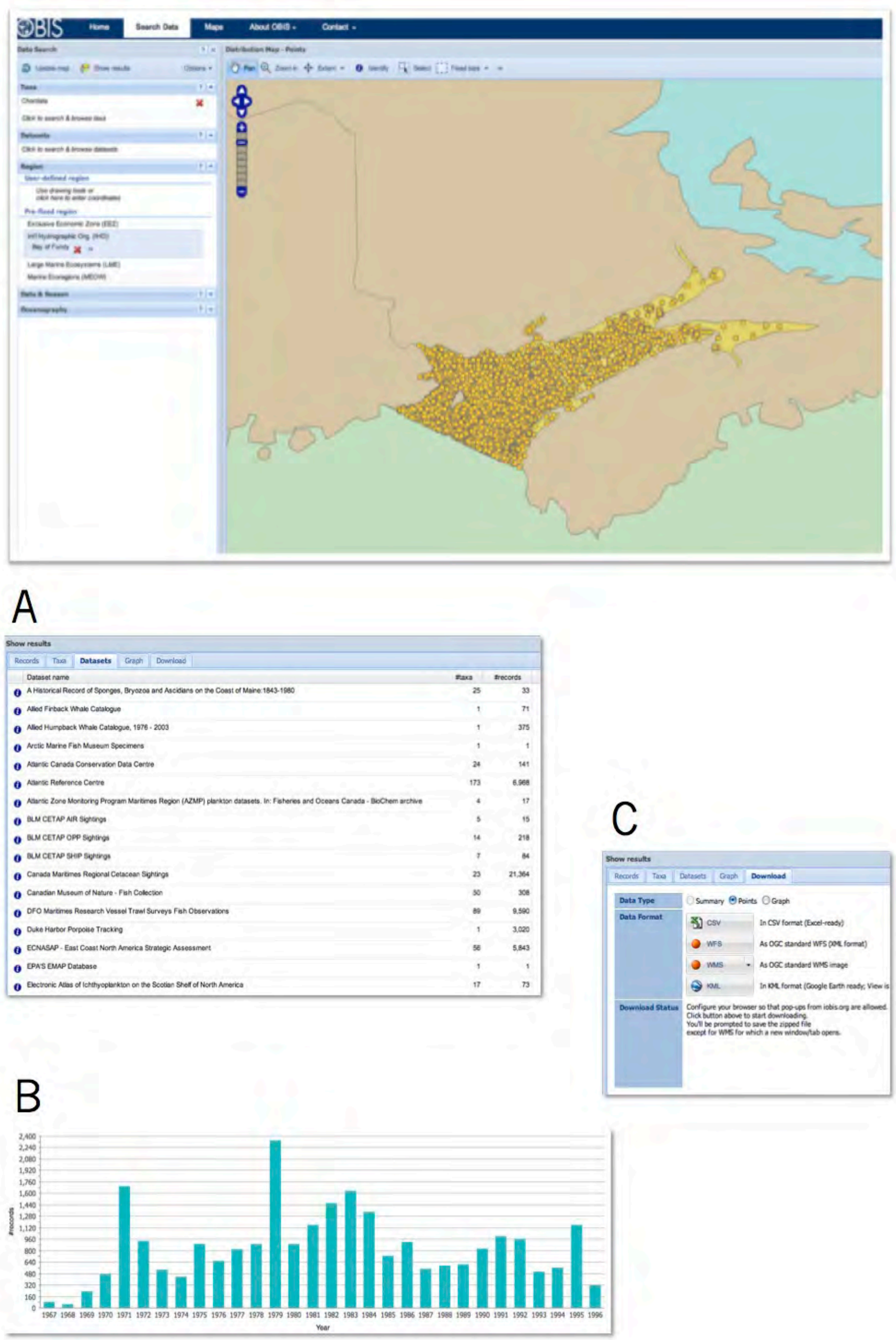

Figure 1. Examples of a region-based search on OBIS. Above, all records viewed on a map limited to the Bay of Fundy Region. Below, data by dataset providers (A), records by year (B) and download options (C).

Global marine view: provides Canadian scientists, environmental managers, and students with access to a wealth of global data that may be relevant to Canadian biodiversity even when not originating from local sources.

Meta-analyses: enables the study of biodiversity at the regional, national, and global scale. Includes efforts to identify biodiversity hotspots and large-scale ecological patterns, analyze dispersions of species over time and space, and plot species' locations with temperature, salinity, and depth.

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Session L. Conservation

FACTORS TO CONSIDER IN EVALUATING THE MANAGEMENT AND CONSERVATION EFFECTIVENESS OF A WHALE SANCTUARY TO PROTECT AND CONSERVE THE NORTH ATLANTIC RIGHT WHALE (*EUBALAENA GLACIALIS*)

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Several evaluation frameworks are available to assess the effectiveness of MPAs. Few if any models have been specifically designed to evaluate MPA effectiveness (by itself or within a network) in protecting a migratory marine mammal. This purpose of this paper is to identify key design factors (criteria and principles) to be used in protecting a migratory species within the context of a MPA system and to design an evaluation framework for a MPA that protects a migratory right whale population. Results indicate that an evaluation of MPA effectiveness for whale conservation must consider both the value provided by a single MPA and the contribution of multiple MPAs in a network extending over the species' migratory range. Key criteria/principles for individual MPA design include: boundary definition based on species habitat needs and consideration of socio-economic and cultural factors; local protection of critical whale habitats against key known threats; and adaptive ecosystem based management. Individual MPAs must be appropriately located, sized, spaced and shaped to consider adult migratory movements, behaviors, habitat needs, distribution, oceanographic conditions, and physically linked processes to maximize their contribution to a network. A network must maintain long term habitat protection, include the full range of significant habitat types to support life stage shifts, and ensure ecological linkages/connectivity between individual MPAs over large distances. The evaluation framework was based on the IUCN MPA evaluation model (Hockings et al. 2000) which is comprised of a cyclical six stage management/project cycle process (i.e. context, planning, inputs/resource allocation, process, outputs and outcomes). Incorporated into the re-designed framework are relevant components of other MPA assessment models by Hockings et al. 2000, Stolton et al. 2003, Corrales 2004, Staub and Hatziolos 2004, Pomeroy et al. 2004, Pomeroy et al. 2005, Stern 2006, Stolton 2007, IUCN-WCPA 2008, and Brown et al. 2009 [see paper in *Marine Policy*]. Within the context of a right whale population the evaluation framework defines biophysical, governance and socio-economic/political objectives, associated indicators of change, and the status of indicator achievement. With adjustment/refinement to account for species differences, it is recommended that this evaluation framework be used as a management tool in assessing the conservation and management effectiveness of MPAs protecting other migratory marine species. Further information on the evaluation framework and a case study evaluation of the Grand Manan Conservation Area is available in the published document referenced above.

The above text is an excerpt from a paper published in *Marine Policy* 35(2) (March 2011): 163–180. See published paper for references.

Hinch, P.R. and De Santo, E.M. 2011.

Factors to consider in evaluating the management and conservation effectiveness of a marine protected area for the North Atlantic right whale (*Eubalaena glacialis*)

(hinchpr@gmail.com)

DALHOUSIE UNIVERSITY *Inspiring Minds*

Abstract

Several evaluation frameworks have been designed to assess the effectiveness of marine protected areas (MPAs) in protecting marine species and habitats. Few if any models have been specifically designed to evaluate MPA effectiveness (by itself or within a network) in protecting a migratory marine species. Focusing specifically on the North Atlantic right whale population in the Bay of Fundy, this study identified key components of an MPA to protect a migratory right whale and to design an MPA evaluation framework to assess the capacity of an MPA to protect the species. For copies of the journal publication (Mar. Pol. **35**:163-180), contact hinchpr@gmail.com.

Acknowledgements: Authors thank Paul Kendrick and Drs. C.Taggart, D.Vanderzwaag, and P.G. Wells for conversations and advice that helped clarify some issues discussed in the paper.

(Photo sources: Whales of the Bay of Fundy and New England Aquarium websites)

Introduction

The North Atlantic right whale is one of the most endangered of the large population migrates annually along the east coast of North America from Florida to the Bay of Fundy, Gulf of St. Lawrence, and offshore Newfoundland to spend summer and autumn in Canadian waters. As a high proportion of the population migrates here, Canada has an important role in its protection. Currently no evaluation framework is available to assess the effectiveness of an MPA/conservation area in protecting a migratory marine mammal species. This study designed such an evaluation framework (also see Mar. Pol. **35**:163-180).

Guiding questions

- How do you effectively protect a migratory species within the context of an MPA and MPA network system?
- What are the key design criteria/principles for individual MPAs and MPA networks within the context of whale conservation ?
- What are the essential components of an evaluation framework to assess the effectiveness of an MPA protecting a migratory species?

Methods

- A literature search was conducted for information on: a) right whale lifecycle history (e.g. migratory patterns, distribution, abundance, habitat use, and threats); b) guidelines on how to protect a migratory species; c) IUCN MPA guiding principles and design criteria; and d) essential components of MPA evaluation frameworks.
- Within the context of a whale population, an evaluation framework based on the IUCN MPA evaluation model (Hockings *et al.* 2000) was developed comprised of six stages (i.e. context, planning, inputs, process, outputs and outcomes) while incorporating components of a rapid checklist or scorecard assessment by Staub and Hatziolos (2004) and comprehensive evaluation by Pomeroy *et al.* (2005).
- For each stage, the framework defined factors (i.e. biophysical, socio-economic and governance) to evaluate the management and conservation capacity of the MPA and to indicate the status of factor achievement.

(Photo sources: New England Aquarium, St. Andrews Biological Station (DFO), and NOAA websites)

Results

- Individual MPAs must: delineate boundaries based on species habitat needs; consider socio-economic and cultural implications; protect critical whale habitats against key known threats; manage on an adaptive precautionary ecosystem basis; and implement an effective surveillance and monitoring system. Individual MPAs must be appropriately located, sized, spaced and shaped to consider adult migratory movements, behaviors, habitat needs, distribution, oceanographic conditions, and physically linked processes.
- A network must: maintain long term habitat protection, include and replicate significant habitat and ecosystem types to support lifecycle stages, maintain resistance and resiliency, and ensure ecological linkages/connectivity among individual MPAs over large distances. Ecological boundaries of MPAs in networks must be adaptable to changes in oceanographic conditions that result in prey and whale population shifts.

Some Components of the MPA Evaluation framework - see publication for complete framework

Biophysical issues:	**Status:**
• Critical habitat boundaries are scientifically defined	Achieved
• Consideration of long term cumulative/ synergistic impacts of threats from human activities and natural change	Ongoing
• Key threats are mitigated/being addressed	Ongoing
• Best available scientific information used in management decisions, based on annual monitoring of the population	Achieved
• Resilience, resistance, representation, replication, and connectivity are considered in MPA design	Ongoing
• Comprehensive research and monitoring program	Ongoing
Socio-economic aspects:	
• Key stakeholders are identified	Achieved
• Socio-economic impacts of threat mitigation and codes of practice are factored into decisions	Ongoing
• Assessment of overall costs/benefits to communities are conducted/planned	Not included
• Extensive cross border cooperation/collaboration on research, threat mitigation and conservation efforts	Ongoing
• Opportunities for effective stakeholder participation in planning/decisions	Planned
• Assessment of costs/benefits to communities and community satisfaction with educational programs, communications, involvement in decisions, benefit sharing, access to information, and conflict resolution process	Not included
• Multidisciplinary team is involved in protected area management and research	Achieved
Governance aspects:	
• Approved conservation/recovery strategy in place and implemented	Achieved
• Approved site management plan in place and implemented	Not included
• Conservation area is part of an ICZM and national MPA initiative, legally protected, and internationally recognized	Achieved
• Funding for research, monitoring, recovery and site management are sufficient and sustainable	Not discussed
• Laws, policy instruments, and effective surveillance/monitoring system are in place and effectively implemented	Ongoing
• Evaluation framework is in place to assess progress against the conservation/recovery and site management plans	Not included
• Codes of practice developed with stakeholder involvement	Ongoing
• Leadership, commitment and support for the conservation/recovery plan are apparent	Achieved
• Cross-border mitigation approaches applied in a consistent/standard way in Canada and US	Not discussed

Conclusions

- Protection of migratory right whales must occur on 3 levels:
  1) local protection of critical habitats (feeding, breeding, nursing areas) against threats;
  2) regional protection of their food web and habitat on an ecosystem basis; and
  3) international protection beyond jurisdictional boundaries against threats throughout the migratory area.
- An evaluation of MPA effectiveness must consider both the value provided by a single MPA and the contribution of multiple MPAs in a network over the species' migratory range.

Recommendations

- Apply the evaluation framework to Grand Manan and Roseway Basin Conservation Areas
- Conduct conservation activities within the context of a regional (BoF/GOM) integrated MPA network. Activities should include:
  a) evaluation of Canadian conservation area contributions to the regional/international right whale protection network;
  b) continued involvement in cross-border research; and development of a regional management strategy, coordinated monitoring program, and conservation agreements, standards and protocols;
  c) evaluations of consistency of policy/recovery plan applications in Canada and the US;
  d) continued search and designation of new critical habitats in national/international waters; and
  e) learning from the experiences of MPAs protecting whale populations in other countries
- Apply the evaluation framework to MPAs protecting other migratory marine species

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Session M. Fish and Fisheries

AN OVERVIEW OF THE DFO/FISHERMEN AND SCIENTISTS RESEARCH SOCIETY, LOBSTER COLLECTOR PROJECT

Tricia Pearo[1] and John Tremblay[2]

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For the past four years the collaborative lobster collector project between DFO and the FSRS has worked towards getting an estimate of the number of lobster young-of-the-year (YOY) that have settled to the ocean floor each year. The post-larvae and later stages (YOY plus juveniles that settled in previous years) are sampled with collectors that mimic their natural nursery habitat; that is wire mesh traps filled with rocks that are deployed on the ocean bottom.

Annual estimates of the abundance of lobster YOY will help fisheries science achieve several goals. Chief among these is:

- prediction of the relative numbers of lobsters that will recruit to the fishery in different years, and
- improved understanding of the causes of differences in the size of lobster populations.

The longer the time series of annual YOY estimates, the greater the potential for scientists to achieve these goals.

FISHERMEN AND SCIENTISTS RESEARCH SOCIETY, LOBSTER RECRUITMENT INDEX FROM STANDARD TRAPS (LRIST)

Shannon Scott-Tibbetts

Fishermen and Scientists Research Society, Halifax, Nova Scotia

The Lobster Recruitment Index from Standard Traps (LRIST) project began in the spring of 1999. The goal of the project is to provide an index of the number of lobsters that will moult into the legal sizes in the coming seasons. The project was initiated by the Fishermen and Scientists Research Society (FSRS) in cooperation with the Invertebrate Fisheries Division, DFO at the Bedford Institute of Oceanography (BIO). The initial phase of the project was planned for five years but after reviewing the project's usefulness, it is scheduled to continue for the foreseeable future. The project involves over 170 volunteer fishermen fishing 2, 3 or 5 standard traps each in fixed locations. The traps are fished in locations from the northern tip of Cape Breton around the southern tip of Nova Scotia and up the Bay of Fundy. The lobster fishing areas (LFAs) represented are 27, 28, 29, 30, 31a, 31b, 32, 33, 34 and 35. The standard trap is a trap with one inch mesh, wire construction, five inch entrance rings, and without escape mechanisms. The fishermen sex and measure all the lobsters they catch in the standard traps. The lobster's carapace is measured into one of 15 size groups using a specially designed gauge. Participating fishermen also monitor bottom temperatures with a minilog temperature gauge in one of the standard traps. These bottom water temperatures are forwarded to the oceanographers at BIO and are a great addition to their coastal temperature monitoring database.

Fishermen and Scientists Research Society
Lobster Recruitment Index from Standard Traps (LRIST)

OVERVIEW

Goal: to provide an index of the number of lobsters that will molt into the legal sizes in the coming seasons

- LRIST began in the spring of 1999.
- It began as a 5 year project. After reviewing the project's usefulness, it is scheduled to continue for the foreseeable future. It has just completed its 11th year of collecting quality scientific information.
- LRIST involves volunteer fishermen fishing standard traps in fixed locations.
- The fishermen sex and count the lobsters in 15 size groups using a specially designed gauge. Before Fall 2003, the measuring gauge had 8 size groups.
- The standard traps are wire with one-inch mesh, and no escape mechanisms.
- Participants also monitor bottom temperatures with a minilog temperature gauge in one of the standard traps.
- LFA 33 also participates in a Commercial Trap study where the fishermen fish three of their own commercial traps near the Recruitment Traps. This study has been in effect since Fall 2002.

MEASURING GAUGE (Currently used)

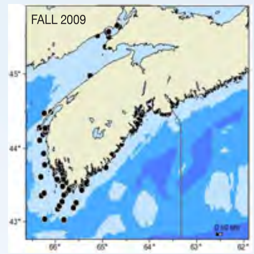
Size 1 (less than 10.99mm)
Size 2 (11mm – 20.99mm)
Size 3 (21mm – 30.99mm)
Size 4 (31mm – 40.99mm)
Size 5 (41mm – 50.99mm)
Size 6 (51mm – 60.99mm)
Size 7 (61mm – 70.99mm)
Size 8 (71mm – 75.99mm)
Size 9 (76mm – 80.99mm)
Size 10 (81mm – 90.99mm)
Size 11 (91mm – 100.99mm)
Size 12 (101mm – 110.99mm)
Size 13 (111mm – 120.99mm)
Size 14 (121mm – 130.99mm)
Size 15 (greater than 130mm)

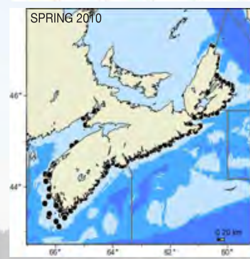
Note: Size groupings 8 and 9 are in 5mm increments to give a clear indication of the number of lobsters just under the legal size limit.

The new measuring gauge was designed (Fall 2003) to reflect smaller and larger size groupings. The GOMLF(Gulf of Maine Lobster Foundation) lobster fishermen have been using the same new designed gauge.

Dimensions

- Height 14 inches
- Width 21 inches
- Length 40 inches





RESULTS FROM FALL 2009

- This was the eleventh fall (Nov-Feb) with data from the standard traps
- 87 fishermen took part in LFA's 33, 34 and 35
- 258 project traps were fished in 2009
- 4605 total project hauls in Fall 2009
- The LFA's combined for a total of 21,550 lobsters measured

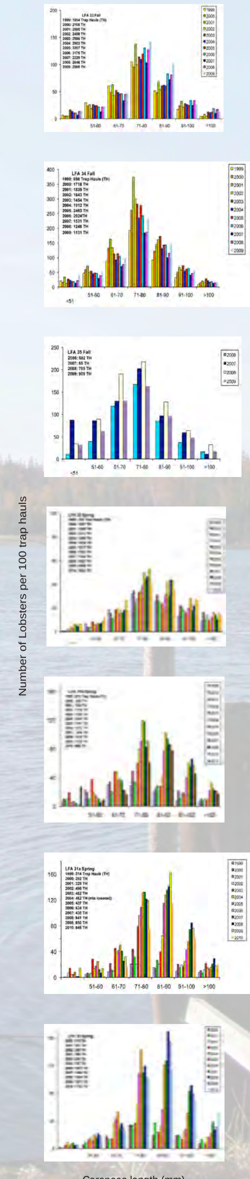
LFA 33 3.68 Lobsters/ Trap Haul
LFA 34 6.42 Lobsters/ Trap Haul
LFA 35 5.47 Lobsters/ Trap Haul

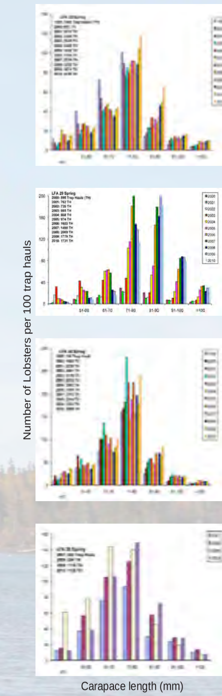
RESULTS FROM SPRING 2010

- 165 fishermen took part in the spring of 2010
- LFA's 27, 28, 29, 30, 31A, 31B, 32, 33, 34 and 35 were sampled
- 513 project traps were fished in 2010
- 18,458 total project trap hauls in Spring 2010
- All project traps combined in Spring 2010 – total of 64,090 lobsters measured

LFA 27 3.45 Lobsters/ Trap Haul
LFA 29 4.34 Lobsters / Trap Haul
LFA 30 3.69 Lobsters/ Trap Haul
LFA 31A 2.87 Lobsters/ Trap Haul
LFA 31B 2.55 Lobsters/ Trap Haul
LFA 32 1.52 Lobsters/ Trap Haul
LFA 33 2.91 Lobsters/ Trap Haul
LFA 34 5.32 Lobsters/ Trap Haul
LFA 35 4.16 Lobsters/ Trap Haul

- LFA 28's results will not be shown as there are not enough participants to allow grouped results.





COMMERCIAL TRAP STUDY RESULTS

Fall 2009

- 45 participants from LFA 33
- 2469 commercial trap hauls were recorded
- 6243 lobsters measured
- Average of 2.52 lobsters caught per trap haul

Spring 2010

- 45 participants from LFA 33
- 4002 commercial trap hauls were recorded
- 6614 lobsters were measured
- Average of 1.65 lobsters caught per trap haul

ONGOING ANALYSES

- Comparison of standard traps with commercial traps
- Analyses of the data to get an indication of exploitation rates, used in LFA assessments
- Analyzing the predictability of the trends in recruitment
- Analyses of temperature effects on catch rates
- Annual changes in numbers of undersize lobsters

We look forward to future years of this study and to the new challenges we face in providing scientific insight into today's lobster fishery issues. For more results please contact the FSRS office at 902-461-8119.

ACKNOWLEDGEMENTS

FSRS would like to thank all Fishermen who participated in the project and the community technicians for their work onboard vessels and for working with the fishermen. The FSRS gauge was a modified version of one designed by lobster biologists in the Invertebrate Fisheries Division (IFD) (St. Andrews) for use by LFA 35 fishermen. Pictures contributed by Jeff Graves, and Carl MacDonald.

Poster created March 8, 2011 by Shannon Scott-Tibbetts (FSRS), and BIO technographics.

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The 10th BoFEP Bay of Fundy Science Workshop

"Sustaining the Bay of Fundy: Linking Science, Communication, Policy and Community Action"

Date: June 2014

Location: Halifax, Nova Scotia

Proposed Major Topics:

Advances in understanding macro-tidal estuaries
Coastal communities - needs and action
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 knowledge – use and influence
Science-policy linkages
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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